SuperMap
Smart Power Grid Solution

SuperMap Software Co., Ltd.


"Innovate IT Value
with Geo-intelligence."
"Create Cutting-edge Technologies Constantly,
Light up Every Corner of the Planet
with Geo-intelligence!"

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1 Overview of SuperMap Smart Power Solutions

The SuperMap Smart Power Solution is a comprehensive digitalisation framework built upon a multi-tiered technical architecture. It integrates Geographic Information Systems (GIS), big data analytics, and microservices technologies. Through a holistic design encompassing "hardware support – data-driven operations – platform empowerment – business implementation – multi-terminal interaction", it enables digitalised management, intelligent operations, and efficient decision-making within power systems. This solution provides technical support and business empowerment across the entire lifecycle of the power industry, from planning and construction to operation, maintenance, and management.

1.1 Solution Value

Through the integration of GIS, big data, and microservices technologies, this solution delivers three core values:

Maximising Data Value: Deep integration of multi-database collaboration and GIS technology unlocks the synergistic value of power geographic information and operational data, delivering precise data support for power planning and maintenance.

Fully Closed-Loop Business Processes: Dual coverage via web and mobile applications enables end-to-end digitalisation of power operations—from management and monitoring to field execution—enhancing operational efficiency.

Flexible and Scalable Architecture: Designed with microservices and containerisation, the system enables rapid iteration and elastic scalability, adapting to future business growth and technological evolution within the power industry.

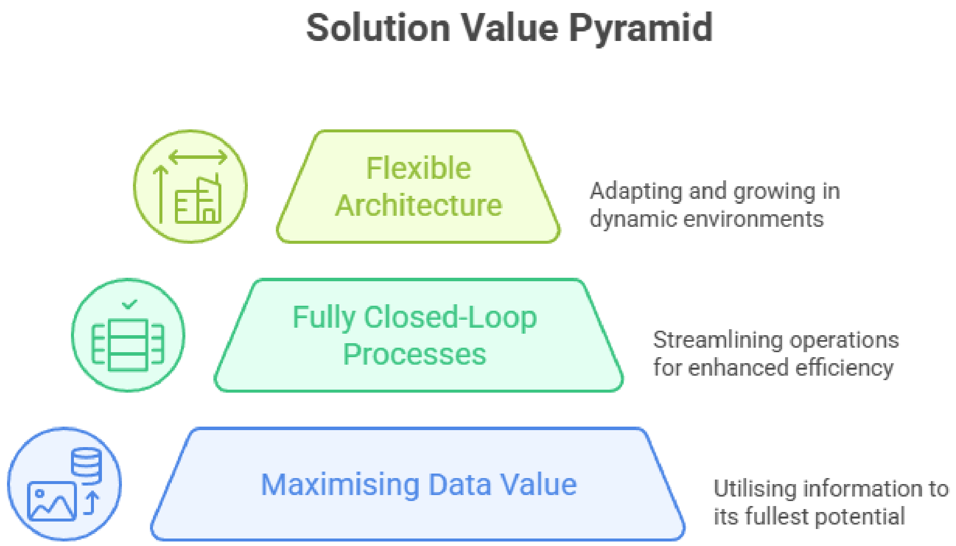


Figure 1 :Solution Value

1.2 Overall Architecture

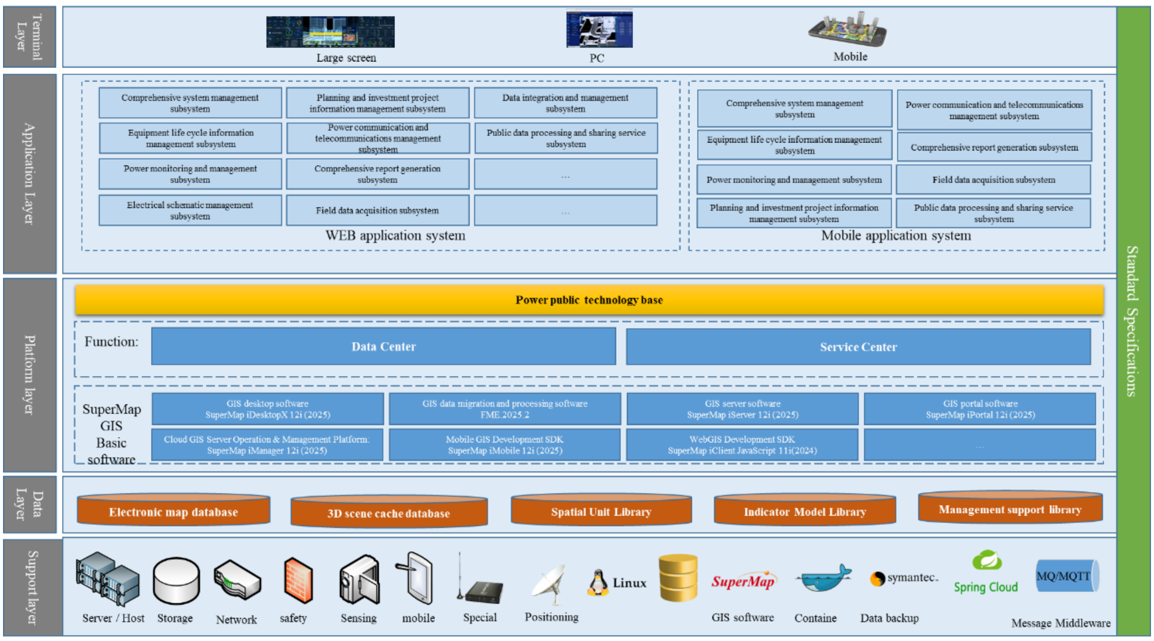


Figure 2 : Overall Architecture

The architecture diagram illustrates **the multi-tiered framework** of the power system, organised from bottom to top as: **Support Layer, Data Layer, Platform Layer, Application Layer,** and Presentation Layer. Compliance across the entire architecture is ensured through **standards/specifications** and **policy** regulations. Each layer collaborates to achieve comprehensive management, data processing, business applications, and multi-terminal presentation for the power system.

- **Support Layer**: Comprises hardware facilities including servers/hosts, storage devices, network equipment, security devices, sensing devices, mobile devices, specialised equipment, and positioning devices. It also incorporates foundational software such as the Linux operating system, databases, SuperMap GIS software, container management software, data backup software (Symantec), microservices middleware (Spring Cloud), and messaging middleware (MQ/MQTT). This layer provides hardware support and the underlying software runtime environment for the entire system.
- **Data Layer**: Comprising five major database categories—**electronic map database**, **3D scene cache database**, **spatial unit repository**, **indicator model repository**, and **management** support repository—storing electronic map data, 3D scene cache data, spatial unit data, indicator model data, and management support data respectively. This forms the core data storage of the system, supplying data resources to upper-layer applications.
- **Platform Layer**:
  - The core is **the public power technology foundation**, comprising two major functional modules: **the data centre and the service centre**. It undertakes the roles of data integration, service encapsulation, and distribution.
  - Built upon **SuperMap GIS** foundational software, this suite encompasses GIS desktop applications, server management platforms, data migration and processing tools, server-side software, portal solutions, and client-side development tools, thereby providing the technical foundation for the

geographic information system.

- **Application Layer**: Comprising **WEB application systems** and **mobile application systems**, it implements various power business functions:
  - The WEB Application System incorporates subsystems for integrated system management, planning and investment project information management, data integration and management, equipment lifecycle information management, power telecommunications management, public data processing and sharing services, power source monitoring and management, comprehensive report generation, electrical schematic management, and field data acquisition.
  - Mobile Application Systems encompass subsystems for integrated system management, power telecommunications management, equipment lifecycle information management, comprehensive report generation, power supply monitoring and management, field data acquisition, planning and investment project information management, and public data processing and sharing services, fulfilling mobile device operational and information query requirements.
    - **Presentation Layer**: Provides visualised system interfaces through three terminal **types—large screens, PCs, and** mobile devices—enabling multi-terminal information display and interaction.
    - **S tandards & Regulations**: Underpinning the entire architecture, these provide compliance and normative guidance for system design, development, and operation, ensuring construction and operation align with industry standards and policy requirements.

Overall, this architecture achieves comprehensive coverage from hardware support, data storage, and platform services to business applications and terminal display through layered design. Leveraging GIS technology and microservices architecture, it underpins the integrated management, data consolidation, and multi-scenario business applications of the power system.

2 Foundational Base Map Data Repository

2.1 Establishment of the Base Map Geodatabase — Spatial Database (SMDB)

Establish **a base map geodatabase (SMDB)** compliant with power industry standards. This enables unified storage, management, and service delivery of fundamental geographic information including topography, roads, water systems, buildings, administrative boundaries, and remote sensing imagery. It provides geospatial support for power grid equipment, line, and operational management systems. Construction steps and technical processes are as follows:

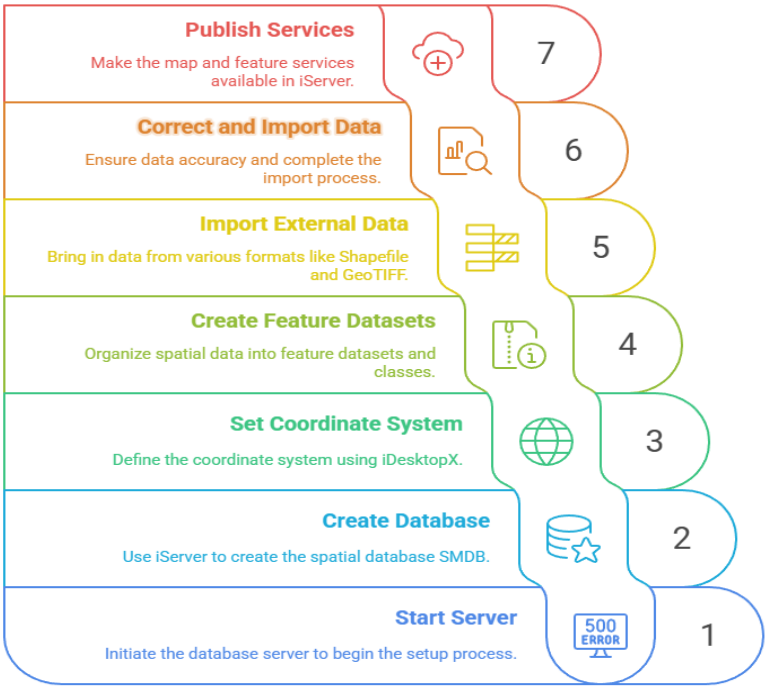


Figure 3：workflow

2.1.1 Establishment of the Spatial Database

- Create an enterprise-level geodatabase within a GIS database management system (e.g., PostgreSQL, SQL Server, Oracle);
- Register the database connection within the **SuperMap iServer** management console;
- Establish spatial indexes and metadata structures;
- Define database naming conventions to serve as a unified repository for base map data.

2.1.2 Configure the national coordinate system

- Configure the spatial reference system for the database in **iDesktopX,** which support 5000+ coordinate systems

2.1.3 Creating Feature Datasets and Feature Classes

- Use **iDesktopX** to create a data source and connect to SMDB;
- New Feature Dataset:
  - Administrative_Boundary
  - **Transportation** (Roads and Railways)
  - **Hydrology** (Rivers and Water Systems)
  - Building
  - **Vegetation** (Vegetation and Land Cover)
- Create corresponding feature classes for each dataset, defining the geometry type (point, line, polygon) and attribute fields;
- Establish topological relationship rules (such as road continuity and watercourse flow direction consistency).

2.1.4 Create a raster dataset

- Create a "Raster Dataset" within **iDesktopX**;

- Store satellite imagery, aerial imagery, and digital elevation models (DEM);
- Supports multi-resolution pyramid structures to optimise display performance;
- Store raster data within SMDB and establish fast indexes.

2.1.5 Importing External Data

- Execute data import and transformation :
  - Supported formats include: Shapefile, DWG, DXF, GeoTIFF, KML, GDB;
  - Perform the following on imported data:
    - Coordinate system conversion;
    - Attribute field matching;
    - Geometric cleaning and duplicate detection;
    - Data ingestion (writing to SMDB).
- Automated batch processing via Workspace ensures data consistency.

2.1.6 Service registration and publication

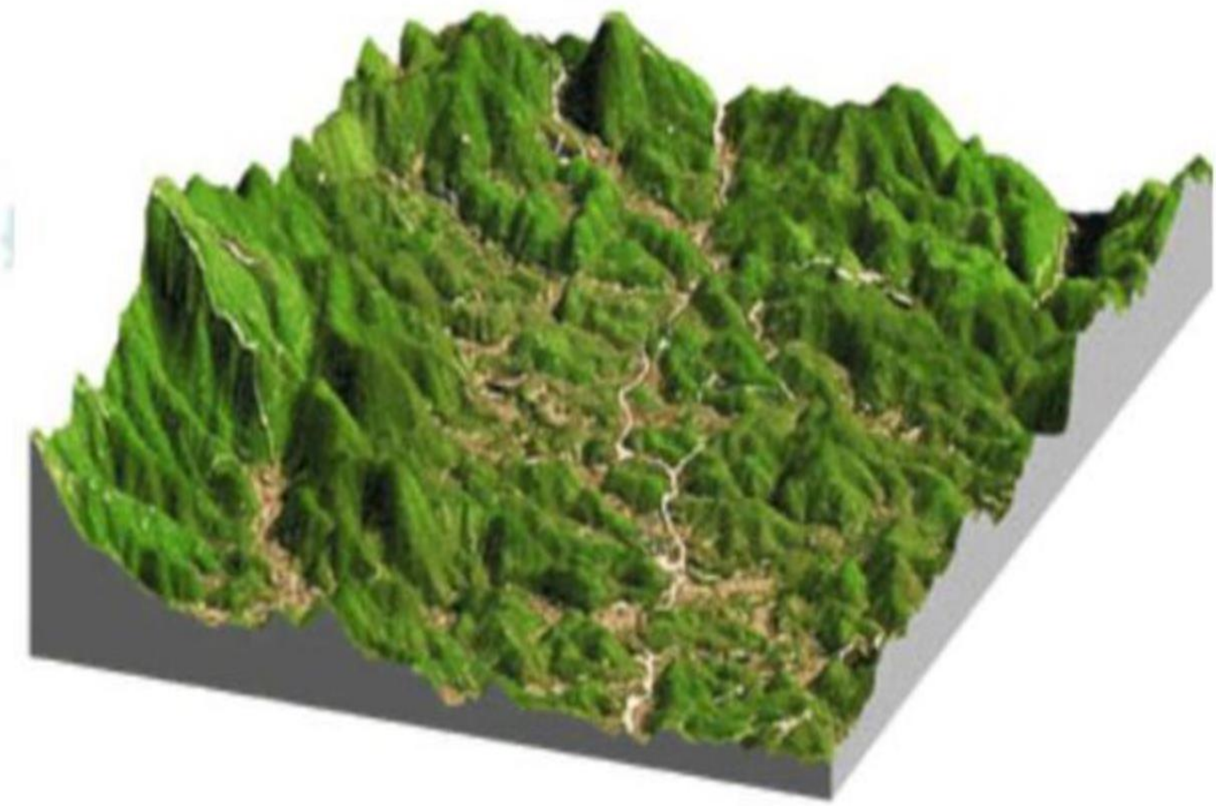
- Within **iServer**:
  - Register Landbase data source;
  - Publish Map Services, Feature- -Services, and Image Services;
- In **iPortal**:
  - Manage service catalogues and access permissions;
  - Provide a unified entry point for iClient (Web) and iMobile (mobile devices)

2.2 Map data loading and transformation

After ensuring all geospatial data types (including vector, cadastral, and raster data) undergo standardised processing, they are consolidated into an enterprise-grade spatial database (SMDB) to achieve efficient data management and visualisation.

2.2.1 Load multi-scale base geospatial data

- Utilise **SuperMap iDesktopX** to load foundational geospatial data (e.g., administrative divisions, transportation networks, water systems, land use) at multiple scales (1:2,000 / 1:10,000 / 1:50,000) into the database.
- Organise data into **thematic groups** (e.g., topography, cadastral parcels, infrastructure, water systems, vegetation, imagery, administrative divisions) according to planning themes.



2.2.2 Conversion and integration of digital cadastral data

- Use **Workbench** to convert cadastral data from various formats (such as Shapefile, DWG, DXF) into **an intermediate spatial database**

(such as GDB or GeoDatabase format).

- Perform coordinate system transformations to standardise data.
- Migrate the standardised cadastral layers to **the central GIS spatial database (SMDB)** using the **SuperMap iServer data import** tool.

2.2.3 Import raster imagery data

- Create raster datasets within **iDesktopX** for storing imagery, remote sensing, and elevation data.
- Import and mosaic **satellite imagery, aerial photographs, and DEM data** via **iDesktopX or Raster Transformer**.
- Construct image pyramids and preview caches to optimise display performance.

Data quality control and service publication

- Perform topological checks, projection consistency verification, and attribute integrity checks.
- Use **iServer** to synchronise and publish data layers as map and image services;
- Register services via **iPortal** for access and use by **iClient (web-based) and iMobile (mobile-based)** applications.

2.3 Create standardised symbol sets

2.3.1 Standard Interpretation and Requirements Analysis

- Conduct in-depth research and deconstruction of standards pertaining to the symbolisation of power grid facilities, including but not limited to: graphical representations, colour schemes, and dimensions for symbols denoting transmission lines of varying voltage levels, substations, distribution transformers, pylons, switchgear, etc.

- Collaborate with subject matter experts to clarify symbolisation requirements for static display and dynamic rendering (e.g., operational status, load conditions) within digital maps.

2.3.2 Symbol Library Design and Creation Based on iDesktopX

- **Core Tool:** Utilise **SuperMap iDesktopX** as the central platform for symbol production, leveraging its robust graphic editing and symbol management capabilities.
- **Symbolisation Types:**
  - **Point Symbols:** Represent discrete facilities such as substations, pylons, and distribution boxes. Utilise iDesktopX's symbol generator to precisely draw compliant geometric shapes (e.g., combinations of circles, rectangles, triangles), strictly defining fill colours, outline colours, and dimensions. For complex facility symbols, employ TrueType font symbols or image symbols to ensure detailed representation.
  - **Line Symbols:** Represent transmission and distribution lines. Utilising **iDesktopX's advanced line** editor, we shall define line units, loop patterns, and drawing rules to create symbols such as dashed lines, dotted lines, and composite lines that clearly distinguish voltage levels (e.g., 500kV, 220kV, 110kV). Directional line symbols with arrows will also be designed to indicate power flow direction.
  - **Area symbols:** Employed to denote substation perimeters, power supply zones, and similar areas. We shall design compliant fill patterns (such as diagonal hatching, grid fills) and boundary styles, ensuring area elements are aesthetically pleasing whilst avoiding visual confusion with point and line symbols.

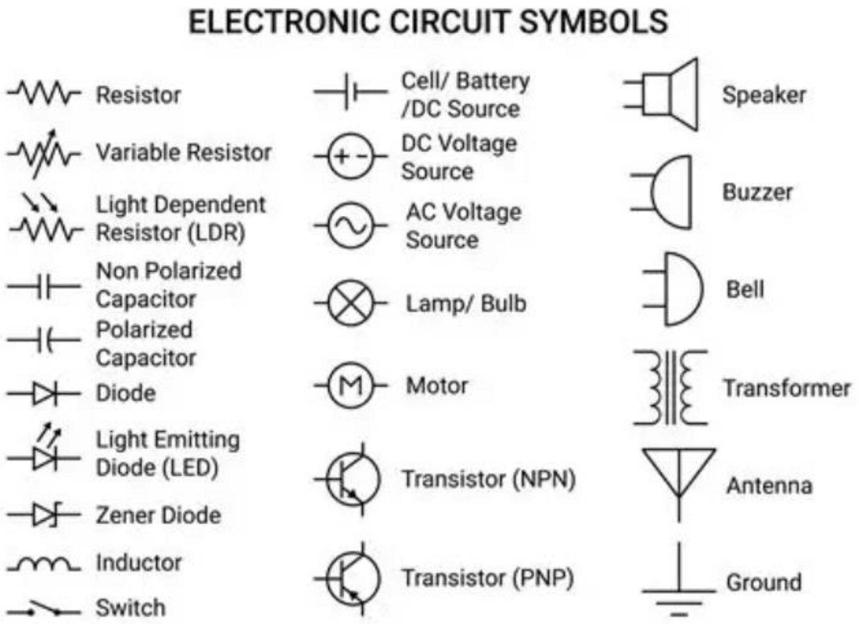


Figure 4 : electronic circuit symbols

2.3.3 Systematic and Standardised Management of the Symbol Library

- Create a unified **"Standard Grid Symbol Library"** file (.sym) within iDesktopX for centralised, categorised management of all customised symbols.
- Establish a scientific symbol classification system, such as multi-level directories organised by "voltage level-equipment type", facilitating rapid retrieval, invocation, and reuse by project team members.
- Assign standardised names and metadata descriptions to each symbol to ensure unambiguous meaning and prevent misuse.

2.3.4 Symbol Application and Quality Verification

- Apply the created standard symbol library to the demonstration area grid data for this project to conduct practical mapping exercises.
- Leverage iDesktopX's layer style configuration to associate symbol attributes with grid feature attribute fields (e.g., voltage, type), enabling rule-based batch automation for symbolisation.
- Output thematic map samples and conduct multiple rounds of verification

and calibration against standard documents and operational stakeholders to ensure the visual representation of each symbol is entirely accurate.

2.4 Compilation and Styling Design

2.4.1 National Basic Geospatial Map Compilation and Import

- Compile and organise the complete set of nationally procured fundamental geospatial map atlases, including 1:25,000, 1:5,000, and 1:2,000 scale base map data.
- Convert raw data formats (e.g., Shapefile, GeoDatabase, CAD SuperMap UDB/UDX) uniformly and perform projection standardisation.
- Import data into **the Enterprise Geodatabase (SMDB)** and establish corresponding thematic dataset structures.

2.4.2 Map style editing and optimisation

- Utilise **SuperMap** iDesktopX's cartographic style editing capabilities to configure the map symbol system according to standards (administrative boundaries, feature categories, topographic annotations, transport, water systems, etc.).
- Set visible scale ranges for each dataset layer to ensure optimal data density and symbol styles at different zoom levels.
- Apply standard templates to ensure consistent map display across web and mobile platforms

2.5 Establish a company-wide shared base map service.

2.5.1 Web feature layer and web map image layer services

- Publish spatial data services (Feature Service, Map Image Service) using **SuperMap iServer**;

• Support OGC standards (WMS, WFS, WMTS) to ensure interoperability across different systems;

• Configure cached tiles to enhance map browsing performance and response speed;

• Register map services with **iPortal** for unified service catalog and permission management.

2.5.2 Create new vector spatial data service layers

• Establish foundational vector layers such as administrative divisions, topography, road networks, water systems, and buildings according to the power company's base map standards;

• Configure uniform symbology rules and display scale ranges for each layer;

• Enable subsequent overlay display of power facility data (transmission/distribution lines, substations, supply zones, etc.).

• Layer editing and updates via iDesktopX ensure the ongoing maintenance of base map data.

2.5.3 Data Service Sharing Mechanism

• Establish a unified data service access password within iServer, granting departmental or user-specific authorisation;

• Implement service call logging and access monitoring;

• Support online invocation via mobile devices (iMobile) and web front-end (iClient JavaScript).

3 SuperMap GIS Core Software

SuperMap GIS 2025 comprises a comprehensive suite of products, with all products and development packages sharing a unified core. This ensures consistent data formats, programming models, and development frameworks across all offerings. It fully supports the management and utilisation of spatial data pertaining to power grid assets, specifically engineered for network management, analysis, and flexible application development within the power industry.

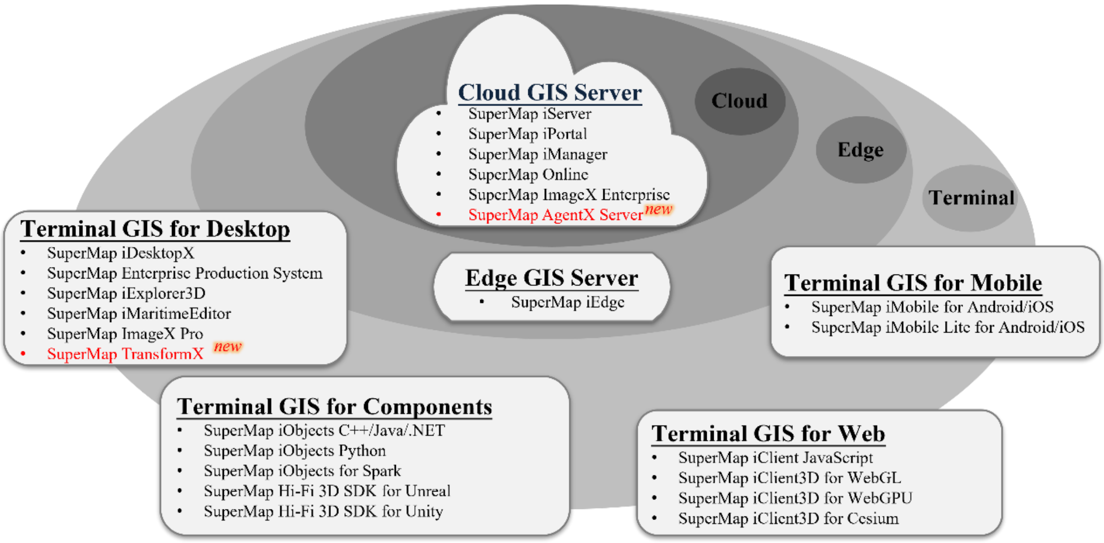


Figure 5 : SuperMap GIS Core Software

3.1 GIS Desktop Software: SuperMap iDesktopX 12i (2025)

SuperMap iDesktopX is a cross-platform, integrated 2D/3D desktop GIS software platform supporting mainstream operating systems including Linux and Windows. It provides capabilities for spatial data production and processing, distributed data management and analysis, cartography, data migration, automated processing, machine learning, image processing, video mapping, and knowledge graphs. It is suitable for data production, processing, analysis, and business system customisation. Key features of SuperMap iDesktopX include:

3.1.1 Data Management

- Supports Windows 7/7 SP1/8/10/11 series and Windows Server 2003/2008/2008.
- Manages data through file-based data sources and workspaces.

• Provides comprehensive dataset management, supporting points, lines, polygons, attribute tables, networks, CAD, text, routes, imagery, raster, models, videos, mosaics, and 3D datasets (point/line/surface).

• Adds support for LAS, multipoint, and relational datasets, enhancing multi-source data compatibility.

• Enhances vector dataset management with new M values, subtypes, conditional values, and attachment management.

• Integrates cloud storage services for convenient access to cloud-based imagery and vector data.

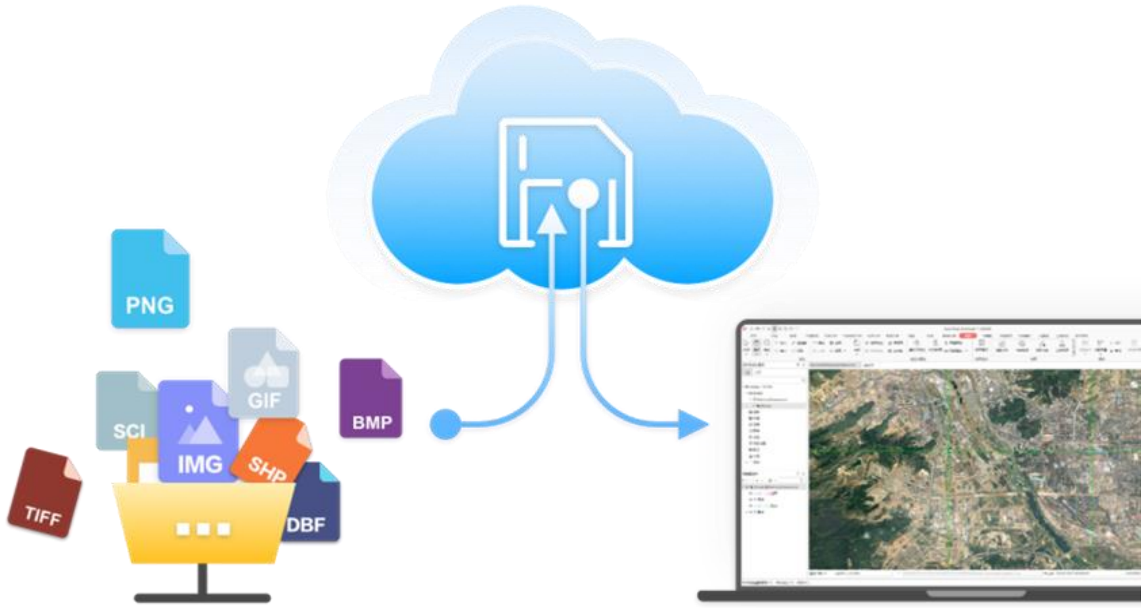
• Supports direct opening of common vector and imagery files, enabling them to be used directly in analysis tools with output in standard formats.

• Provides attachment management capabilities, supporting the addition, viewing, editing, and management of multiple types of attachments for features, enabling efficient linkage and unified management between spatial data and external files.

• Provides over 5,000 common projection methods and geographic coordinate systems.

• supports multi-coordinate system management and transformation with dynamic projection capabilities, enabling accurate conversion and visualization across spatial reference systems for seamless integration and unified display of multi-source data.

• Supports multiple data indexing methods, including R-tree, quadtree, dynamic index, gallery index, and field index, improving data access and retrieval efficiency.



• Supports both file-based and database-type data sources (Oracle, PostGIS, MySQL, etc.), capable of managing terabyte-scale spatial data

• Inherits user roles and permissions from the server, ensuring consistent security and access control across desktop and server environments. This allows automatically apply server-defined user privileges—such as data editing, viewing, and management permissions—within the client application, enabling seamless integration with enterprise-level authentication and authorization mechanisms for secure and unified data operations.

• Supports opening various online map services, including MapWorld (Tianditu), Google Maps, WorldTerrain, OGC, XYZTile, SuperMap GalaxyMap, 4D Earth, and Careland.

• Supports accessing OGC-compliant web services such as WFS, WMS, WCS, and WMTS.

• Enables connection to cloud storage services for browsing imagery and vector data.

• Supports access to SuperMap Online resources, including symbols, color schemes, data, and maps.

• Interacts seamlessly with the iServer platform to publish workspaces (maps and data), local tiles, and MongoDB tiles as REST or OGC services for resource sharing.

• Supports message and data collaboration via Online accounts.

• Supports direct opening and analysis of common vector/image files

• Offers streaming data management, database user management, and mosaic image management

• Enhanced vector management capabilities (M-values, subtypes, attachment management)

• Supports visual capabilities of dataset structure design, including feature classes, tables, relationships, subtypes, and domains. It enables template-based modeling and schema import/export for standardized and efficient data management.

• Supports domain (range) management, used to define the valid value range of a field, representing all possible values that may appear in a database table.

• Supports dataset CRUD operations (create, read, update, delete).

• The SQL Query Tool executes Spark SQL queries on data tables (DataFrames). Spark SQL enables flexible and efficient data filtering, complex statistical analysis, and spatial computation through spatial functions.

• Supports comprehensive mosaic dataset management, including adding imagery, rebuilding extents, clipping display ranges, reassigning image paths, balancing mosaic colors, creating image pyramids, building overviews, and generating histograms.

• Supports related table query and mapping, enabling cross-table retrieval and using related attributes for symbolization, labeling, and thematic mapping to integrate and visualize multi-source data.

• Supports storing and managing spatial data in a SAN environment, enabling high-performance access, centralized management, concurrent multi-user use, and enterprise-level backup and recovery.

• Supports imagery updates, allowing incremental or full updates of images within mosaic datasets to maintain data timeliness and integrity, enabling continuous and seamless image management and visualization.

• Supports desktop scale display, showing the current map scale in real time to assist with spatial measurement and map navigation.

• Supports comprehensive metadata management, including creation, editing, and maintenance of dataset metadata. Users can define metadata for datasets, feature classes, and geodatabases, enabling metadata-based search, cataloging, and compliance with international standards (e.g., ISO 19115).

3.1.2 Real-time stream processing and dynamic data updates

• The new version enhances "Stream Capabilities" to support real-time data ingestion, processing, and response.

• Enables application of data processing workflows for dynamic event response, real-time monitoring, and decision support scenarios.

• Integration with cloud platforms, IoT devices, and sensor systems is supported to enhance data timeliness.

3.1.3 Data editing and processing

• Includes drawing points, lines, polygons, and text objects, with support for object snapping

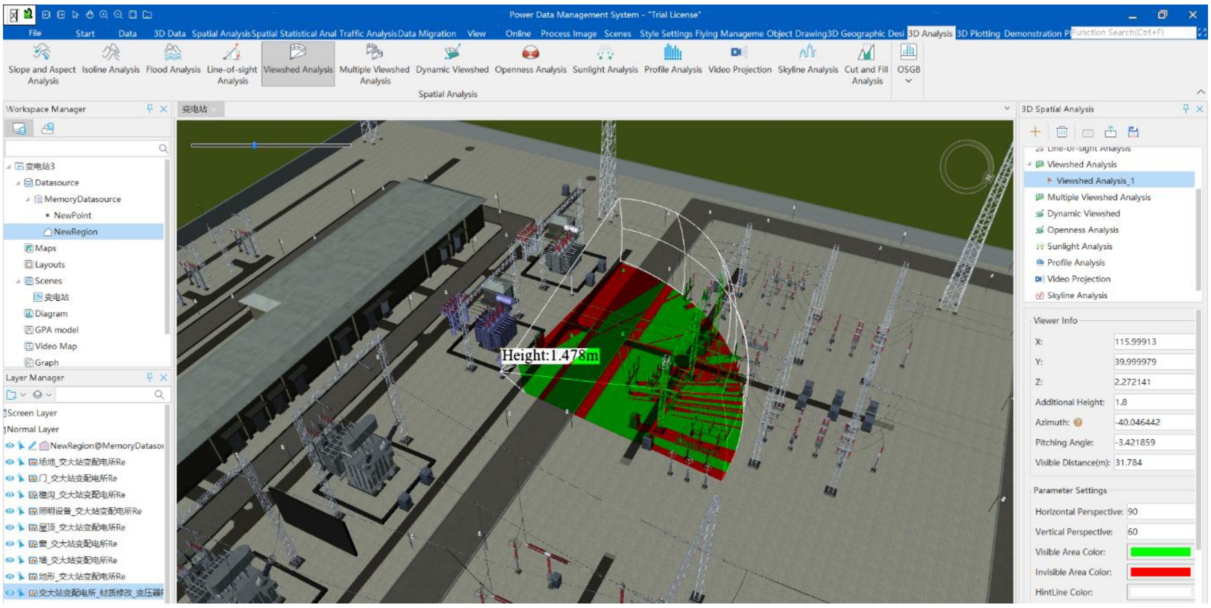
• Allows modification of spatial shapes for lines and polygons

• All attribute table editing operations include modifying attribute structures, calculating geometric properties, updating columns, statistical analysis, and more.

• Supports coordinate system configuration and projection transformation

• Offers vector and raster data processing: merging, reclassification, clipping, stitching, NDVI analysis, etc.

• Supports 2D/3D data and model registration



• Provides interactive object editing tools for clipping, calculation, and other spatial operations.

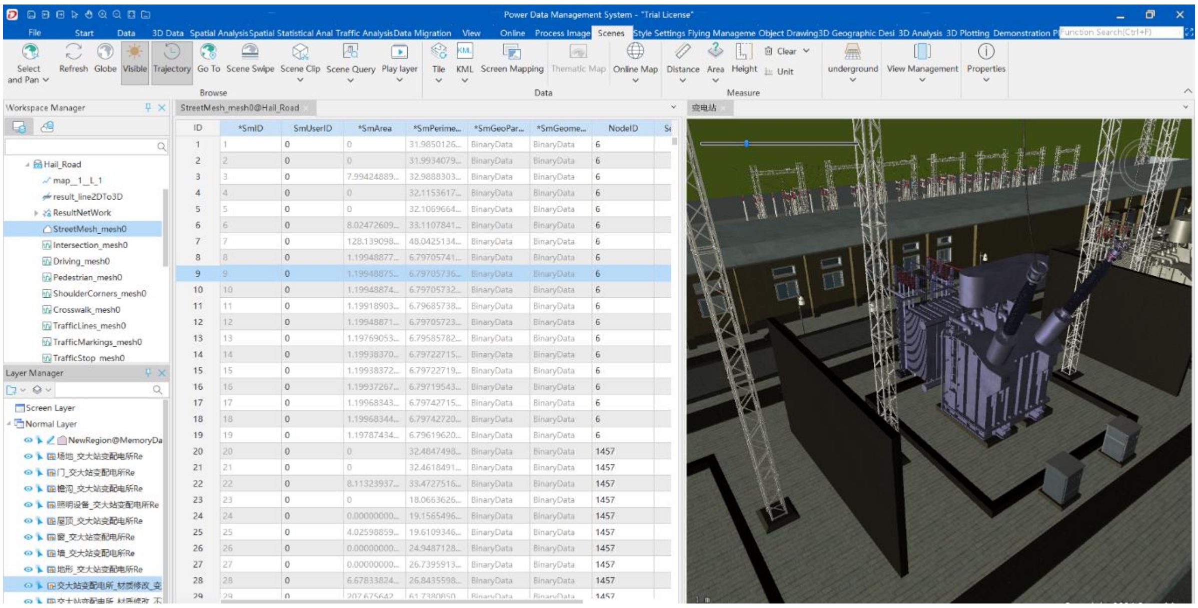
• Adds a template editing function, enabling rapid data editing based on map feature categories.

• Supports drawing point, line, polygon, and text objects, with object snapping capabilities.

• Supports node editing for spatial objects.

• Enables multi-layer editing for complex map compositions.

• Provides comprehensive attribute table operations, including creation, editing, browsing, filtering, find-and-replace, drag-and-drop value assignment, export, column updates, geometry property updates, and statistical analysis.



• Attribute and spatial data conversion, template-based rapid editing, multi-layer and node editing

• Supports versioning and transaction management, enabling multi-user collaboration and historical traceability

• Supports data replication and distribution management

• Provides comprehensive object editing tools, including object operations, endpoint editing, object type conversion, object movement, object manipulation, and route editing.

• Supports data version management, enabling multi-user collaborative editing on the same dataset. Offers version registration, version submission, conflict resolution, and historical moment management for data traceability.

• Provides data replica management, allowing administrators to distribute and collect datasets, facilitating offline or external network data editing.

• Supports database transaction management to ensure data consistency and integrity.

• Optimizes the SQL query tool with expression validation and error prompts. For PostGIS data sources, detailed error information is provided to help locate issues precisely.

• Supports DEM production, including generation from sampling points and radar point clouds.

• Offers powerful relational table query and mapping capabilities, supporting multi-source table association, visual analysis, and intuitive data relationship representation for efficient decision-making.

• Provides comprehensive raster data processing functions, including raster algebra operations, data updates, resampling, reclassification, image composition, segmentation, mosaicking, weighted sum, NDVI/NDWI calculation, multi-band synthesis, aggregation, raster mosaic creation, contour extraction, and raster clipping.

• Supports topology processing, including topology checking, error correction, polygon construction, and topology graph visualization.

3.1.4 Data conversion

• Supports import/export of 30+ formats including: *.udbx, *.obj, *.3ds, *.tiff, *.img, *.shp, *.dwg, etc.

• Supports direct editing of FileGDB and GeoPackage data without import or conversion.

• Supports imports of various data formats, including AutoCAD data, ArcGIS data, image raster data, LIDAR data (TXT/LAS/PLY), Google data

(KML/KMZ), vector files, GeoJSON, SimpleJSON, telecom data, Geo3DML geological model files (XML), and more.

• Supports exporting vector, raster, model and other data formats, including GeoJson files, VCT files, TIFF files, ArcGIS Grid files, telecom raster files, TIN terrain file, etc.

• Supports batch model import from a single folder, with all imported models aligned to the same geographic reference origin. Supported formats include: *.s3mb, *.s3m, *.osgb, *.osg, *.3ds, *.x, *.dxf, *.obj, *.fbx, *.dae, *.stl, *.off, *.sgm, *.gltf, *.flt, *.mod, etc.

• Provides direct reading of third-party vector data, including Shapefile, FileGDB, and GeoPackage.

• Offers 8 types of 3D model import GPA tools, supporting .obj, .dae, .3ds, .x, .dxf, .fbx, .skp, .gltf/.glb, and .xml (3D geological models).

• Supports TIFF, JPEG, JPEG 2000, and MrSID formats, enabling efficient import, display, and analysis of high-resolution imagery while ensuring compatibility with existing GIS workflows.

• Data type conversion supports mutual transformation among points, lines, and polygons. For example, lines can be converted to polygons, polygons to lines, lines to points, points to lines, and polygons to points.

• CAD and composite/simple data conversion includes three aspects: CAD → simple data, simple data → CAD, and CAD → 3D model data.

• Network data conversion: arcs from network datasets can be extracted to generate new line datasets, and network nodes can be extracted to generate new point datasets.

• Route data conversion: route objects can be converted to new line datasets.

• Field-to-text conversion allows a dataset field to be converted into a text dataset, enabling map labeling.

• Text-to-field conversion adds text from a text dataset into a dataset's attribute table, specifying the target field for storage.

• Text-to-point conversion extracts anchor points of text objects to generate new point datasets.

• Attribute-to-point conversion uses field values as X/Y coordinates to create corresponding point objects, generating one or more point datasets.

• Supports 2D ↔ 3D conversion: 2D datasets (point, line, polygon) can be converted to 3D datasets using a specified elevation field, and 3D datasets can be converted back to 2D datasets, automatically removing elevation information.

• Supports various dataset types, including point, multipoint, line, polygon, attribute table, network, text, route, imagery/raster, and video datasets.

• Dataset management includes creation, copying, deletion, closing, renaming, sorting multiple datasets, viewing dataset properties, and setting dataset encoding.

• Generate high-precision Digital Elevation Models (DEM) from LiDAR point cloud data.

3.1.5 Mapping and statistics

• Supports various thematic map types, including single-value, range, uniform label, single-value label, range label, statistical, graduated symbol, aggregated, and custom thematic maps.

• Provides rich point, line, and fill symbol libraries, with the ability to import additional symbols.

• Supports label editing and management, including moving labels, label preprocessing, label management, and label weight control.

• Enables drawing of legends, insets, charts, map grids, and lunar insets on maps.

• Supports layer blending modes.

• Provides advanced label display options, including automatic label conflict avoidance, word wrapping for long labels, labeling small features, vertical labels, label masking, label prioritization, labels along lines, subscript/superscript display, flowing labels, and vertical display.

• Offers conflict detection to identify overlapping or obscured objects.

• Supports raster and imagery layer stretching methods, including min-max stretching, standard deviation, histogram equalization, histogram matching, Gaussian stretching, and percentile clipping. Supports Gamma adjustment for nonlinear brightness and contrast.

• Supports temporal data playback and multi-version cached data, allowing layers to be played dynamically in a specified sequence.

• Supports saving and loading layer and map templates.

• Supports exporting maps as images or PDF files, with the ability to split map output by features according to selected fields.

• Supports map coordinate system configuration and dynamic projection, allowing real-time transformation between spatial reference systems for seamless integration and unified display of multi-source data.

• Supports cartographic templates with predefined layouts, symbols, scales, and legends, and allows template import and export for quick reuse, sharing, and standardized map production, improving efficiency and consistency.

3.1.6 Map tiles

• Supports multiple tile types, including raw tiles, compact tiles, and MongoDB tiles.

• Provides tile generation capabilities, including single-process or multi-process generation of raster or vector tiles, tile updates, append operations, and resume/recovery functions. Generated tiles can be saved to cloud storage.

• Supports vector tiles generation at custom scales.

• Offers tile management functions, including tile verification, boundary checks, tile erasure, merging, extraction, and conversion.

• Supports tile publishing and browsing, enabling practical tile-based map applications.

• Supports incremental tile updates and automatic background tile generation, enabling efficient and continuous map service publishing and visualization without manual intervention.

3.1.7 3D scenes

- Supports integrated 2D/3D display and interaction
- Supports loading diverse terrain, imagery, vector, model, and online services (OGC, iServer, OSM, etc.)
- Offers diverse navigation and visualisation tools (sun path, underground mode, scroll view, etc.)
- Supports 3D model and vector editing, exporting to multiple formats (OSGB, KMZ, GLTF, etc.)
- Supports standard data integration and management for IFC, CityGML, GIM, etc.
- Supports 3D planar and spherical scenes, allowing addition of massive terrain, imagery, vector, and model data for real-time rendering.
- Provides tile loading capabilities, supporting single or batch loading of tile datasets from folders. Supported tile types include: 3D tiles (.scp), 3D imagery tiles (.sci, .sci3d, .sit, .tiff, .tif), 3D terrain tiles (.sct), 3D vector tiles (.scv), global map tiles (.sci), and voxel raster tiles (.scvo).
- Supports loading online data sources, including MapWorld (Tianditu), OpenStreetMap, STK terrain, iServer REST and terrain services, ArcGIS map services, and OGC map services (WMS, WMTS).
- Provides 3D thematic mapping, supporting creation of single-value, range, label, statistical, and custom thematic maps based on vector points, lines, and polygons, with editable map styles.

• Provides terrain-based 3D spatial analysis, including slope and aspect analysis, contour analysis, inundation analysis, and cut-and-fill analysis.

• Offers line-of-sight analysis, evaluating visibility between any two points in the scene.

• Supports viewshed analysis, multiple viewshed analysis, and dynamic viewshed analysis, determining visible and non-visible coverage areas from specified observation points.

• Provides openness analysis to assess the openness of specified areas.

• Supports solar analysis, calculating sunlight exposure for specified areas over a defined time period.

• Offers profile analysis, analyzing terrain, detailed urban models, and BIM data along a profile line, including measurements, queries, maximum/minimum elevation and slope display, and result export.

• Supports video projection, allowing specified video files to be projected and played within the 3D scene.

• Provides skyline analysis, generating skylines and maximum height limits from specified observation points, with result export.

• Supports generation of DSM, DOM, DOM+DSM, 2.5D maps, and façade maps, enabling export of 2.5D maps with corresponding vector polygons and façade maps with vector data.

3.1.8 Spatial analysis and statistics

• Provides vector analysis functions, including buffer, multiple buffer, and 3D buffer analysis.

• Offers raster statistical analysis, including basic statistics, common statistics, neighborhood statistics, regional statistics, block statistics, and elevation statistics.

• Supports SQL queries and vector spatial queries.

• Provides raster analysis, including slope, aspect, and contour extraction.

• Supports six geographical metrics: central feature, mean center, median center, directional distribution, and others.

• Offers five spatial pattern analysis modes, including spatial autocorrelation, high/low value clustering, average nearest neighbor, and geographic detector analysis.

• Supports geographically weighted regression (GWR) and ordinary least squares (OLS) for scientific modeling and statistical prediction.

• Provides hotspot analysis, clustering, outlier detection, density clustering, and other pattern exploration functions.

• Supports spatial sampling and statistical inference, including BShade prediction and sampling, single-point regional estimation, and statistical inference.

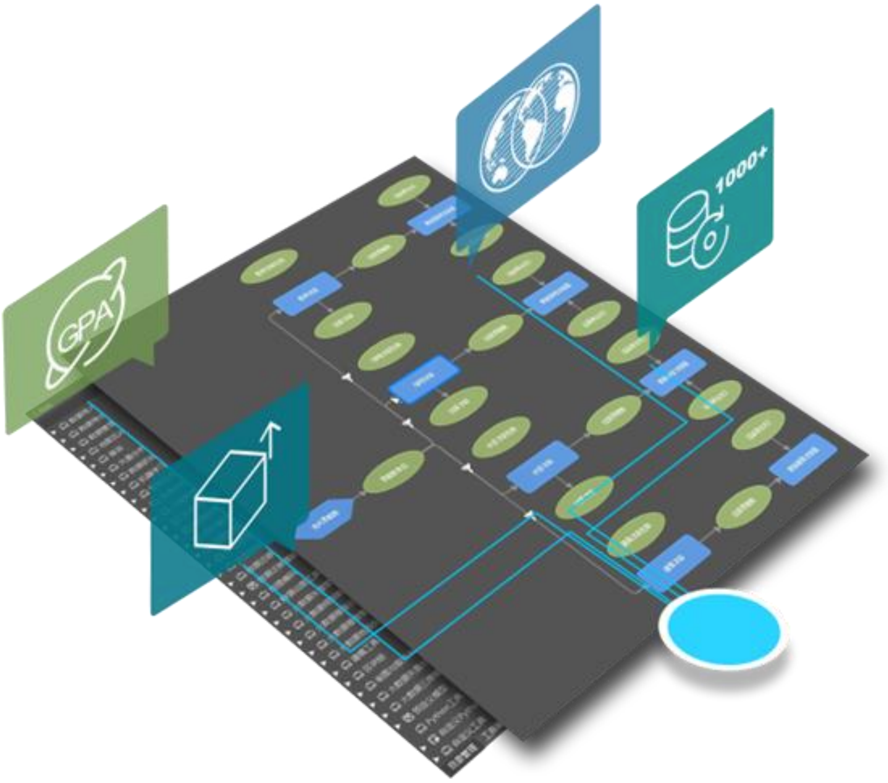
3.1.9 Data quality and topology

• Supports topology checks, repairs, feature generation, and logical map generation

3.1.10 Network Analysis

- Supports transport and facility network analysis: optimal routing, site selection zoning, logistics distribution, accessibility analysis, etc.
- Supports linear reference and 3D network analysis (including 3D optimal routing)
- Supports construction of 3D network datasets from specified 3D point, line, or combined point and network datasets.
- Supports building 3D network datasets based on spatial topological relationships among 3D points and lines.
- Provides 3D optimal path analysis to find the least-resistance path between two points in a 3D network.
- Offers pipe burst analysis, identifying upstream/downstream valves and affected pipelines based on burst points.
- Supports network dataset construction for infrastructure modeling.
- Provides transportation network analysis, including site allocation, traveling salesman problem (TSP), logistics distribution, optimal path analysis, and nearest facility search.
- Supports facility network analysis, including feature tracing, adjacency analysis, accessibility analysis, critical feature analysis, connectivity analysis, and loop checking.
- Provides dynamic linear referencing for locating features along linear networks.
- Supports route planning and navigation capabilities.

3.1.11 Automated Processing (GPA)



- Supports automated workflows, allowing a series of geoprocessing tools to be logically connected into models for automated execution.
- Provides iteration over files, datasets, and variables for batch processing, with support for preconditions and inline variable replacement.
- Offers a task manager to monitor model execution progress, tool parameters, and execution status, enabling traceability of model runs.
- Supports importing and exporting automated processing models, and allows models to be saved as tools to simplify business logic.
- Supports publishing models as services for sharing with iServer.
- Allows creation and import of model library files, with password protection for encryption and security.
- Supports custom toolboxes, enabling users to copy/paste frequently used tools into personalized toolsets.
- Allows adding tools to tabs, providing flexible customization of functional

entry points.

3.1.12 Big data analytics

- Supports HDFS data upload and download.
- Provides vector and raster management tools for big data.
- Provides vector and raster analysis for big data, including spatial overlay, trajectory analysis, terrain analysis, and raster statistics.
- Offers oblique imagery processing tools, including preprocessing, texture compression, normal calculation, and individual building extraction.
- Provides 3D tile generation tools for big data, including batch generation of model tiles, point cloud tiles, terrain tiles from raster files (TIN), 3D Tiles to S3M conversion, and S3M to 3D Tiles conversion.
- Supports online computation and analysis, including buffer analysis, density analysis, overlay analysis, single-feature spatial queries, and regional summary analysis.
- Provides Spark local (multi-process) mode to improve single-machine resource utilization and enhance execution performance when using big data tools.

3.1.13 Customisation and Development

- Supports customisable visualisation interfaces and plug-in extensions
- Provides extensive UI controls, tool interfaces, and Python secondary development capabilities
- Enables rapid customization of interfaces and functionality through visual and interactive methods.
- Provides a rich set of UI controls and tool APIs.
- Supports customization of startup screens and product names.
- Supports extension development via a desktop-based, plugin driven

framework.

3.1.14 Statistical Chart

• Supports creation of various chart types, including bar, column, pie, line, bubble, area, combination, scatter, time-series, and histogram charts.

• Enables direct conversion between charts and thematic maps.

• Supports chart display customization and export as images.

• Provides a rich set of chart visualization tools for rapid statistical analysis and data mining based on attribute data.

• Supports exporting charts or converting them into thematic maps.

3.1.15 Geocoding

• Supports integration with standard geocoding services, such as SuperMap Online and ArcGIS Geocoding Service.

• Supports geocoding input from CSV, Excel, Shapefile, GeoJSON, and GDB formats.

• Supports parsing of multiple field types, including coordinates (latitude/longitude), address text, and POI names.

• Provides batch geocoding and reverse geocoding capabilities.

• Supports visualization of geocoding results and export in common formats, such as SHP, KML, and GeoPackage.

• Supports automatic database creation and spatial index building for geocoding results, improving query and rendering performance.

• Supports index-based map search, fuzzy matching, and rapid feature location, enabling efficient retrieval and spatial analysis.

3.1.16 Remote Sensing Image Production, Management and Processing

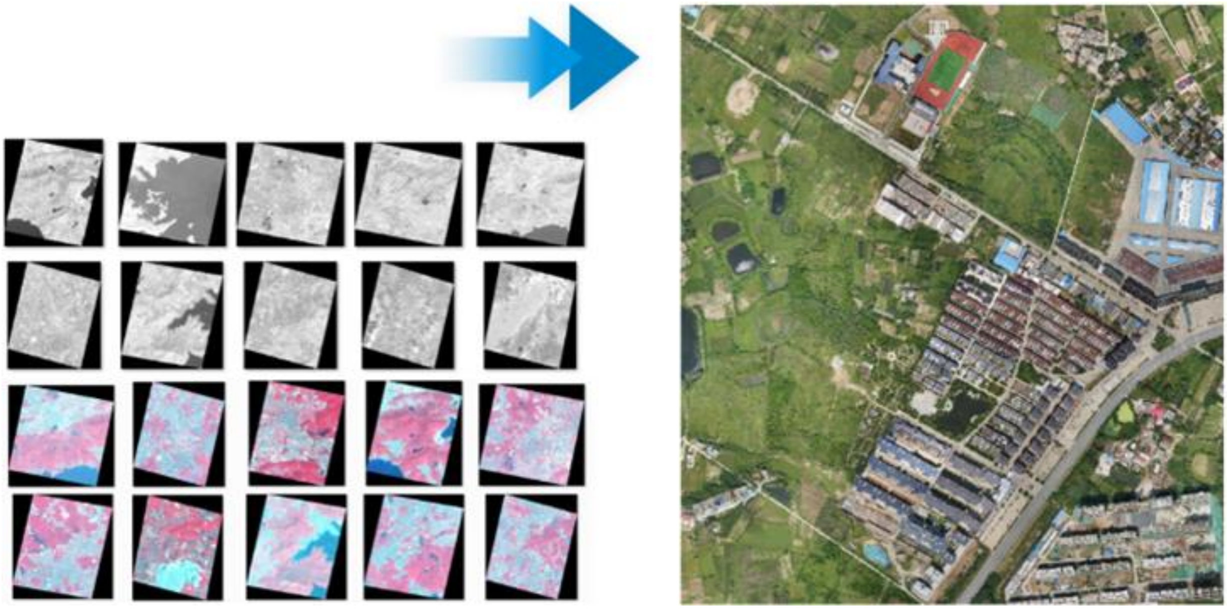
• One-stop remote sensing product production process: Providing a one-stop preprocessing workflow from radiometric calibration, atmospheric correction, orthorectification, fusion, mosaicking to clipping.

• Support remote sensing and drone muti-source image.

• AI-Powered High-Quality Image Production.

• Efficient Image Production, Automatic Cloud Repair, Automatic Color Harmonization and Distributed Technology.

• Production and application integration, covering the entire lifecycle of "data production - management - release - application".



• Supports remote sensing image processing, with access to 22 mainstream satellite data sources, including GF, ZY3-02, and SuperView-1.

• Provides automated production workflows for DOM, DSM, and DEM generation.

• Supports full workflow management of intermediate and result data through mosaic datasets.

• Enables generation and management of tie points and ground control points.

• Supports image fusion, registration, and color balancing.

• Provides image quality evaluation, including planar accuracy and fine planar accuracy assessment.

- Supports relief, road, and building pattern detection.

- Supports remote sensing production using satellite and UAV imagery, including image preprocessing, geometric and radiometric correction, mosaicking, classification, and thematic analysis, enabling accurate extraction and utilization of multi-source remote sensing information.

3.1.17 Data Sharing and Service Release

- Supports access to online map services such as OGC, SkyMap, OpenStreetMap, WorldTerrain and SuperMap REST.

- Supports one-click publishing of maps, data, analysis, and 3D scenes services.

- Supports data and services management in SuperMap Online and SuperMap iPortal.

- Map Service Publishing Tool allows specified datasets to be published directly as iServer map services with designated layer styles.

- Multi-Service Publishing Tool enables publishing of multiple service types (map services, data services, etc.) based on a workspace.

- MongoDB Tile Publishing Tool publishes MongoDB tiles as iServer map services, vector tile services, and other service types.

- Image Service Publishing Tool publishes specified imagery as image services, supporting multiple service types simultaneously, including OpenAPI Image Service, WMS 1.1.1, WMS 1.3.0, WMTS 1.0.0, and WMTS-CHINA.

- UGCV5 Tile Publishing Tool publishes existing raster tiles and MVT vector tiles as SuperMap iServer map or vector tile services.

- 3D Tile Publishing Tool publishes 3D tiles (3D model tiles, 3D imagery tiles, 3D terrain tiles) as iServer 3D services.

• Supports forwarding ArcGIS REST services to SuperMap iServer services based on the REST service URL.

• Allows publishing SuperMap workspace types as ArcGIS REST services via SuperMap iServer.

3.2 GIS Data Migration and Processing Software

The software is a leading data transformation, integration, and automation platform specialising in the interoperability, cleansing, conversion, publishing, and workflow automation of spatial (GIS) and non-spatial data. It has seen significant enhancements in real-time stream processing, multi-source data ingestion, automated workflows, and cloud/hybrid deployment capabilities. Its applications span diverse sectors including government administration, infrastructure, public safety, smart cities, BIM/GIS integration, data sharing, and big data processing.

3.2.1 Multi-format, multi-system data ingestion and transformation

- Supports hundreds of data source formats (vector, raster, point cloud, BIM models, CAD, databases, etc.), enabling read-transform-write workflows.
- Supports various coordinate systems and projection conversions, ensuring data compatibility across different systems.
- Robust format conversion capabilities: including Shapefile, GeoJSON, GDB, TIFF, IMG, OBJ, 3DS, and more.
- The latest version enhances support for cloud services and real-time streaming data ingestion.

3.2.2 Automated Processes and Workflow Design

- Provides a visual "Workflow Designer" (Workbench), enabling users to construct complex data processing flows by dragging and dropping components.

- Supports batch processing, iteration, variable substitution, and conditional control to automate large-scale data transformation tasks.
- Supports exporting, sharing, and reusing modelled workflows to enhance project implementation efficiency.
- The latest version introduces real-time data flow capabilities for on-site/mobile teams to access and edit data.

3.2.3 Real-time stream processing and dynamic data updates

- The new version enhances "Stream Capabilities" to support real-time data ingestion, processing, and response.
- Enables application of data processing workflows for dynamic event response, real-time monitoring, and decision support scenarios.
- Integration with cloud platforms, IoT devices, and sensor systems is supported to enhance data timeliness.

3.2.4 Spatial Data and GIS/BIM Integration Capabilities

- Strengthened spatial data processing capabilities, including coordinate transformation, geographic projection, and spatial analysis.
- Supports interoperability and integration between GIS and BIM model data, applicable to smart city and infrastructure domains.
- Supports direct deployment of transformation results to mapping systems, 3D visualisation platforms, or Web GIS publishing.

3.2.5 Cloud deployment and scalability

- Supports on-premises deployment, enterprise server deployment, and cloud deployment.
- Within cloud/hybrid environments, supports elastic scaling, load balancing, and integration with cloud storage/computing services.

- Integrates with big data platforms (e.g., Hadoop, Spark), database clusters, and cloud storage for large-scale data processing.

3.2.6 Data Quality Control and Cleansing

- Offers comprehensive data cleansing, duplicate value handling, missing value imputation, attribute updates, and spatial error correction.
- Supports data validation, transformation rule definition, process monitoring, error logging, and process tracing to ensure data reliability.

3.2.7 Extensibility, Customisation, and Integration Capabilities

- Offers plug-in and script-based extension interfaces (e.g., Python scripts, custom transformers) to facilitate secondary development and customisation.
- Supports embedding within enterprise systems or invocation as service components, suitable for complex project requirements.
- Supports web services, API integration, and third-party system connections (e.g., GIS platforms, ERP, BI).

3.2.8 Visualisation, reporting and monitoring capabilities

- Provides monitoring interfaces for conversion processes, logs, metrics, and task statuses to facilitate project control.
- Supports previewing data conversion results, visual inspection, and generating quality reports.
- Supports output in multiple formats for data sharing, publishing, and presentation purposes.

3.3 GIS Server Software: SuperMap iServer 12i (2025)

SuperMap iServer 2025 is a server GIS software development platform built upon a high-performance, cross-platform GIS kernel. It is distributed and scalable, offering comprehensive GIS service publishing, management, and aggregation capabilities while supporting multi-tiered extension development. It delivers robust web services related to spatial big data, GeoAI, and 3D technologies, etc. Deeply integrating microservices, container orchestration, service mesh, serverless computing, and more, it provides multiple SDKs to facilitate the construction of cloud-native GIS application systems based on microservice architecture.

SuperMap iServer primarily delivers the following capabilities:

3.3.1 System Compatibility

- Supports mainstream Windows and Linux operating systems.
- Supports mainstream databases: Oracle, SQL Server, PostgreSQL/PostGIS, MySQL, MongoDB, Elasticsearch, and others.

3.3.2 Flexible Deployment and High Availability

- Supports single-server, multi-server clusters, microservices, and containerised deployments, enabling flexible scaling with high performance and availability.
- Built-in GIS microservices including maps, data, 3D, AI, and streaming data.
- Microservice images are lightweight, launch rapidly, and consume minimal resources.

3.3.3 Distributed Storage and Computation

- Supports distributed databases, file systems, and computing platforms such as Spark and Hadoop.
- Delivers distributed spatial analysis, data processing, and real-time stream data computation capabilities.
- Support distributed tile generation services (single-machine multi-process tile generation, multi-machine distributed tile generation), and generate two types

of tiles to meet different application requirements, including: (1) Map tiles: in raster format, suitable for basic data, can be used as the base map for online maps, using tiles can significantly improve the efficiency of map generation and online access; (2) Vector tiles: small in size and fast in production, suitable for vector layers with frequent data changes (such as POI data), which can further avoid changes in base map tiles.

3.3.4 GIS Service Publication and Aggregation

●Support multiple service API, including:

○ SuperMap REST (REST service interface / REST / JSR service interface);

○ OGC (WMS 1.1.1, WMS 1.3.0, WMTS 1.0.0, WMTS-ArcGIS, CSW 2.0.2, OGC API-Feature, OGC API-Tiles, WFS 1.0.0, WFS 2.0.0, WCS 1.1.1, WCS 1.1.2, GML 2.1.2/3.2.1, KML 1.0, SLD 1.0, GeoPackage 1.0, GeoRSS, WPS 1.0.0)

●Support data publishing services based on SuperMap for third parties, thereby enabling the client sides of third-party platforms to directly open. The distributed third-party service interfaces supported include: ArcGIS REST service interface, Baidu REST service interface, Google REST service interface, TMS REST service interface, and OSM REST service interface.

●Supports publishing data service, including Dataset management, data query, coordinate conversion, online editing of datasets, statistical analysis, it supports database transaction capabilities, as well as the rule modeling and texture update functions for model data sets.

●Supports multiple service types including maps, tiles, data, 3D, and spatial analysis.

●Supports the reception of common data formats such as CSV, TXT, JSON, and GeoJSON from other system.

●Supports aggregation of SuperMap, third-party, and OGC standard services.

●Support the direct publication of various storage methods (local file system, object storage system, FTP server, HTTP server, shared directory), storage formats (.tif, .img, .ecw) of image or raster data, as well as existing mosaic data sets as image services.

●Supports publishing image service from multiple image data formats, such as MrSID, TIF, BMP, JPG, as well as image compression formats like ECW and SIT, etc.

●Provide functions such as browsing, statistics, legend, query, retrieval and local update for image or raster data, and the display style of image thumbnails is consistent with the image collection.

●Support the addition and deletion of image data, and data download.

●Support the configuration of dynamic caching schemes for image services.

●Provide the ability to monitor image data directories and automatically add new image files.

●Provides silent slicing capabilities, generating image map tiles efficiently in the background, enabling the image service to simultaneously have the ability to provide tile services.

●Includes built-in spatial and 3D analysis, distributed analysis, serverless computing, and GIS agent services.

3.3.5 Spatial Big Data Processing and Publishing

• Supports distributed processing and real-time ingestion of vector, raster, and stream data.

• Supports mainstream real-time transmission protocols (Socket、WebSocket、 HTTP、JMS、Kafka, etc.) and multiple data formats (XML, CSV, JSON, GeoJSON, etc.).

• Supports "tile-free" publishing and cache optimisation to enhance high-concurrency access performance.

• Offers over 700 analytical tools covering vector, raster, 3D, AI, and spatio-temporal big data analysis.

3.3.6 Real-time Stream Data Service

• Supports connection to mainstream real-time data transmission protocols such as Socket, WebSocket, HTTP, JMS, and Kafka. Also supports reception of common data formats such as CSV, TXT, JSON, and GeoJSON.

• Support publishing real-time data service based on the stream processing model, providing the capability for accessing stream data as well as real-time filtering, processing and output functions.

• Achieve real-time data output through the transmitter, supporting the storage of historical data in the iServer DataStore. It also supports output in the form of messages and enables real-time data transmission to the client via the data stream service in the WebSocket manner. This provides a technical foundation for the real-time data visualization of the client's SuperMap iClient.

3.3.7 Web Editing and Image Processing

• Supports online editing and spatial analysis of 2D and 3D data.

• Provides image browsing, retrieval, statistics, appending, and cache management functions.

• Supports remote sensing image enhancement, classification, mosaicking, quality assessment, and engineering processing.

• Support the addition and management of attachments for elements, enabling users to associate multimedia files such as images and documents with spatial elements, thereby enhancing the information expression and business application capabilities of the data.

3.3.8 Comprehensive Development and Integration Interfaces

• Provides comprehensive REST API, Java SDK, and multi-platform client SDKs (Android, iOS, JavaScript, WebGL/WebGPU, etc.).

• Interoperability with third-party map APIs

• Support the extension of REST interfaces at all levels, including: extending existing REST resources or adding new ones, extending expression types, extending parameter passing formats, and extending HTTP request processors.

• Support kernel container-level domain service extension mechanisms, including: extending support for new data sources, extending new service types, and extending support for publishing industry domain functions as REST services.

3.3.9 Geo-Processing Automation (GPA) Service

• Support GPA service, including basic component tools for vector and raster data import, export, processing, etc

• Supports the reading of various vector, raster, table data and 3D data; Supports the export of various vector and raster data.

• Support multiple data type conversion tools, including: conversion between 2D and 3D data; Conversion between CAD,composite data and simple data; Conversion between polygon and model data; Conversion of point, polyline and polygon; Conversion between network data and point-polyline data; Conversion between attribute data and spatial data.

• Support other extension module tools such as spatial analysis tools, network analysis tools, big data tools, machine learning tools, stream data processing tools, and 3D geographic design tools, etc.

3.3.10 Server Data Management and Security

- Support the configuration of each layer of the management service (service provider, component provider, service interface, etc.)
- Supports ensuring server security, including a file management root directory, dynamic encryption for GIS services, security configuration, user (group) management, role management, login configuration (CAS login, Keycloak login, LDAP login, third-party login), role-based access control, and support for user groups. It also supports setting that the first n passwords cannot be reused, setting a protection mechanism for password error attempts to prevent brute-force cracking, and setting scenarios for resetting passwords. It supports storing authentication and authorization information in a database and also supports expansion. This facilitates the unified management of authentication and authorization information by administrators.
- Support authentication and authorization based on Keycloak, achieving unified account management among cloud, edge and end devices. Support single sign-on across cloud platforms. Support authorization for third-party applications to log in to the cloud GIS server.
- Support conventional server protection measures, including firewalls, fixed ports, and HTTPS encrypted communication.
- Support enables HTTP caching, which can accelerate frequently accessed services during high concurrency. Support enabling request caching to cache request results locally, accelerate access, and cover all service functions, including maps, data, spatial analysis, network analysis, traffic transfer analysis, and 3D services, etc.
- Supports real-time refreshing of dataset changes, capable of capturing

dataset changes from PostGIS, PostgreSQL, and Yukon data sources without delayed updates. Support the automatic release of free datasets, effectively reducing memory usage.

• Support the availability detection and exception waiting mechanism for server startup dependencies. Normal startup can only be achieved when all essential startup dependencies are successfully connected

• Provide the automatic synchronization capability for multi-node GIS services. Support the automatic synchronization of multi-node service configuration information based on databases (Oracle, PostgreSQL, Kingbase, GaussDB, Vastbase, HighgoDB, GBase 8c), and be able to dynamically synchronize the GIS service changes of any node.

• Support data registration, registering the database or data file to iServer as the data source of the service, including: (1) Distributed tile libraries: MongoDB, Alibaba Cloud OTS; (2) Big data file sharing: shared directories, HDFS directories; (3) Spatial databases (supporting the changes of data sets in the database by iDesktopX or business systems): PostgreSQL, Oracle, HDFS, PostGIS, DM, HighGo DB, Kingbase, Yukon, Vastbase. (4) Machine learning models.

3.3.11 Geocoding Service

• Provide forward and reverse address matching capabilities: Support querying corresponding geographic coordinates through textual address descriptions (forward geocoding), as well as reverse querying textual address descriptions through geographic coordinates (reverse geocoding), to achieve mutual conversion between addresses and spatial locations.

• Support multiple address data source publishing: Support directly publishing predefined address index files as geocoding services; simultaneously support batch aggregation and forwarding of third-party geocoding services (such as ArcGIS

Server services), to achieve unified management of multi-source services.

• Offer flexible query parameter control: Allow users to set the maximum number of results returned per query to enhance query efficiency; support limiting the query area by specifying a search range (such as city, region, or geometric boundary), to make address matching results more precise.

• Integrate distributed computing framework: Geocoding services can be combined with processing automation (GPA) services, leveraging distributed computing platforms like Spark and Hadoop to process massive address data, ensuring service performance and stability in high-concurrency and large-data-volume scenarios.

3.3.12 Web Map Printing Service

• Supports GeoPDF which is printed as A0/A1 map.

• Supports secondary editing of geospatial/text information in printing results.

• Provides extensible layout template for transportation, land, etc.

3.3.13 Cloud-Native deployment

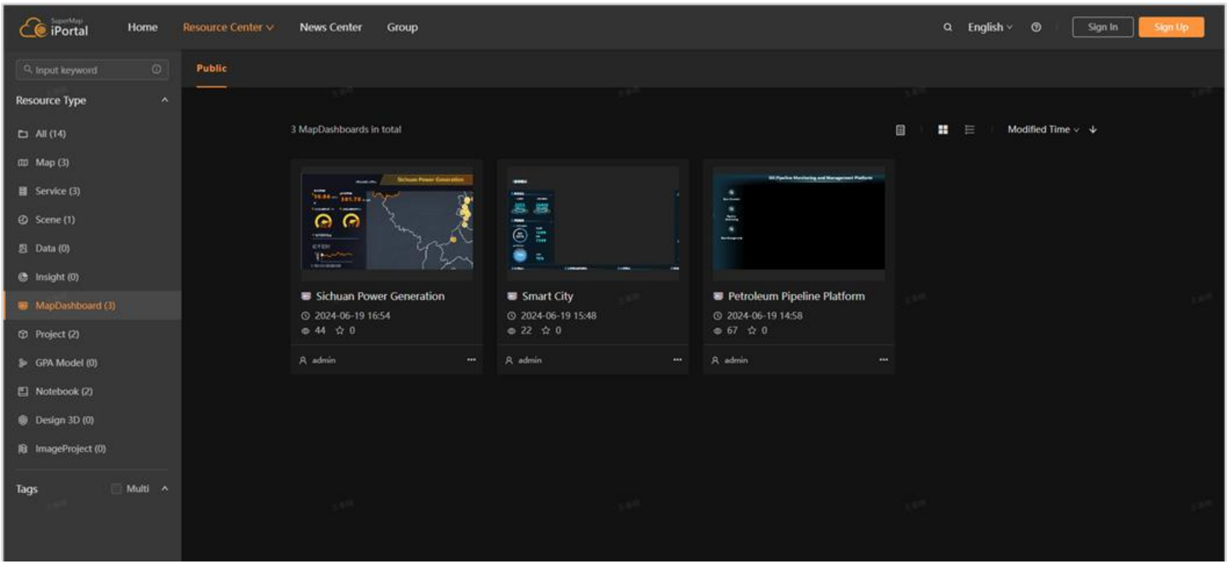
• Provide cloud-native environment.

• Supports serverless computing. The computing modules of microservices are decomposed into smaller, specialized, faster-starting and resource-saving function computing units for execution, facilitating applications to execute precisely and rapidly on demand, and expand flexibly.

•Support unlimited number of concurrent user visit.

3.4 GIS Portal Software: SuperMap iPortal 12i (2025)

SuperMap iPortal is an integrated GIS portal software platform for resource consolidation, search, sharing, and management. It enables rapid zero-code website creation, multi-source data integration, multi-source heterogeneous service registration, and multi-source service permission control. Offers a rich suite of web applications for thematic map creation, spatial feature editing, distributed spatial analysis, 3D visualisation, 3D modelling, automated spatial data processing and analysis, and industry-specific dashboard creation and display. Serves as the user centre, resource centre, and application centre for the cloud-edge-end integrated GIS platform, enabling rapid construction of GIS portal sites.



3.4.1 System Compatibility and Data Support

- Supports mainstream operating systems: Windows (x64) and Linux (Red Hat, CentOS, Ubuntu, SUSE, etc.).
- Supports multiple databases: Oracle, SQL Server, PostgreSQL/PostGIS, MySQL, MongoDB, Elasticsearch, DB2, etc. PostGIS database data resources support exporting data in ShapeFile format.
- Supports uploading and registering multiple data types, including UDB, Shapefile, GeoJSON, FileGDB, SMTiles, CSV, Excel, PDF, and more.
- Supports multi-type service registration and management: SuperMap REST, ArcGIS REST, OGC (WMS, WMTS, WFS, WCS, WPS), etc., featuring batch registration, automatic synchronisation, dynamic validation, and secure access control.

• Support dynamic online/offline verification for successfully registered services.

• Support batch registration of GIS services and automatic synchronization, and support automatic parsing of metadata information for registered services.

• Support batch registration of non-public iServer services by binding credentials.

• Support the configuration of data storage as a shared directory with the hosted server iServer, enabling quick and direct publication of services.

• Support users to randomly distribute the data they upload to the portal to multiple GIS servers for service publication.

• Support the registration of PostGIS, PostgreSQL, Oracle, SQL Server, and DM database workspaces and the publication of services.

3.4.2 Flexible portal construction and resource management

• Offers "zero-code" visual portal design, enabling customisation of homepages, navigation bars, themes, layouts, and interface styles.

• Supports departmental resource management, organisational structure, and role-based access control, enabling logical isolation and granular authorisation.

• Supports OSS massive file management, supports Java and Python SDKs. Supports AD (Active Directory) and LDAP user authentication protocols.

• Facilitates portal resource sharing and security governance, with access permissions configurable by department, group, user, or geographic scope.

• Supports administrator resource quota management, resource transfers, access approvals, logging, and monitoring functions.

• Provides a full-featured REST API supporting custom extensions, secondary development, and third-party system integration.

• Supports single sign-on (SSO), LDAP, OAuth 2.0 and other authentication methods, featuring access control, encrypted communication and security auditing capabilities.

- Supports multilingual interfaces and internationalisation settings.

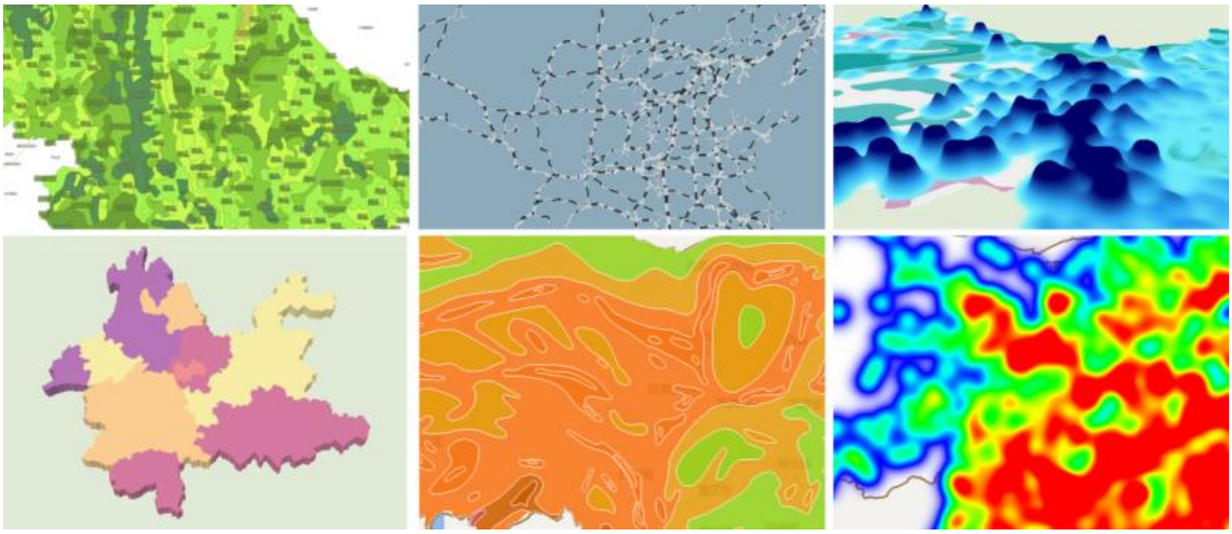
3.4.3 GIS Data Management and Visual Analytics (DataViz)

- Supports integration with multiple base map sources: Google Maps, Tianditu, Baidu Maps, Bing Maps, OpenStreetMap, etc.
- Supports vector tile and multi-type web layer overlay display.
- Supports data upload and visualisation in formats including Excel, CSV, GeoJSON, and Shapefile.
- Supports real-time data stream integration and visualisation, compatible with iServer data stream services.
- Supports layer style configuration, annotation, multimedia information display, and layer controls (visibility, transparency, refresh rate, etc.).
- Support viewing the property table information of vector layers, and the property table supports query. Support the REST query the elements of the Map layer.
- Support distance measurement and area measurement.
- Supports geocoded address matching for mapping and POI search.
- Support configuration element pop-up window. In this pop-up window, allows add images, videos and text content.
- Support the creation of thematic maps, including: basic thematic maps (basic styles), single-value thematic maps, segmented thematic maps, graded symbol thematic maps, heat maps, and migration maps.

3.4.4 GIS Data Management and Visual Analytics (MapStudio)

- Supports adding ArcGIS REST VectorTile services and XYZ Tile services via URL.

- Custom web symbol configuration capability supports defining web symbols using JPG and PNG images.
- Feature snapping functionality enables snapping to existing layer features or features being drawn.
- Data export functionality supports exporting data to CSV, GeoJSON, and JSON formats.
- Supports local updates to the boundaries of selected elements.
- Supports creating point, line, and polygon layers or data.
- Supports setting the visibility level range of layers.
- Supports querying layer attribute information and replacing layer data sets.
- Support distance measurement and area measurement.
- Supports viewing the legend of layers.
- Supports layer search and POI search.
- Supports configuring Google Map, Bing Map, OpenStreetMap, and China Dark Map as base maps, and supports setting solid color base maps.
- Feature editing supports splitting/merging features and deleting vertices using shortcut keys.
- Supports configuring layer styles with 2D/3D and animated visualization effects.
- Supports templates for point layers, line layers, polygon layers, composite symbols, heatmaps, and clustering maps.
- Provides processing tools including grid-based aggregation, zonal summarization, and overlay analysis to unlock the value of spatial information.
- Supports adding OGC WMTS, OGC WMS, and ArcGIS REST VectorTile services through search.



3.4.5 Resource Security and Operations Management

- Supports role-based access control, granular permission allocation, and resource key access mechanisms.
- Support sharing GIS resources with designated departments, groups and users, and support multiple sharing permissions such as viewing and editing.
- Allow administrators to set resource quotas for ordinary users.
- Support the transfer of user assets to other users when deleting a user.
- Support the setting of shared permission for GIS services based on spatial range. Shared objects can only access the service content within the specified geographical range.
- Supports system backups, log recording, operational monitoring, and service access statistics.
- Supports sensitive information encryption, CAPTCHA verification, secure login detection, session management, and account protection policies.
- Provides a unified user centre for cloud-edge-end account unification and authorised third-party application login.
- Supports portal-level management and preview of 3D services and resources.
- Support the ability for administrators to manage resources differently from

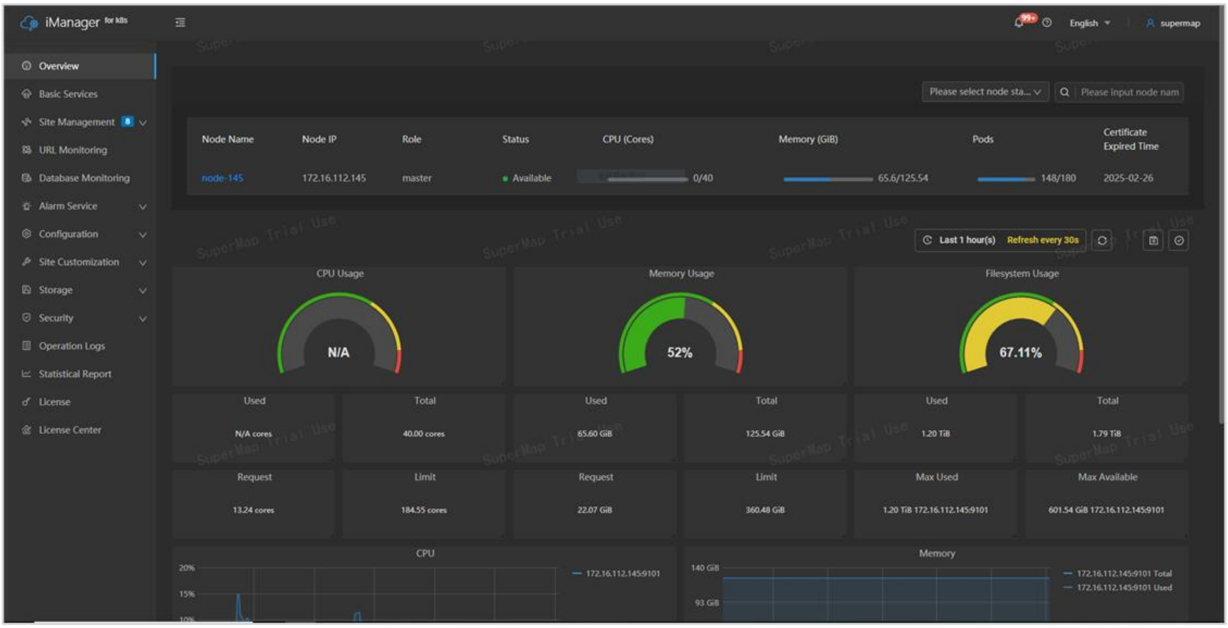
ordinary users. Support administrators to manage all the maps, services, scenes, data, insights, big screens, projects, GPA models, 3D designs, Notebooks, groups, etc. in the portal. Support administrators to set the sharing scope for all resources in the portal. Support ordinary users to manage all their own resources.

- Supports encryption configuration for sensitive information.
- Supports setting of login verification codes.
- Supports setting for detecting remote logins.
- Supports account locking and expiration settings.
- Supports session information management.
- Supports regular system backups.

3.5 Cloud GIS Server Operation & Management Platform: SuperMap iManager 12i (2025)

SuperMap iManager is a comprehensive GIS operation and management platform for unified management and maintenance of GIS application services, infrastructure, big data, and AI systems.

Built upon **a Kubernetes cloud-native architecture**, the platform enables **one-click creation, elastic scaling**, and **intelligent** operations. It supports granular management across the entire lifecycle of GIS services, significantly enhancing system efficiency and stability.



3.5.1 Cloud-Native Deployment and Compatibility

• Supports mainstream Windows and Linux operating systems, alongside domestic server environments from Huawei, Inspur, Sugon, and others.

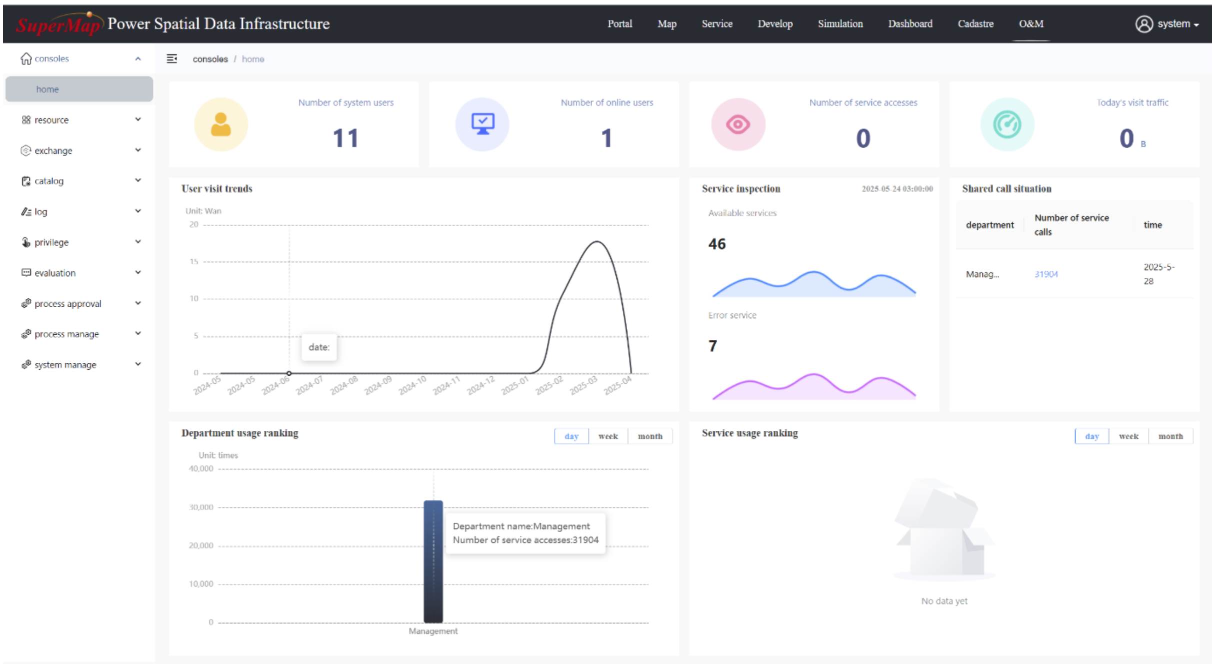
• Supports ARM architecture and accommodates containerised and distributed high-availability deployment models.

3.5.2 System-wide Monitoring

• Provides real-time monitoring of GIS servers, portals, databases, and websites.

• Supports monitoring of metrics including CPU, memory, disk usage, request volume, average response time, and online status.

• Provides system topology overviews, node health status, and map access hotspot distribution monitoring.



3.5.3 Visualised Operations Interface

- Utilises front-end component-based technology, supporting customisable dashboard layouts with drag-and-drop functionality, resizable elements, and the ability to save personalised views.

3.5.4 Database and Infrastructure Management

- Supports monitoring of mainstream databases including MySQL, Oracle, MongoDB, and PostgreSQL.
- Simultaneously monitors operational status across cloud and physical machine environments.

3.5.5 Load Balancing and High Availability Mechanisms

- Includes a universal load balancer supporting strategies such as weighted round-robin, IP hashing, and least connections.
- Integrated HA mechanism effectively prevents single points of failure, ensuring stable system operation.

3.5.6 User and organisational management

- Supports multi-level organisational structures and role-based access control.
- Administrators can centrally manage users, GIS environments, and resource groups, facilitating collaboration and isolation among organisational members.

3.5.7 Alert and Notification Management

- Supports customisable alert rules, silent periods, and multiple notification methods (interface pop-ups, emails, topology flashing).
- Features an integrated intelligent alert engine that leverages AI technology for anomaly detection, enabling intelligent operations and maintenance.
- Provides alert interfaces for extending third-party notification methods.

3.5.8 System Maintenance and Security

- Offers data backup and recovery, log collection, and visualised log viewing.
- Supports automatic locking of abnormal accounts and anti-brute-force mechanisms.
- Supports automatic offline alerts for monitored entities, ensuring secure and controllable operations.

3.5.9 Open Integration and Extensibility

- Provides comprehensive REST API interfaces for seamless integration with third-party systems.
- Frontend employs modern technology frameworks such as ReactJS and Redux, supporting secondary development and flexible expansion.

3.6 Mobile GIS Development SDK: SuperMap iMobile 12i (2025)

SuperMap iMobile is a mobile GIS development platform. Built upon core functionalities such as map browsing, data collection, data analysis, and route navigation, it integrates AR mapping, emergency marking, mobile 3D capabilities, and cloud collaboration. This enables rapid development of online and offline, 2D and 3D mobile GIS applications. It delivers advanced, professional, and intelligent mobile GIS services for developers of specialised data collection products, industry-specific mobile GIS solutions, and mass-market mobile GIS applications.

3.6.1 Multi-platform compatibility and flexible adaptation

- Supports Android, iOS, SyberOS, ZTE XitOS and other operating systems,
- enabling rapid adaptation for customised mobile devices based on ArmLinux.

3.6.2 Multi-source Map and Data Access

- Supports loading OGC standard (WMS, WMTS, WFS) and REST map/data services.
- Supports third-party online maps including Tianditu, Baidu, Google, AutoNavi, Bing, and OSM.
- Supports SuperMap global base maps and multi-threaded offline caching for seamless browsing.

3.6.3 Comprehensive data support

- Supports vector data formats including Shape, DWG, and MIF, alongside imagery/terrain data such as TIFF, IMG, and DEM.
- Supports MVT vector tile browsing and symbol style modification, with CSV text data import capability.

3.6.4 Flexible map display and editing

- Supports layer grouping management, order adjustment, transparency settings, and customisable symbols.
- Supports high-resolution SVG vector symbol display and unified management of dynamic layer styles.
- Provides tablet pen annotation, scale, legend, colour picker, positioning, compass and other controls.

3.6.5 Efficient data collection and editing

- Supports multi-method collection including point plotting, freehand drawing, and GPS, along with undo operations.
- Supports adding, deleting, modifying, and querying attribute fields, along with data editing.
- Offers GPS track collection (standard, road-tracking, distance, time, intelligent) with filtering and noise reduction processing.

3.6.6 Cloud Collaboration and Distributed Capabilities

- Access SuperMap iServer services for spatial/attribute queries and 3D scene browsing.
- Supports real-time streaming data ingestion and dynamic visualisation.
- Deep integration with iPortal enables unified management and synchronisation of cloud-based maps, services, data, and scenes.
- Supports multi-user, multi-device data collection and synchronous updates, with real-time results displayed on large screens.

3.6.7 Analytics and Web Service Integration

- Interfaces with SuperMap distributed analytics services, supporting aggregation, density, buffer, and overlay analysis types.

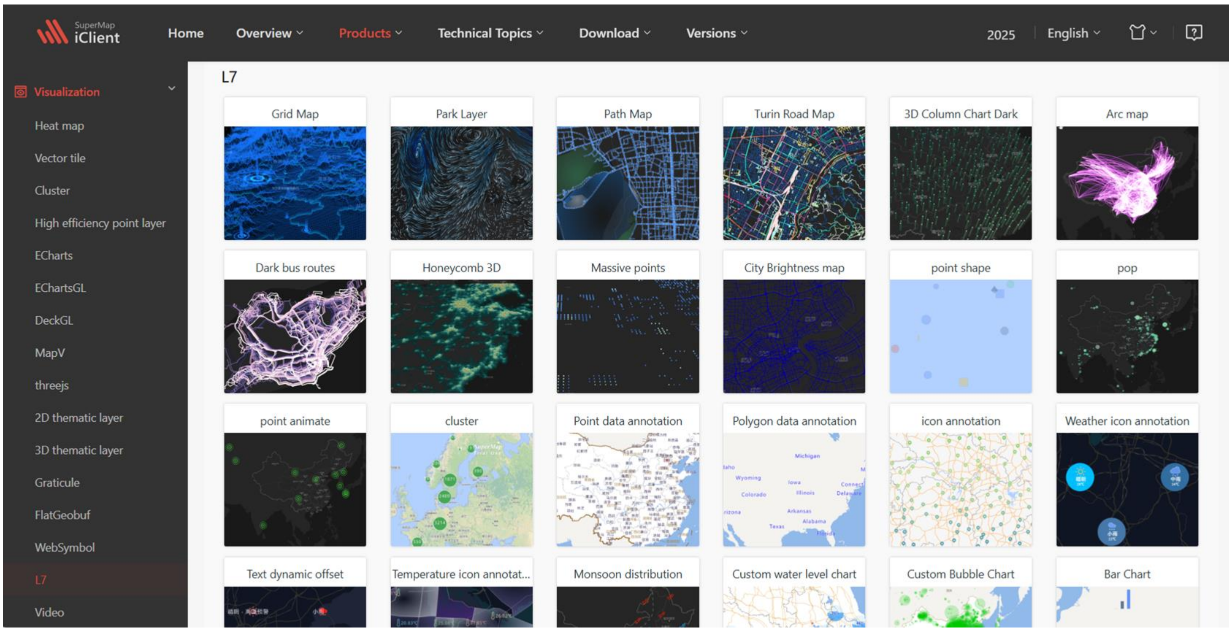
- Supports network analysis services including route planning, travelling salesman problems, and logistics distribution analysis.

3.6.8 Simulation and Extensibility

- Supports a 2D situation simulation module, enabling import/export of simulation animations in XML and JSON formats.

3.7 WebGIS Development SDK: SuperMap iClient JavaScript 11i (2024)

SuperMap iClient JavaScript is a GIS web- client development platform built upon modern web technology stacks. It serves as the unified JavaScript client for the entire SuperMap GIS product suite and online GIS platforms. The platform enables rapid development of 2D and 3D WebGIS applications, featuring robust capabilities in map display, spatial analysis, data querying, and visualisation. It provides a flexible front-end development framework for enterprise-grade GIS applications.



3.7.1 2D WebGIS Application Development SDK

- Supports mainstream web map frameworks: Leaflet, OpenLayers, MapboxGL, MapLibreGL.
- Supports integration with mainstream GIS services: SuperMap REST, ArcGIS REST, OGC (WMS, WMTS, WFS), etc.
- Supports multi-coordinate system map display and layer overlay (EPSG:4326, EPSG:3857, etc.).
- Provides spatial operations including distance measurement, area calculation, extent and geometry queries, and SQL queries.
- Supports online querying and editing of data services (fields, buffers, extents, collections, etc.).
- Includes built-in spatial analysis (buffer, overlay, Voronoi polygons, interpolation, etc.) and network analysis (shortest path, service area, site selection, transit transfer, etc.).
- Comprehensive API documentation and online examples facilitate rapid development and debugging.

3.7.2 3D WebGIS Application Development SDK

- Supports 3D data rendering: terrain, imagery, oblique photography, BIM, point clouds, underground utility networks, etc.
- Supports spatial location picking, 3D queries (SQL, spatial, box selection) and multi-object hierarchical queries.
- Offers multiple 3D measurement tools (spatial distance, area, height, ground-level measurement, etc.).
- Supports comprehensive 3D spatial analysis: line-of-sight, field-of-view, shadow, skyline, profile, slope gradient, height restrictions, setback lines, solar radiation, etc.

- Supports visualisation effects including 3D flight paths and camera animations, model explosions, and dynamic layers.
- Supports drawing point, line, surface, and solid objects, along with particle effects such as wind fields, flames, and smoke.
- Supports geological body model analysis (stretching, sectioning, explosion, clipping, excavation, etc.).

3.7.3 Map Libraries and Chart Libraries

- Supports global custom header configuration for 2D clients to pass user-defined metadata.
- Map development library supports: Leaflet, OpenLayers, MapboxGL-JS, iClient Classic.
- Chart development library supports: ECharts, D3, MapV, DECK.GL.
- Adopts MVVM (Model-ViewViewModel) as the architecture design, and is compatible with other frameworks, such as Angular and native H5 development.

4 Unified database construction for power grid GIS data

4.1 GIS database design

4.1.1 Objective Approach

4.1.1.1 Core Objectives

Centred on "GIS integration + power grid business-driven" principles, adhering to the tenets of "demand-oriented, clear structure, easy scalability, and high security". Employing object-oriented modelling techniques to construct core GIS software database models and internal software database models. This encompasses database design for power grid and communication infrastructure management, supporting multi-level grid management (high-voltage/medium-voltage/ low voltage), communication infrastructure management, and GIS databases for power grid topology and resource flow monitoring. This fulfils requirements for power system operation analysis, fault simulation, and grid automation.

4.1.1.2 Design Principles

The core principle of the power grid GIS database design is to integrate multi-level grid management requirements (high-voltage/medium-voltage/low-voltage) through spatial information as the connecting link. This achieves unified association between "spatial data - facility data - operational data" while meeting objectives for flexible expansion, cross-system integration, and intelligent empowerment. It supports hierarchical grid monitoring and analysis.

4.1.1.2.1 Multi-level Grid Spatialised Comprehensive Management Principle

Covering all tiers of high-voltage, medium-voltage, and low-voltage power equipment, this system establishes complete associations between "equipment –

location – topology" through GIS spatial attributes, eliminating management blind spots. Each spatial entity (e.g., pylons, transformers, meter boxes) must be linked to operational attributes such as "unique equipment ID + voltage level + operational status", enabling visualised management where "clicking a device on the map → displays comprehensive information".

4.1.1.2.2 Spatial Data Model Extensibility and Customisation Principles

Adaptable to new equipment or technologies (e.g., 5G IoT terminals) without disrupting existing GIS database layer structures or operational associations. Employing a "core spatial model + extensible fields" design, the foundational model preserves core attributes while reserving customisation interfaces for extensible fields.

4.1.1.2.3 Cross-System Spatial Data Interconnection Integration Principle

Enables seamless integration between GIS databases and systems such as SCADA and IoT devices, ensuring bidirectional communication between spatial data and real-time operational data to prevent data silos.

4.1.1.2.4 Principles for Spatial Network Analysis Support

Leveraging GIS spatial topology and attribute data to support operational analysis and dispatch analysis within power systems, enhancing spatial visualisation capabilities for decision-making. Based on multi-level grid spatial topology, this enables a closed-loop support process: "fault point localisation → impact scope analysis → dispatch plan generation" (e.g., for medium-voltage line faults, GIS automatically delineates affected low-voltage transformer districts and displays switchable backup supply lines).

4.1.1.2.5 Smart Grid Digital Empowerment Principle

Utilising GIS spatial data as the foundation, this drives the digitalisation of the power grid, supporting the automation development of smart grid (e.g., automated inspections, remote control). Spatialised intelligent decision-making models are constructed, such as automatically recommending charging point installation locations based on the spatial distribution of GIS transformer station loads; analysing risk areas for icing, tree obstructions, etc., based on line spatial alignment and terrain data.

4.1.1.2.6 Spatial Data Quality Assurance Principle

Ensure the accuracy, completeness, and timeliness of spatial data within the GIS database to provide a reliable spatial foundation for all business applications. Conduct regular spatial data validation, promptly correct erroneous data, and synchronously maintain the timeliness of both spatial and business data.

4.1.1.3 Design Approach

4.1.1.3.1 Employ a layered modelling approach for multi-source data design and organisational management

Adopt a "generic model + business model + extension model" architecture, focusing on business scenarios such as power grids and telecommunications. Prioritise coverage of four core functions: equipment management, network interconnection, resource flow monitoring, and fault impact analysis, avoiding redundant design.

4.1.1.3.2 Construct data models based on standardised metadata items

Metadata is data about data, describing content, scope, quality, management methods, ownership, and delivery mechanisms. It assists users in discovering data, assessing suitability, accessing, transforming, and utilising information. During database design, relevant metadata standards must be referenced to establish standardised metadata items, upon which the data model is constructed.

4.1.1.3.3 Employing Temporal and Hybrid Storage for Data Updates and Version Management

This project requires particular attention to version management for operational data concerning power grids and telecommunications infrastructure. Consequently, temporal capabilities must be extended beyond spatial data management to accommodate dynamic updates and version control for large-scale operational data. A hybrid storage model will be employed: spatial data such as pylons and power lines will reside in a geodatabase, while non-spatial data including equipment parameters and real-time monitoring will be stored in a relational database.

4.1.1.3.4 Establishing a Resource Catalogue for Centralised Multi-Source Data Management

The project database manages diverse data types, with some data migrated from GIS databases and other data integrated from existing systems such as PMIS, CMIS, OMS, ERP, IMIS, and HRMS. To achieve centralised management of multi-source data, unified resource cataloguing technology will be employed to establish a resource directory. This will enable metadata collection, resource registration, and unified management of the resource directory across multiple databases.

4.1.2 Requirements Analysis

4.1.2.1 Functional Requirements

(1) Spatial Object Management: Support spatial coordinate input and visual editing for equipment such as pylons, substations, and optical cable joints, associating attribute data.

(2) Network Topology Modelling: Establish physical connection

relationships between equipment (e.g., line-transformer-busbar), supporting topology traversal and automatic calculation of fault impact scope.

(3) Resource Flow Monitoring: Integrates SCADA real-time data to display power flow distribution and communication bandwidth utilisation, supporting historical data retrieval.

4.1.2.2 Non-functional Requirements

（1） Performance: Supports concurrent queries for 100,000 devices with response time ≤ 200ms.

（2） Scalability: Modular design enabling new device types (e.g., renewable energy charging points) without generic model reconstruction.

（3） Security: Supports secure data storage and role-based access control (RBAC).

4.1.3 Metadata Information Design

Metadata constitutes data describing data, serving as descriptive information for power grid data and communication infrastructure resources. Addressing the management demands of vast grid data volumes, **metadata enables effective discovery, rapid retrieval, integrated organisation**, and **efficient management of data resources**, **while supporting traceability of changes to power grid data.**

Metadata primarily comprises **metadata information, identification details, data quality information, spatial reference system data, content specifications, distribution parameters, and responsible unit contact particulars**. Metadata may also be categorised by type into business metadata, technical metadata, operational metadata, and administrative metadata.

Table1 : Metadata Information Description

Metadata Type	*Description Information*
Identification Information	*Describes the fundamental details of each thematic dataset*
Quality Information	*Information providing an overall assessment of the dataset's quality, including accuracy information, annual information, etc.*
Spatial Reference System Information	*Explanation of the spatial reference system used by the dataset. Includes fundamental details of the spatial reference system employed; for raster data, this must also specify the origin of the grid, grid orientation, and storage order. Each dataset description includes one coordinate system.*
Content Information	*Describes the content information of the dataset. Includes the names, identification codes, and meanings of each feature class.*
Distribution information	*Details the distributor of the dataset and methods for obtaining the data. Includes information on where the dataset is located, how to access it, and associated costs.*
Responsible Organisation Information	*Includes the responsible organisation's name, contact person, responsibilities, and contact details (telephone, fax, postal address, postcode, email address, website).*

4.1.4 Unified Data Classification

The core of the unified data classification system is a standardised hierarchical framework built around "business domains + data characteristics". This covers the entire business chain of power grid planning, construction, operation, maintenance, and marketing, addressing cross-departmental data silos while aligning with international standards. It supports data sharing, governance, and intelligent applications (e.g., dispatch optimisation, fault prediction). Based on core grid business scenarios, data is categorised into eight primary levels, including foundational ledger data and operational monitoring data. Each level is further subdivided into secondary categories, with clear definitions of data sources and core purposes to ensure comprehensive coverage without duplication.

4.1.5 Data Storage Design

4.1.5.1 Database Selection Design

D atabase selection for GIS power grid and communication infrastructure must centre on three core requirements: spatial data processing capability, business load adaptability, and cost-effectiveness with scalability. Differentiated choices between Oracle, SQL Server, and PostgreSQL should be made based on their technical characteristics and scenario suitability. This ensures support for both spatial topology analysis and visualised equipment management within the power grid GIS, while also meeting real-time data interaction demands (e.g., link status monitoring, channel parameter transmission) for communication infrastructure.

Regarding core business alignment: Oracle leverages its high-availability architecture (e.g., RAC clusters), massive data storage capacity, and mature spatial data module (Oracle Spatial) to handle topology relationship storage for high-voltage grids and link data exchange for communication backbone networks. Its data partitioning technology supports efficient queries across ultra-large-scale assets (e.g., millions of pylons, tens of thousands of communication nodes), meeting dispatch centres' stringent requirements for real-time performance and stability. SQL Server, leveraging simplified spatial data operations (e.g., Geometry/Geography types), enables integrated visualisation of power equipment spatial positioning and communication link status without complex configuration, thereby reducing operational costs. PostgreSQL, leveraging its open-source nature and robust spatial extension plugin (PostGIS), emerges as the preferred choice for low-cost pilot scenarios or renewable energy support systems. Its support for custom spatial indexes and geographic topology analysis fulfils data storage requirements for low-voltage substation GIS and distributed photovoltaic communication equipment. Its open-source nature significantly reduces long-term licensing costs while enabling flexible expansion (e.g., adding spatial attributes for new renewable energy charging points or parameter fields for 5G communication modules), accommodating business changes driven by technological iteration.

4.1.5.2 Physical Data Storage Design

The core of physical storage design for power grid data lies in matching storage media and architectures to data types (real-time / historical / spatial / structured). This approach balances storage costs with operational responsiveness while meeting core requirements of "high reliability, low latency, and scalability". It establishes real-time data storage mechanisms supporting vector data, tabular data, raster/ remote sensing data, and three-dimensional data. It must handle big data or equivalent volumes, enabling map-based access and visualisation of such datasets to support comprehensive data retrieval across operational scenarios including dispatch, maintenance, and marketing.

4.1.5.2.1 Grid Data Classification and Storage Requirements

Characteristics of different grid data types vary significantly. Physical storage design must first clarify data classification and corresponding requirements to avoid performance wastage or bottlenecks caused by a one-size-fits-all storage approach.

Table2 : Grid Data Classification and Storage Requirements

Data Category	Typical Data Examples	Core Storage Requirements	Business Priority

Real-time operational data	SCADA voltage/current, equipment status signals	High-concurrency writes (millisecond-level), low-latency queries (<100ms), high availability	Dispatch and command (highest priority)
Historical Measurement Data	Electricity consumption data, historical power flow, fault recording	Massive storage (TB/PB scale), efficient retrieval by time/region, low cost	Electricity accounting, trend analysis
Spatial GIS data	Equipment coordinates, line topology, transformer station maps	Spatial indexing support, visualisation interaction Low latency, topological relationship storage	Operational positioning, distribution network planning
Structured ledger data	Equipment records, user information, maintenance work orders	Transaction consistency (ACID), high-frequency queries, data integrity	

4.1.5.2.2 Design of physical storage solutions by category

Selecting appropriate storage media (SSD/HDD/object storage), database products, and architectures for different data categories constitutes the core implementation phase of physical storage design.

1. Real-time operational data: "Time-series database + SSD" high IO architecture

Storage medium: All-flash SSD array. Real-time data requires millisecond-level write and query performance. SSDs deliver random IOPS (input/output operations per second) 100–1000 times that of HDDs, eliminating I/O bottlenecks.

2. Historical measurement data: "Time-series database + object storage" tiered storage

Storage Media: "Hot Data (Recent 3 Months) - SSD" + "Cold Data (Over 3 Months) - Object Storage ( )". Hot data requires frequent queries (e.g., monthly electricity billing), with SSD ensuring speed; cold data queries are infrequent (e.g., annual audits), where object storage (e.g., S3, Alibaba Cloud OSS) costs merely one-tenth of SSD, significantly reducing long-term storage expenses.

3. Spatial GIS Data: "Spatial Database + Hybrid Media" Topology-Optimised Architecture

Storage media: SSD (spatial indexes and high-frequency access data) + HDD (historical map layers). Spatial queries (e.g., "select all pylons within a designated area") rely on spatial indexes, where SSDs accelerate index retrieval; historical map layers (e.g., 2020 distribution network topology) undergo infrequent queries, making HDD storage more economical.

4. Structured ledger data: "Relational database + dual-media backup" high-reliability architecture

Storage media: SSD (primary database, supporting high-frequency queries) + HDD (backup database, ensuring data security). Ledger data (e.g., equipment records) undergoes frequent queries (e.g., by operations personnel accessing records at any time), with SSD enhancing response speeds; the HDD backup database offers low-cost storage for scheduled full backups.

4.1.5.3 Data Logical Storage Design

The core of GIS power grid data logical storage design involves constructing a layered, standardised logical structure based on data business attributes and associative relationships. This approach is independent of specific storage media, focusing on resolving "data classification organisation, entity association, and business adaptation". It provides a unified logical framework for physical storage implementation and business system invocation.

Logical storage serves as the central hub connecting the "data acquisition layer" and the "business application layer", requiring the achievement of three core objectives:

Standardised Data Structures: Unify field definitions (e.g., equipment ID coding rules, timestamp formats) to prevent interaction conflicts caused by custom data formats across different business systems (dispatch, operations, marketing).

Clarified entity relationships: Define logical connections between core entities (e.g., equipment, operational data, users) – such as a single transformer corresponding to multiple operational records – to support cross-entity queries (e.g., "retrieve real-time current readings for a transformer in a specific transformer district alongside associated user electricity consumption").

Flexible Business Adaptation: Organise logical data views by operational scenarios (e.g., real-time monitoring, historical analysis, topology computation), enabling applications to access data as required without direct manipulation of raw data.

Core Logical Storage Architecture: "Three-Layer Model + N Entity Types"

Employing a layered design of "Foundation Layer - Association Layer - Application Layer", each layer assumes distinct responsibilities while adapting to grid business diversity through "Core Entities + Extended Attributes".

1. First Layer: Foundation Data Layer (Standardised Storage of Raw Data)

Stores unprocessed raw data, organised into logical tables by data type. Ensures data remains "unadulterated" with a unified structure, forming the foundation of the entire logical storage system.

Table3 : Data Logical Storage Design (Schematic)

Data Category	Core Logical Tables	Key Fields (Example)	Design Considerations
Equipmen	Equipment Information	Equipment ID (Uniform coding, e.g. "TX - Province code - Voltage level - Serial number"), Equipment	Equipment ID serves as unique primary key, linked

Data Category	Core Logical Tables	Key Fields (Example)	Design Considerations
t Ledger Data	Table (tb_equipment)	type, Rated parameters, Commissioning date, Affiliated area ID	to area table for regional management
Real-time Operational Data	Real-time Data Table (tb_real_time)	Data ID, Equipment ID (foreign key, linked to Equipment Table), Collection Timestamp (millisecond precision), Voltage, Current, Power	Create a composite index on "Device ID + Collection Timestamp" to accelerate queries
Historical measurement data	Historical Measurement Table (tb_hist_meas)	Measurement ID, Device ID, User ID (foreign key), Measurement Time (to the minute/hour), Electricity Consumption, Metering Status	Partitioned by "User ID + Measurement Month" to accommodate electricity accounting scenarios
Spatial GIS Data	Spatial Information Table (tb_spatial)	Spatial ID, Device ID (foreign key), Coordinates (latitude/longitude), Topological relationships (e.g. "Connected line ID"), Layer affiliation	Associated with PostGIS spatial index, supporting "select devices by area" functionality
User Profile Data	User Information Table (tb_user)	User ID, Username, Electricity Voltage Level, Address, Substation Area ID (Foreign Key, linked to Substation Area Table)	User ID is unique; association with distribution area table enables hierarchical management

2. Second layer: Associated data layer (cross-entity relationship integration)

Integrate foundational layer data through "related tables" or "views" to eliminate data silos, providing a "one-stop" logical entry point for business queries and avoiding frequent cross-table joins.

Core association logic examples:

Equipment - Operational Association View (v_equip_real): Integrates the "Equipment Table + Real-time Data Table", containing fields such as "Equipment ID, Equipment Type, Acquisition Time, Voltage, Current", supporting queries for "real-time status of specific equipment types".

User - Measurement - Equipment Association Table (tb_user_meas_equip): Linked via "User ID + Equipment ID", containing fields such as "Electricity Consumption, Metering Time, Equipment Operational Status", enabling "linked analysis of user electricity consumption and metering equipment status".

Spatial - Topology Association View (v_spatial_topology): Integrates "Spatial Table + Line Table + Equipment Table", containing fields such as "Equipment Coordinates, Associated Line, Line Connection Relationships", supporting GIS topology analysis (e.g., fault isolation range calculation).

3. Third Layer: Application Data Layer (Business Scenario Customisation)

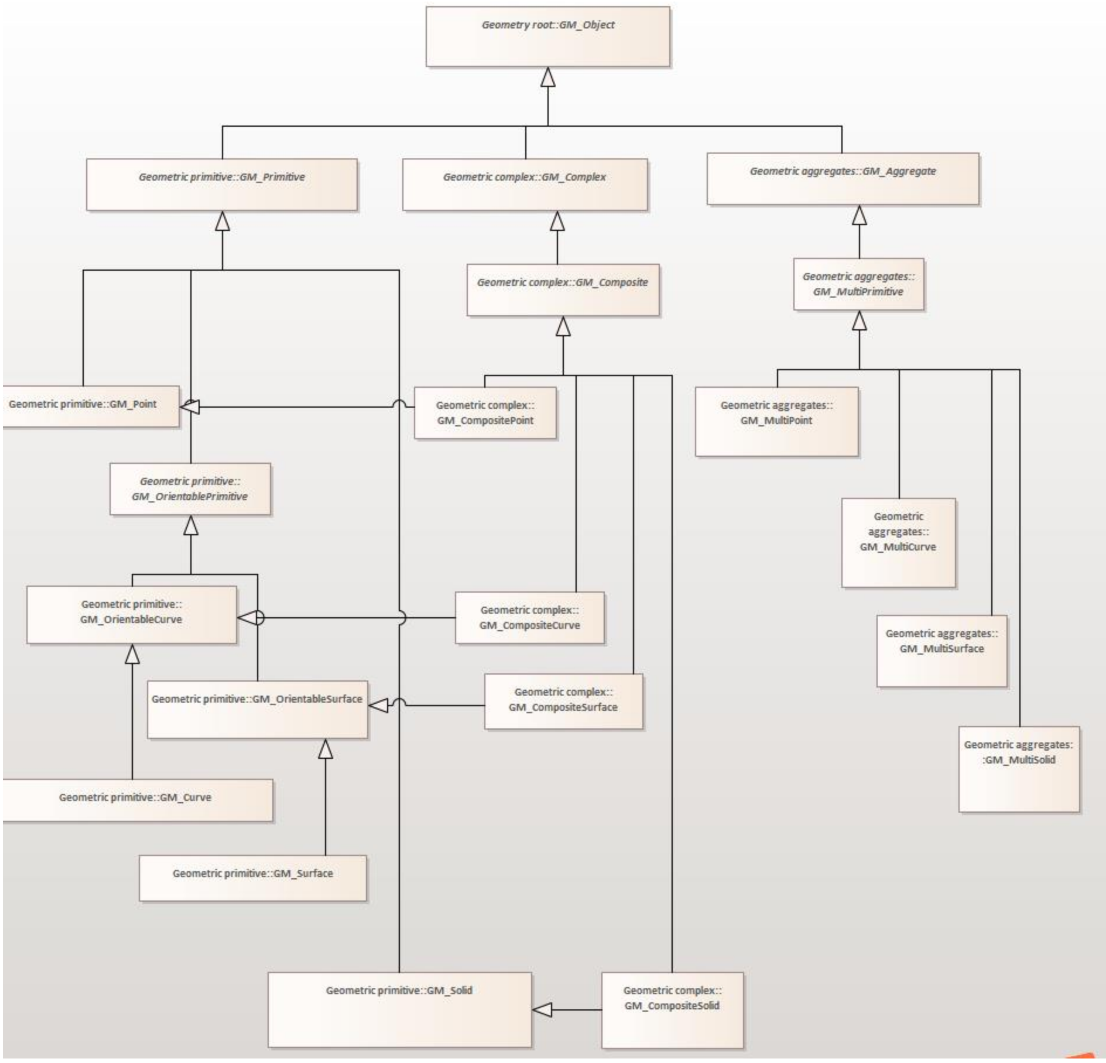
C onstructs "specialised logical views" tailored to specific operational scenarios (e.g., dispatch monitoring, operations maintenance, electricity marketing), retaining only business-critical fields to simplify application invocation complexity.

4.1.6 Database Planning and Design

The database planning and design must support vector data, raster data, attached documents, images, and other file types. It must support the definition of user access permissions within the database (administrator, editor, viewer), allowing the creation, modification, and deletion of data layers. For each data type, the table structure, attribute data types, and object attribute tags can be defined, permitting the establishment of relationships between different data layers.

4.1.6.1 GIS Database Generic Model Design

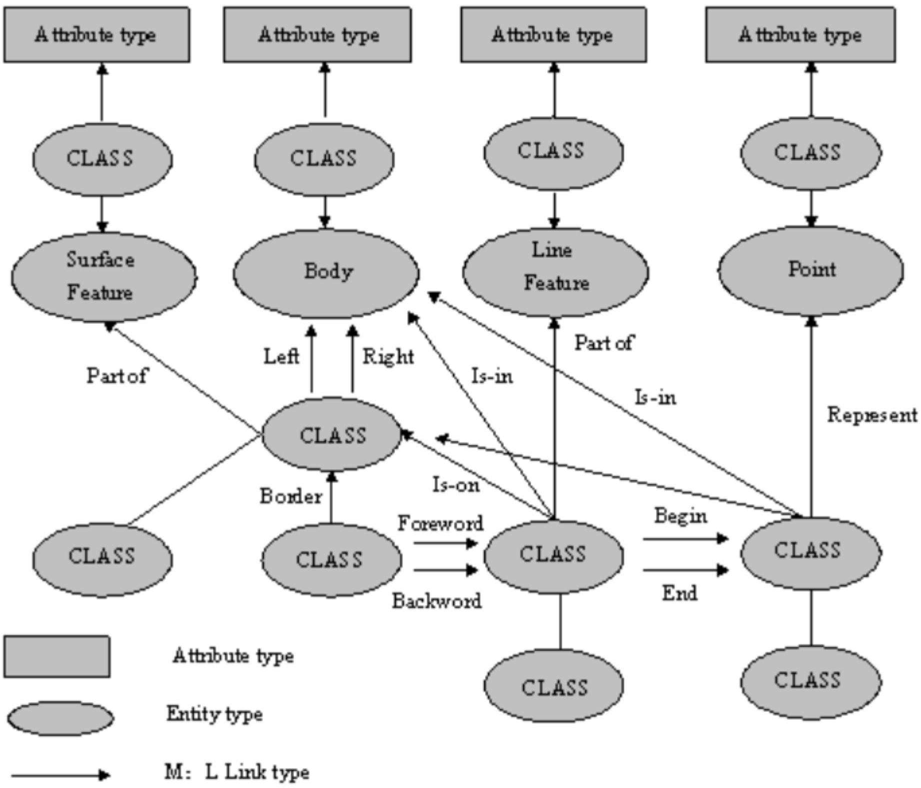
The core of the GIS database generic model design lies in separating spatial and attribute data for power grid systems, establishing relationships through unique identifiers. This approach simultaneously fulfils requirements for multi-source data integration, spatial query analysis, and standardised data management. The GIS generic model comprises four principal components: point, line, polygon, and network graphic elements; data formats compliant with OGC standards; logical relationships between data entity object attributes and data entities; and metadata information.



4.1.6.1.1 Feature Information

Stores the geometric location information of entities, forming the core of the GIS database.

Vector data: Stores discrete spatial entities such as points, lines, and polygons. Points include monitoring stations and Points of Interest (POI); lines encompass roads, rivers, and pipelines; polygons represent administrative districts, land parcels, and lakes. Raster data stores continuous spatial coverage information, such as satellite imagery, Digital Elevation Models (DEM), and remote sensing maps.



4.1.6.1.2 Data formats

Formats typically comply with OGC (Open Geospatial Consortium) standards, such as UDBX, Shapefile, GeoJSON, and Geometry.

4.1.6.1.3 Data Attributes

Non-spatial information associated with spatial entities, describing the characteristics of the entity.

Basic Attributes: Common information applicable to all entities, such as unique ID, name, creation date, update date, and data source.

Storage method: Stored in relational table format, linked to spatial data modules via "spatial entity ID".

4.1.6.1.4 Associative Relationships

Establishes logical relationships between different data entities to ensure data integrity and query efficiency.

One-to-one relationship: One spatial entity corresponds to one attribute record, e.g., "one building corresponds to one property ownership record".

One-to-many relationship: One primary entity corresponds to multiple subordinate entities, such as "one road corresponding to multiple traffic signals".

Many-to-many relationship: Implemented via intermediate tables, e.g., "one area corresponds to multiple pollution sources, one pollution source affects multiple areas".

4.1.6.1.5 Metadata Information

Records descriptive information about data for management and traceability purposes.

Basic data information: Data name, version, coverage area, coordinate system (e.g. WGS84, CGCS2000).

Quality information: Data accuracy, error range, completeness.

Administrative information: Data producer, update frequency, access permissions.

4.1.6.2 Power Grid Data Model Design

4.1.6.2.1 GIS Network Generic Model

The GIS Network Generic Model serves as the core data foundation for constructing any GIS-based power grid network analysis application. Drawing upon graph theory concepts, it abstracts the real world into edges, junctions, link references, and link directions, endowing them with spatial geometric information and attributes.

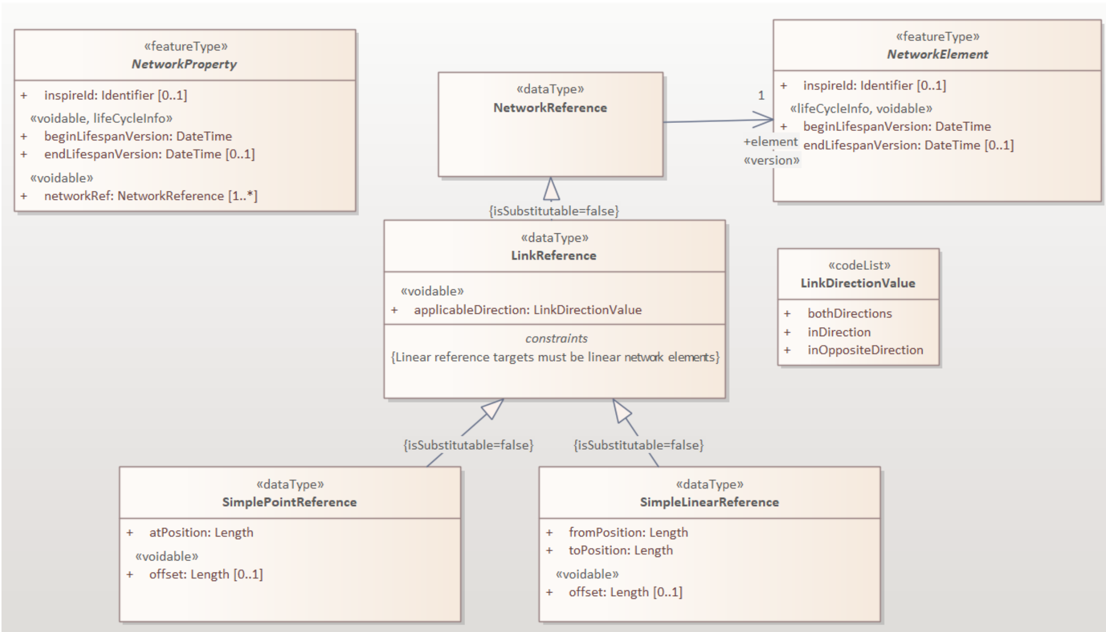


Figure 6 : GIS Network Generic Model

4.1.6.2.2 Power Grid Operational Data Model Design

Based on requirements for multi-level grid management (high-voltage, medium-voltage, low-voltage), and referencing the GIS Network Generic Data Model, the Power Grid Business Data Model Design was developed. The design core focuses on constructing a standardised, scalable, and business-adaptive data architecture to integrate data across all power grid segments, supporting core operational scenarios such as dispatch, operations and maintenance, and marketing.

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4.1.6.3 Communications Infrastructure Business Data Model Design

The core of the communication infrastructure data model design lies in standardising the description of attributes and associative relationships for grid-supporting communication resources (equipment, links, topology). This enables coordinated management between "communication facility status" and "grid operational requirements", supporting scenarios such as communication fault localisation, bandwidth resource allocation, and service-bearing assurance. This ensures communication stability for core grid operations including SCADA, electricity consumption collection, and renewable energy grid integration.

4.1.6.4 Extended Data Model Design

Building upon the existing core ER model of the power grid, this extension design focuses on enhancing the precision management and operational monitoring capabilities of equipment assets. By introducing expanded entities such as equipment technical parameter archives, real-time measurement data, operational status monitoring, and maintenance history records, it constructs a comprehensive data system covering the entire lifecycle management of equipment. Concurrently, it deepens the topology connection relationships to support dynamic operational mode analysis and precise fault localisation. Furthermore, it establishes integrated interfaces with GIS spatial data, SCADA real-time systems, asset management systems. This achieves comprehensive digital mapping from physical grid structure to operational status, providing complete data support for intelligent operations and maintenance, situational awareness, and optimised dispatch.

4.1.7 Database Logical Structure Design

The logical structure design of the power grid database adopts a layered architecture approach, segmenting data by business domain into the asset ledger layer, grid model layer, operational monitoring layer, and business application layer. Primary and foreign key associations establish a complete data chain linking physical equipment to logical topology. The Asset Ledger Layer employs a star schema centred on core equipment tables to organise technical parameters and lifecycle information. The Grid Model Layer adopts graph database principles to construct node-edge topological connections. The Operational Monitoring Layer utilises a time-series database structure to store vast volumes of collected data. A unified equipment coding system and data dictionary ensure cross-system data consistency, while complex business logic is encapsulated through views and stored procedures. This provides standardised, high-performance data access interfaces for diverse grid applications.

4.1.8 Database Physical Structure Design

The physical database structure design must define detailed attributes for object fields and establish connection rules between database objects (spatial connections, logical connections within the power grid). Additionally, connection rules for non-operational assets are defined for asset management purposes, such as utility poles, crossarms, insulators, and grounding rods. Supports detailed representation of power networks, substations, and electrical equipment. Enables management of interconnected grids through a universal network model, integrating high-voltage, medium-voltage, and low-voltage networks to establish a unified operational management framework. Constructs network databases to represent interrelationships between two-dimensional and three-dimensional datasets.

4.2 GIS Data Repository

4.2.1 Data Classification

Provides a multi-dimensional, standardised classification system for power grid data, supporting structured design at the data layer to ensure clear data logic and facilitate subsequent retrieval and reuse.

- **Classification Dimension Design**: Supports hierarchical classification by "Data Type" (equipment data, network topology data, asset data, spatial geographic data, etc.), "Voltage Level" (high-voltage, medium-voltage, low-voltage), "Asset Attribute" (operational assets / non-operational assets), and "Functional Role" (transmission equipment, substation equipment, distribution equipment, etc.).
- **Customisable Classification** Rules: Enables users to add bespoke classification tags (e.g., "Smart Equipment / Conventional Equipment", "Urban Grid / Rural Grid") according to corporate standards. Supports importing, exporting, and version management of classification systems to accommodate differentiated requirements across regional grids.
- **Classification Visualisation**: Presents data classification hierarchies through tree structures, enabling rapid filtering of all data objects within a specific category ( ) and providing an intuitive overview of data coverage.

4.2.2 Data Attribute Management

Structured, granular attribute definitions for core grid elements (networks, substations, electrical equipment) ensure data granularity meets grid analysis and management requirements.

- **Power Network Description**: Supports defining fundamental attributes (e.g., network name, supply area, rated frequency, neutral point earthing method), topological structures (radial/ring/mesh), and operational parameters (maximum load, short-circuit current limits) for high-voltage (220kV and above), medium-voltage (10-110kV), and low-voltage (0.4kV) networks.

- **Substation Description**: Refines substation site information (coordinates, footprint area), voltage level combinations (e.g., "220kV/110kV/10kV"), main busbar configurations (single-busbar sectioning, double-busbar, etc.), and associates functional zones within the station (high-voltage room, low-voltage room, control room, etc.).
- **Detailed Electrical Equipment Description**:

  - Substation Equipment: Define technical parameters and functional attributes for core equipment including current transformers (ratio, accuracy class, installation location), voltage transformers (rated voltage, insulation class), busbars (material, cross-sectional area, number of phases), transformers (capacity, connection group, loss parameters), and circuit breakers (rated breaking current, operating mechanism type).
  - Transmission/Distribution Equipment: Define attributes for lines (conductor type, span length, tower type), switchgear (number of circuits, protection rating), capacitors (capacity, rated voltage), etc., with support for linked equipment drawings (e.g., nameplate photographs, wiring diagrams).

4.2.3 Grid Integration Management

Enable cross-level association between high-voltage, medium-voltage, and low-voltage networks to establish a unified grid operation management model, supporting collaborative analysis across all voltage levels.

- **Cross-Voltage Level Connection Definition**: Define connection points between networks of different voltage levels (e.g., "110kV substation connects to 10kV feeder via main transformer"), specifying parameter mapping relationships for connecting equipment (e.g., "transformer ratio linking high-side voltage to low-side voltage").

- **Network Data Integration**: Supports consolidation of network topology, equipment parameters, and operational data across all voltage levels into a unified model, eliminating data silos. This ensures that "high-voltage side load changes" can trigger "medium-voltage side power flow calculations" and "low-voltage side user supply reliability analyses".
- **Integrated Model Validation**: Automatically verifies logical consistency across hierarchical connections (e.g., "Main transformer capacity matching maximum low-voltage load"), providing model integrity reports (e.g., "A certain 10kV line is not associated with its parent substation").

4.2.4 Grid Schematic Construction

Provides graphical tools to support the creation and management of electrical grid schematic diagrams, enabling real-time linkage between schematics and database data.

- **Schematic Editor**: Incorporates an integrated library of industry-standard electrical symbols (e.g., transformers, switches, instrument transformers), supporting drag-and-drop drawing, automatic snap-to-wire connections, and hierarchical layer management (e.g., "Primary Equipment Layer / Secondary Control Layer"). Enables annotation of equipment numbers, parameters, and other attributes.
- **Data Association**: Device symbols in schematics automatically link to corresponding equipment objects in the database. Modifying equipment parameters in the database (e.g., "circuit breaker rated current") via synchronously updates schematic annotations. Conversely, altering symbol

attributes in schematics (e.g., "switch status") triggers real-time database updates.

- **Schematic Version Control**: Supports saving, exporting (PDF, CAD formats), and version comparison of schematics, recording modification history (e.g., "2023.10.01 Adjusted 10kV feeder switch connection relationships").

4.2.5 Network Database

Establishes a bidirectional association mechanism between 2D and 3D data, enabling multidimensional visualisation and cross-referencing of grid data.

- **Data Set Association Rules**: Define mapping relationships between 2D data (e.g., equipment coordinates in GIS maps, layout plans) and 3D data (e.g., equipment 3D models, substation BIM models). Examples include: "GIS pole coordinate points correspond to pole model ID P001 in 3D models" and "2D line route diagrams correspond to paths in 3D line models".
- **Bidirectional Query and Interlinking**: Supports selecting equipment via point-and-click on 2D GIS maps to automatically retrieve and display corresponding 3D models; alternatively, selecting equipment within 3D scenes synchronously locates the corresponding position on 2D drawings while displaying equipment attributes (e.g., model, installation date) from the database.
- **Associated Data Synchronisation**: Upon updating either 2D data (e.g., equipment location coordinates) or 3D data (e.g., model dimensions), the system automatically refreshes the relationship database to ensure consistency between 2D and 3D data.

5 GIS Service Integration

Services are categorised into two main types based on their nature: Interface Services and Secondary Development Interface Services. Interface Services comprise six sub-categories: Visualisation Services, Data Services, Application Analysis Services, Data Distribution Services, Directory Services, and Other Services. Secondary Development Interfaces include two sub-categories: 2D Map API and 3D Map API. Service classifications are detailed in the table below:

Table: Service Categories

Primary Category	Second-Level Category	Tertiary Category	Definition
Interface Services	Visualisation Services	Services that can directly return rendered maps to users.	
		Web Map Service (WMS)	Provides clients with a rendered map image via the web. Detailed interface rules are defined by the OGC WMS specification.
		Web Tile Map Service (WMTS)	Divides maps into grid tiles according to defined rules, delivering rendered map images to clients on a tile-by-tile basis. Requests adhere to web communication protocols. Detailed interface specifications are governed by the OGC WMTS standard.
		Cache-Based Web Map Service (WMS-C)	Pre-renders map content into images according to defined rules. Upon receiving client requests, outputs maps based on these pre-generated images. Supported request interface is WMS.
	Data Service	Directly returns vector or raster data.	
		Web Feature Service (WFS)	Provides spatial feature information to clients via the web, with

Primary Category	Second-Level Category	Tertiary Category	Definition
			support for filtering operations during feature access. Detailed interface rules are defined by the OGC WFS specification.
		Web Coverage Service (WCS)	Provides spatial coverage information to clients via the web. Spatial coverage information is typically in raster format. Detailed interface rules are defined by the OGC WCS specification.
		Web Feature Service for Geographical Names and Addresses (WFS-G)	The Geographical Address Feature Service adheres to the OGC WFS specification. It publishes geographical address data via the WFS interface.
	Application Analysis Service	Delivers geospatial-related functionalities to users as web services over the network. Users need not understand specific implementation processes or algorithmic principles; desired results are obtained through service invocation.	
		Web Processing Service (WPS)	GIS analysis and processing capabilities are published over the network in a unified, standardised format.
	Data Distribution Service	Extracts and processes data according to specific requirements before providing it to requesters.	
	Catalog Service	Provides cataloguing and query capabilities for geographic information services and service metadata.	
		Resource Directory Service	Organises geographic information data resources according to source and subject coding rules, employing a unified metadata model for all geographic information data resources. Access to the catalogue is

Primary Category	Second-Level Category	Tertiary Category	Definition
			provided via the web.
		Web Directory Service (CSW)	Describe spatial data, services, and other resources using a specific metadata model, categorise and organise these resources according to defined rules, and provide web-based publishing and discovery functionality for spatial data and geospatial service metadata via . Detailed interface rules are specified by the OGC's CSW specification.
	Other Categories	Custom Services	
		Map Service	Custom Service
Secondary Development Interface	2D Map API	SuperMap Web API for JavaScript	
		2D Map Interface	Map creation, data loading, layer operations, map operations, etc.
		General Management Interface	Annotation services, style management, attribute viewing, location retrieval, etc.
		Thematic Data Interface	Layer loading, data querying, etc.
	3D Map API	3D Map API	

6 Power Public Technology Platform

6.1 Data Centre

Power grid operations are complex and involve massive data volumes. Its GIS data exhibits multi-source and heterogeneous characteristics. The existing decentralised management approach suffers from three major pain points:

Inconsistent model formats across specialised systems (e.g., planning, dispatch, operations) necessitate redundant modelling for cross-departmental collaboration, resulting in low data reuse rates. This initiative establishes grid equipment metadata standards based on S3M and other specifications; develops unified data storage capabilities to centrally manage eight major categories of GIS data, achieving uniform data formats and standards. This creates a standardised 2D/3D spatial database that integrates and harmonises multi-source, heterogeneous data.

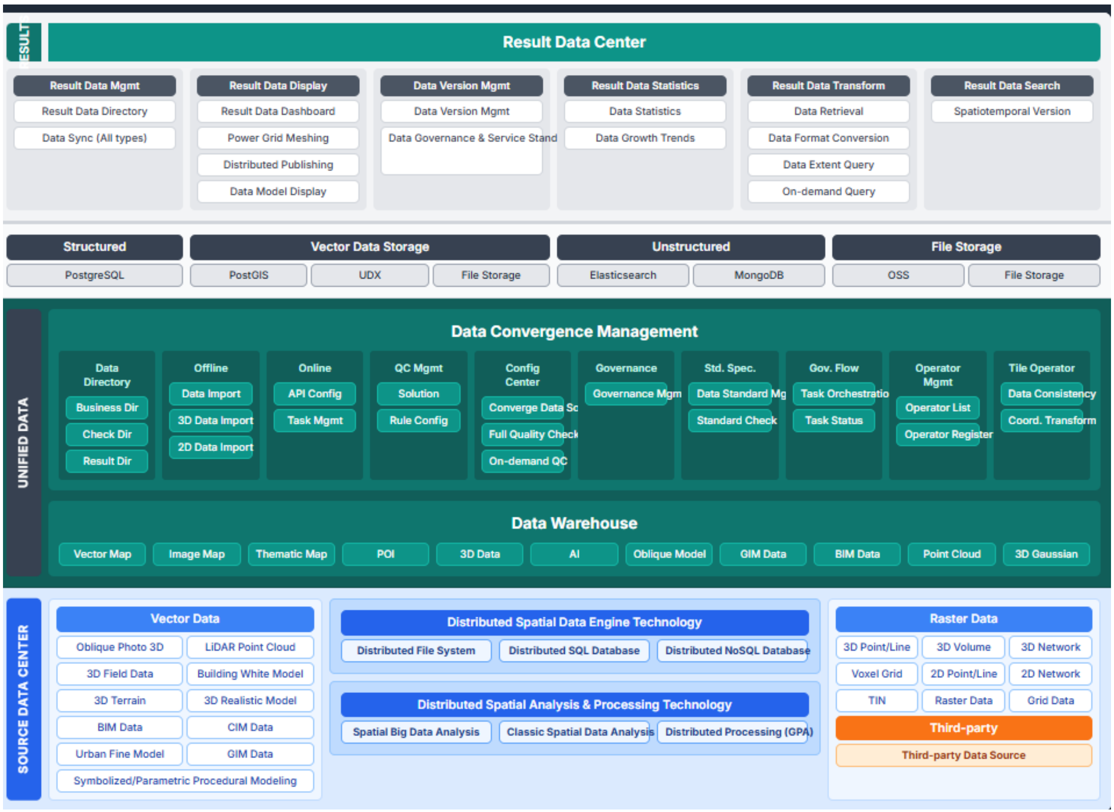


Figure 7 : Unified Data Architecture

6.1.1 Data Statistics

Statistical overview, encompassing statistics on various GIS data types, primarily concerning model quantities and deliverable counts. Includes system introductions and quick access points, presented through graphical representations to aggregate and display the total volume of all GIS data within the system.

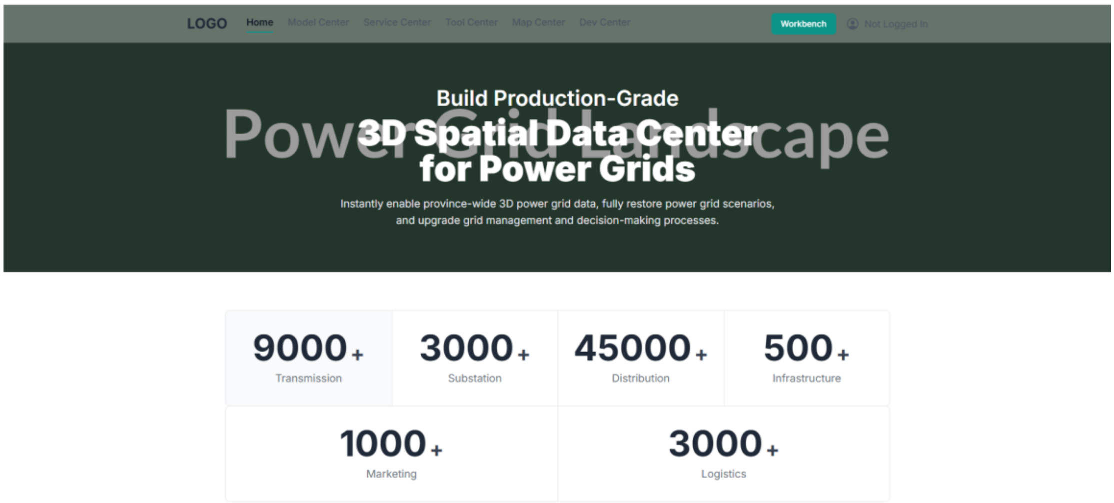


Figure 8 : Data Centre

Total Data Volume Statistics: Quantifies the overall data volume to enable users to rapidly grasp the scale of data holdings.

Data Type Statistics: Classifies statistics by different types of 2D/3D data (e.g., laser point clouds, oblique photography), displaying the proportion of each data type.

Geographical Distribution Overview: Classifies data by geographical region, illustrating the proportion of data within each area.

Data Growth Trends: Track data volume growth across timeframes (e.g., daily, monthly, yearly) using line or bar charts to illustrate expansion patterns.

Service Volume Statistics: Total number of services published on the platform.

Service Invocation Volume Statistics: External invocation activity of platform services

6.1.2 Aggregation Centre

GIS data dispersed across various departmental data sources is aggregated into the data lake through multiple methods, including data import, offline copying, and online transmission. Two- and three-dimensional spatial model data is aggregated according to system-defined data directories and ingestion standards, stored in corresponding storage nodes, and managed under unified governance.

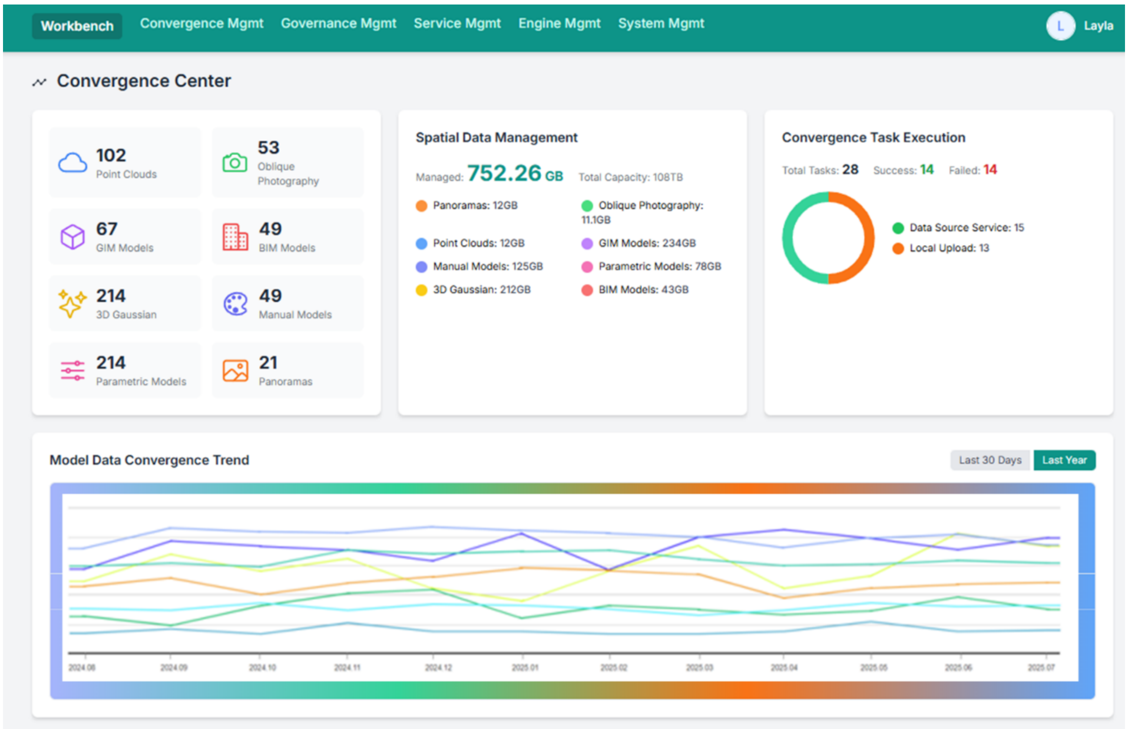


Figure 9 : Aggregation Centre Homepage

6.1.2.1 Data Standard Management

This function supports the storage and management of large-scale 2D/3D data. It integrates and organises various types of 2D/3D spatial model data according to power grid standard requirements, transforming them into model scenario data that meets power grid application needs.

It manages and displays various GIS data standards, guiding units in the production and aggregation of GIS data.

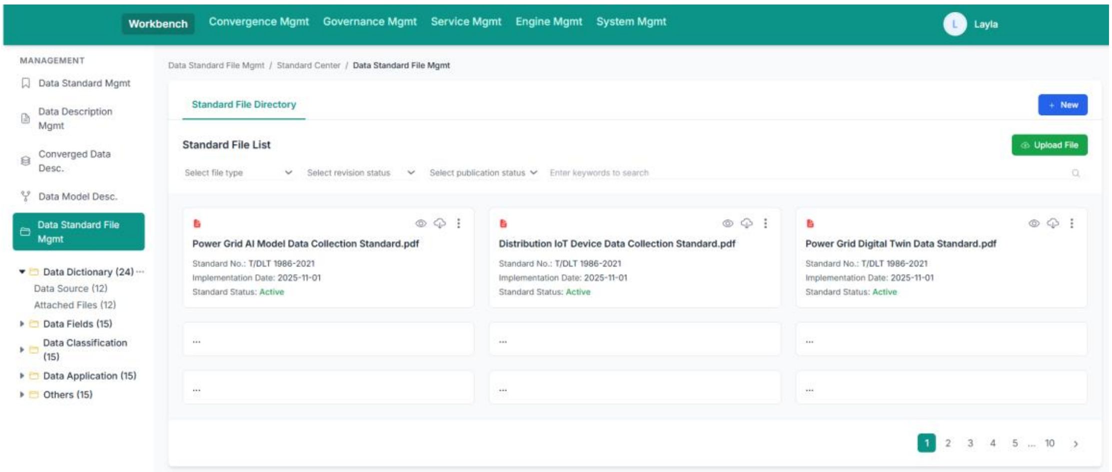


Figure 10 : Data Standard Management

Data Standards List: Presents a comprehensive list of all data standards currently recorded within the system for data aggregation personnel to select and review.

Online Data Standard Browsing: Clicking a specific standard specification name within the list enables online viewing of its corresponding content.

Data Standard File Upload: Supports administrators uploading power industry standards such as GB/T 50228 and DL/T 1499, as well as internally developed standard specification files.

6.1.2.2 Data Storage

Existing data source information (including database type, IP address, port number, instance name, username, password, etc.) can be registered to the platform, with a name assigned to the current data source. Once registered, this data source can be selected for data access. Connectivity testing is performed on registered data sources, with results returned to confirm the data source's availability.

Access Configuration: Existing data source information (including database type, IP address, port number, instance name, username, password, etc.) can be registered on the platform and named for the current data source.

C onnectivity Verification: Conduct connectivity tests on registered data sources, returning connectivity test results to confirm the data source's availability.

6.1.2.3 Data Aggregation

Aggregate various GIS data into a unified data centre via data upload and API methods, supporting task-based scheduling management.

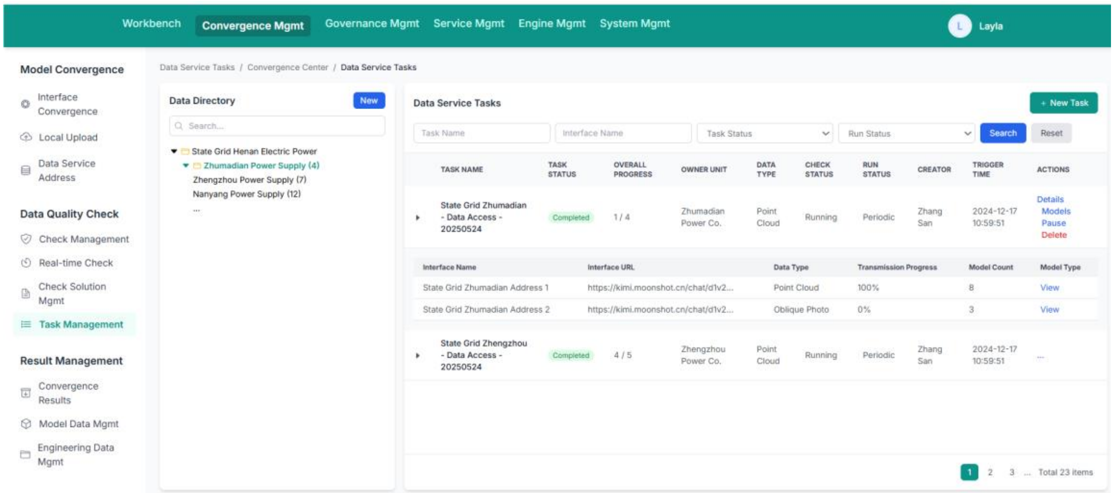


Figure 11 : Data Aggregation Tasks

Offline aggregation: Topographic map data, digital elevation model data, satellite imagery data, oblique photogrammetric model data, laser point cloud data, parametric model data, BIM model data, GIM model data, manually modelled data, and 3D Gaussian data files may be uploaded to the platform.

Online Aggregation: Topographic map data, digital elevation model data, satellite imagery data, oblique photogrammetric model data, laser point cloud data, parametric model data, BIM model data, GIM model data, manually modelled data, and 3D Gaussian data files can be integrated into the platform via interface retrieval.

Metadata Management: Inputs and uploads information related to the model data, including the associated area, basic operational details, and target directory for data upload.

Aggregation API Configuration: Configure URLs and parameters for the aggregation interfaces to be invoked.

Aggregation Scheduling Management: View scheduled tasks in a list format, including scheduling times and types. Perform operations such as stopping, starting, or deleting scheduled tasks.

Scheduling Task Details: View comprehensive information for specific tasks, including task name, aggregation content, execution time, and execution cycle.

6.1.2.4 Model Onboarding Validation

Through a visual configuration interface, perform data integration verification during the data aggregation phase. Automate the generation of inspection tasks, viewable by inspection time and type.

Model File Validity Verification: Checks the integrity of oblique photography folder structures and file size compliance. Validates manual model files, laser point cloud model files, parametric model files, BIM model files, GIM model files, panoramic image files, and 3D Gaussian model files.

Validation Log: Review model file validation results.

6.1.2.5 Source Data Management

Model Data Management: Manage model source data aggregated into the platform, including deletion and list queries. Filter lists by aggregation method (online/offline), data category (BIM/GIM, etc.), and aggregation date.

Version Management: Perform operations such as deletion and viewing of versions.

6.1.3 Governance Centre

E nables rapid configuration for data governance, featuring streamlined, expedited, and visualised data processing workflows. Integrates and organises diverse 2D/3D spatial model data according to power grid standards, generating model scene data compliant with grid application requirements. Perform lightweight processing, individualisation, coordinate system registration, and encoding on 2D/3D data. Through automated orchestration capabilities, configure operators in a workflow-based manner to complete the governance of GIS data from source to deliverable.

6.1.3.1 Governance Operator Management

Operator Registration/Deregistration: Register local or external governance operators on the platform to generate unique identifiers for user invocation.

Operator List View: Quickly retrieve operators by name, tag, or type, supporting fuzzy matching.

Operator Details: View functional descriptions and usage instructions to assist operator deployment.

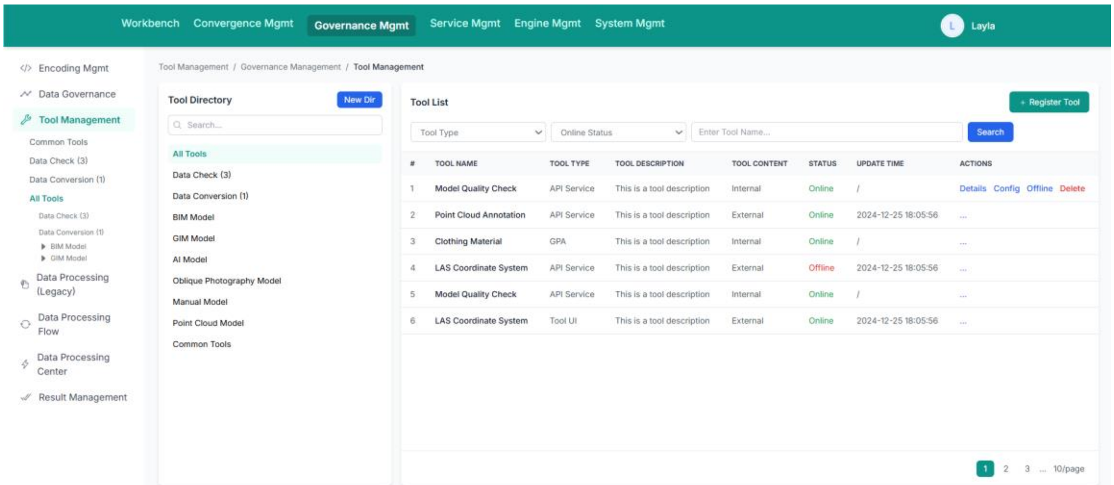


Figure 12 : Governance Operator Management

6.1.3.2 Governance Step Orchestration

Manage governance tasks and steps, display task lists, orchestrate new tasks, oversee running tasks, and view task details and execution logs.

Task List: Retrieve tasks by name, status, or time range to swiftly locate target tasks.

Task Flow Orchestration: Visually drag-and-drop operators to form workflows, setting execution order and parameters for each operator. Initiate execution upon completion.

Task Execution Management: Select processes and datasets, configure scheduling policies, and generate new governance tasks.

Task Details: View task configurations, runtime logs, and output results with real-time status refresh support.

6.1.3.3 Data Governance Operator Set

Perform operations such as model stretching and rotation, tile optimisation, LOD level construction, and model data singularisation for oblique photogrammetric models, laser point cloud models, parametric models, BIM models, GIM models, manually modelled objects, and 3D Gaussian models.

Model Disassembly: Supports disassembling models within the dataset, generating each sub-object of every model object as an independent model object.

Modify Model Elevation Based on Terrain: Adjusts model elevation using DEM terrain data. This involves modifying the height of the model's bottom centre point to match the terrain elevation at its location, achieving terrain-model alignment.

Model Tiling Generation: Generates S3M tile data from specified model datasets.

Model dataset merging: Combines multiple model datasets into a single model dataset.

Model tile top-level reconstruction: For model tiles with suboptimal top-level data visualisation, the top-level reconstruction function regenerates the root node. This not only reduces data volume but also enhances overall visualisation quality.

Surface stretching to generate model tiles: Where no original device model exists, two-dimensional or three-dimensional surfaces may serve as source data.

Following tile generation, data stretching, and texture mapping configuration, the process yields S3M model tile data in the format ` `.

Model dataset projection transformation: Project and transform the model dataset according to the target coordinate system. The transformed model dataset is stored in the target data source.

Model LOD Construction: Constructs LODs for specified models lacking multiple levels of detail, enhancing rendering efficiency and visualisation quality.

Delete Model LOD: Remove the specified level of detail (LOD) from the model data.

Extract model location: Extract the bottom centre point position of the bounding box for the model data and save the extracted result as a 3D point dataset.

Generate 3D tiles from raster imagery: Produce S3M tile data based on specified raster and imagery datasets.

Generate 3D Model Tiles from Raster Image Tiles: Produce spatial 3D model tiles (*.scp) based on specified TIN terrain tiles (*.sct) and 3D image tiles (*.sci3d).

Batch model conversion: Batch conversion of model data into the *.s3mb format.

Remove duplicate points/faces: Clean up overlapping vertices and faces to enhance model quality.

Remove/Calculate Normals: Delete erroneous normals or recalculate smoothed/segmented normals.

Generate Projection Surface: Project the 3D model object onto the XOY plane to generate a 2D surface object, which corresponds to the model's top view.

Extract Model Boundary: Extract the boundary contour of the model data, with results stored as a 3D surface dataset. The model boundary obtained here represents the outer surface edges of the model, excluding internal cavities or internal structures.

Model Clipping: Clipping the model according to a specified clipping plane to obtain model data within a designated range.

Model tile recompression: Apply a higher compression ratio to existing model tiles to reduce file size.

Merge Models: Combines multiple selected models into a single model object while preserving original attributes.

Create Composite Objects: Supports creating composite objects based on parametric objects.

Obtain bounding box: Retrieve bounding box information for specified parametric objects, including centre point, length, width, and height.

Linear Extrusion: Supports constructing closed models via linear extrusion of polygons. Extruded objects are vector surface datasets, supporting both 2D and 3D surface layers (within geographic coordinate systems).

Rotational Extrusion: Supports constructing closed models via rotational extrusion based on 3D point data and 2D surface data, i.e., building GIS data by rotating specified surface data around a designated point by a defined angle.

Stretch closed bodies: Supports constructing stretched closed bodies based on 3D surfaces or models.

Lofting: Supports generating 3D models via lofting based on 3D lines, cross-sections, and associated parameters.

Generating Normals from Oblique Photogrammetry Data: Supports calculating normals for oblique photogrammetry GIS data and generating normal vectors for the resulting data. Normals determine how light interacts with the data surface, thereby influencing rendering effects.

Modify Centre Point for Oblique Photogrammetry Data: This tool, in conjunction with the merged layer function for generating S3M files, adjusts the centre point coordinates of multiple oblique photogrammetry 3D models. This unifies the data centre points across multiple models within the same survey area, facilitating the loading of all data via a single SCP file.

G enerating S3M from Oblique Photogrammetry Data: Using SCP configuration files as source data, oblique photogrammetry GIS data can be converted into S3M tile data. Loading S3M tile data enhances data loading efficiency and enables multi-terminal data sharing and interoperability.

Generating SCP Configuration Files from Oblique Photogrammetry Data: SCP configuration files are generated from oblique photogrammetry GIS data for subsequent S3M tile data production.

Oblique Texture Remapping: Performing texture remapping on refined oblique photogrammetric model data optimises texture quality and enhances loading performance.

Oblique Data Preprocessing: Preprocesses oblique photogrammetric GIS data in OSGB format to verify file integrity and detect corrupted files. Error files and categories are logged, with support for automatic repair of anomalies including bounding box irregularities, triangulation mesh issues, and texture redundancy. The system also automatically clips and backs up erroneous data from the source directory, ensuring subsequent S3M tile generation remains unaffected.

Oblique Data Clipping: Clipping oblique GIS data to specified regions based on polygon data, with support for saving clipped results. This tool enables users to acquire oblique GIS data within specific areas as required.

Tilt Data Hole Extraction: Performs regional hole extraction on oblique photography GIS data, effectively carving a void within the dataset. This enables overlaying other data onto the resulting void to achieve data fusion and matching effects.

Oblique Data Mosaicking: Performs mosaicking on oblique photogrammetric GIS data within a designated area. Upon completion, the elevation of the oblique photogrammetric GIS data within the specified region is adjusted according to designated parameters and the mosaic surface.

Extract Data: Retrieve elevation values from oblique photogrammetric 3D model tile data at specified 2D point/line/surface objects or 3D point/line/surface object locations. Supports assigning elevation values to source 2D points, source 2D lines ( ), or source 2D surface objects to construct 3D points, 3D lines, or 3D objects; alternatively, stores extracted elevation values in designated attribute fields of the data.

Save as Model Dataset: Save oblique photogrammetry GIS data as a model dataset.

Crop: Crop the model according to a specified cropping surface to obtain model data within a designated area.

Tiling: Supports tiling operations between specified model data and specified surface data, ultimately modifying the model data based on the tiling surface.

Hole Cutting: Supports hole cutting operations between specified model data and specified surface data. The model data within the corresponding area of the cutting surface will be removed.

Surface Operations: Supports performing surface operations between terrain tiles (TIN) and model data to generate new data. Supported surface operations include: Difference and Merge.

6.1.3.4 Coordinate System Processing Operator Set

Provides a parameter configuration interface allowing users to input coordinate system parameters (e.g., projection parameters, transformation model parameters).

Plane to CGCS2000: Converts datasets from a plane coordinate system to the CGCS2000 latitude-longitude coordinate system.

Non-Planar Coordinate System to CGCS2000: Transforms datasets from WGS84 coordinate systems or Mercator projection coordinate systems into datasets within the CGCS2000 latitude-longitude coordinate system.

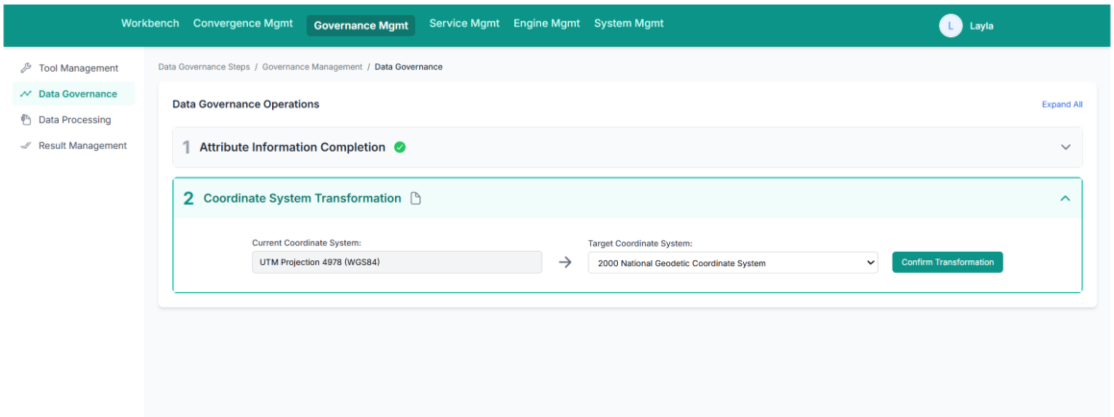


Figure 13 : Design Concept Diagram - Coordinate System Conversion

6.1.3.5 Code Management

Supports creation, editing, and deletion of codes; enables categorised management by data type, creating corresponding codes for different data types.

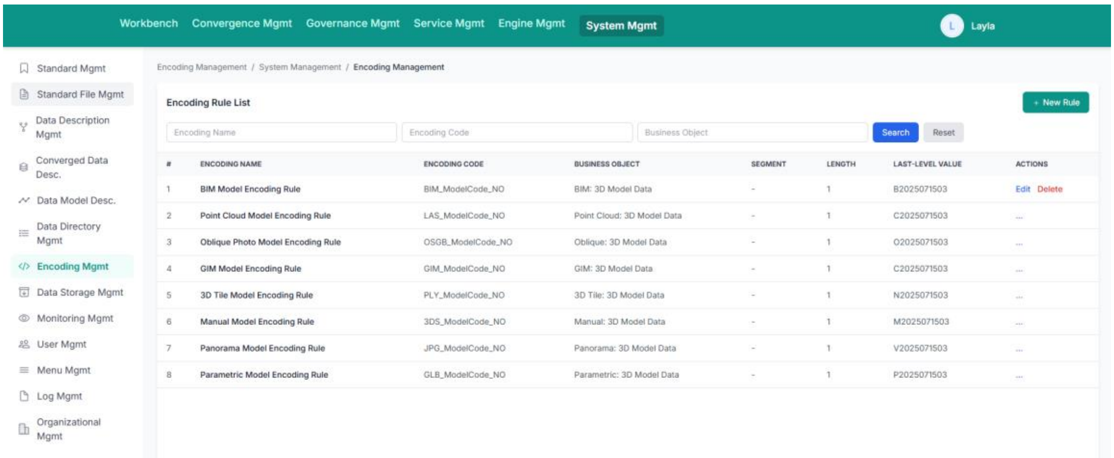


Figure 14 : Code Management

Code Management: Permits administrators or authorised users to create new codes, establishing corresponding codes for different data types (including: manual modelling, oblique photography, laser point clouds, parametric models, BIM models, GIM models, panoramic imagery, and 3D Gaussian).

Coding Rules: Detailed configuration of specific coding rules.

Mapping Relationship Management: Establishes mappings between coding rules and 3D models, completing the association between coding rules and 3D model data.

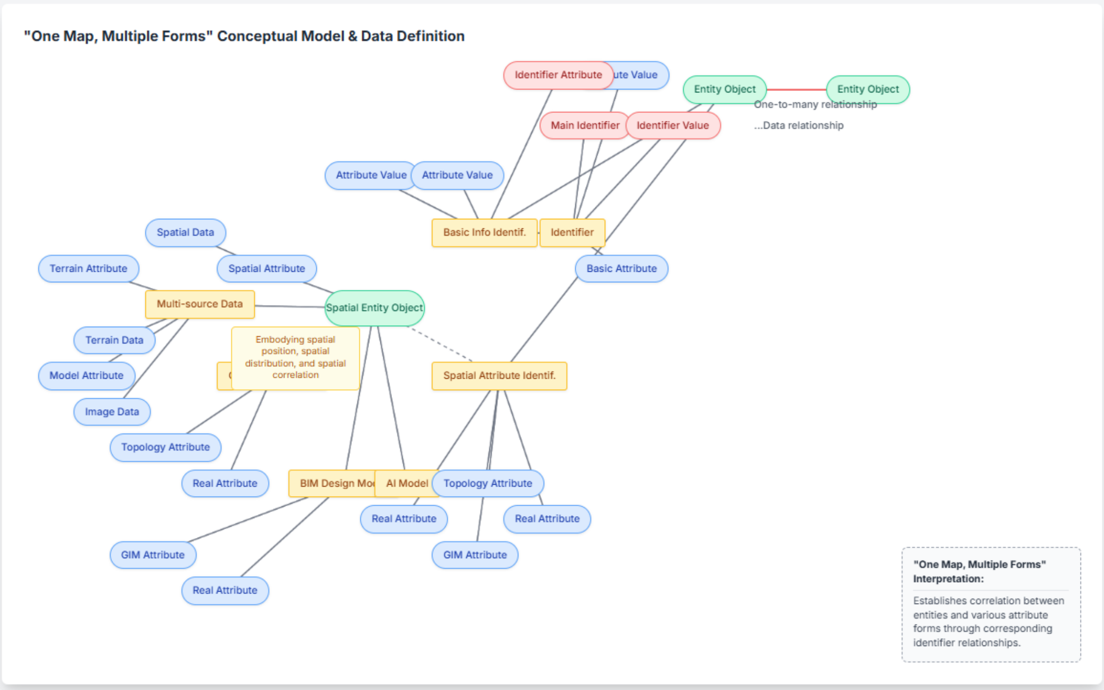


Figure 15 : Design of Coding Rules and Mapping Management

6.1.3.6 Data Quality Inspection

Perform multi-dimensional quality inspection on 2D and 3D data. Evaluate data quality through statistical analysis to ensure compliance and integrity, presenting an overview of the overall quality of data resources.

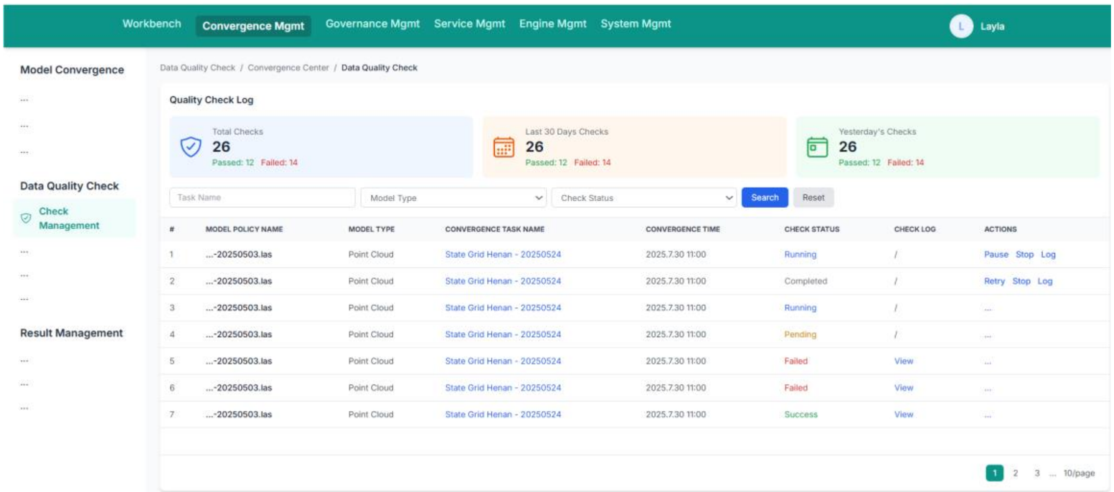


Figure 16 : Design Concept Diagram - Data Quality Inspection

6.1.4 Deliverables Centre

Construct a results database for 2D and 3D data, implementing management and control of results data to enable its administration, display, and statistical analysis.

6.1.4.1 Deliverable Data Management

Manage the results database for 2D/3D data ( ) and 2D/3D data ( ), enabling functions such as viewing and retrieving results data.

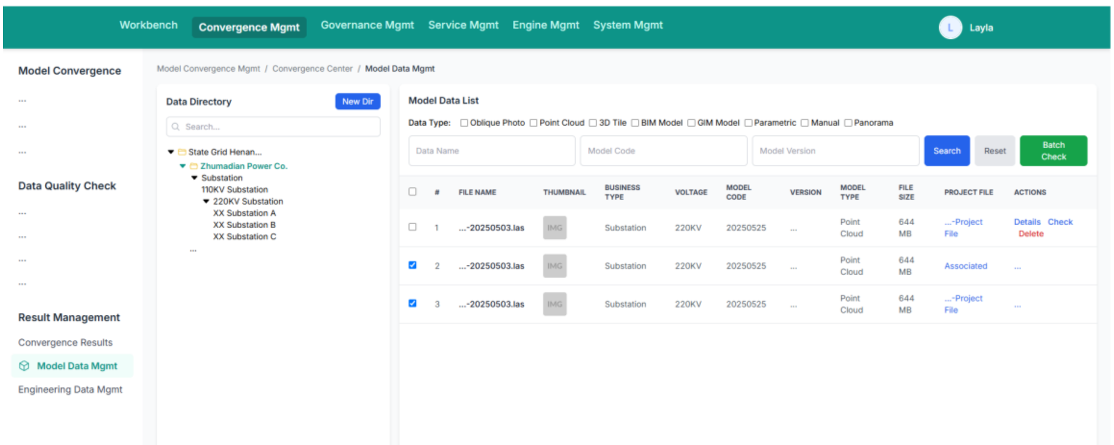


Figure 17 : Results Management

Results Data Listing: Results data displayed categorised by geographical area, equipment type, etc.

Data Retrieval and Query: Query processed deliverable data by data name, data type (oblique photography, laser point cloud, parametric model, BIM model, GIM model, manual modelling, panoramic imagery, and 3D Gaussian deliverable data), professional category, or version number. Query results are displayed in list format.

Data Viewing: Detailed data information for deliverables can be viewed.

6.1.4.2 Data Conversion

Mathematical benchmark matching conversion for model data, data format conversion, and unified data formats. This enables standardisation of 2D/3D model formats across multiple scenarios and devices for power grids ( ), facilitating the integration and application of power grid 2D/3D models.

6.1.4.3 Vector Data Conversion to S3M

Convert vector output data formats to the unified S3M format, achieving standardisation of 3D model formats across multiple scenarios and equipment types within power grids. This facilitates the integration and application of power grid 3D models.

6.1.4.4 Oblique Photogrammetric Model Data Conversion to S3M

Unify the storage format of oblique photogrammetric model data by uniformly converting it to S3M format for storage.

6.1.4.5 Laser Point Cloud Model Data Conversion to S3M

Unify the storage format of laser point cloud model data by converting it uniformly to S3M format for storage.

6.1.4.6 Parametric Model Data Conversion to S3M

Converting the format of parametric model output data to unify data formats enables standardisation of three-dimensional model formats across multiple scenarios and equipment within the power grid. This facilitates the integration and application of power grid three-dimensional models.

6.1.4.7 BIM Model Output Data Conversion to S3M

Unify the storage format of BIM model data by converting it uniformly to S3M format for storage, thereby providing three-dimensional data in the standardised S3M grid data format.

6.1.4.8 Parametric Model Output Data Conversion to S3M

Converting the format of parametric model output data to unify data formats enables standardisation of three-dimensional model formats across multiple scenarios and equipment within the power grid. This facilitates the integration and application of three-dimensional power grid models.

6.1.4.9 GIM Model Output Data Conversion to S3M

Unify the storage format of GIM model data by converting it uniformly to S3M format for storage.

6.1.4.10 Manual Modelling Output Data Conversion to S3M

Unify the storage format of manually modelled data by converting it uniformly to S3M format for storage.

6.1.4.11 Manual modelling output data conversion to S3M

Converting 3D Gaussian output data formats to the standardised S3M format enables unified 3D modelling formats across multiple grid scenarios and equipment types, facilitating the integration and application of grid 3D models.

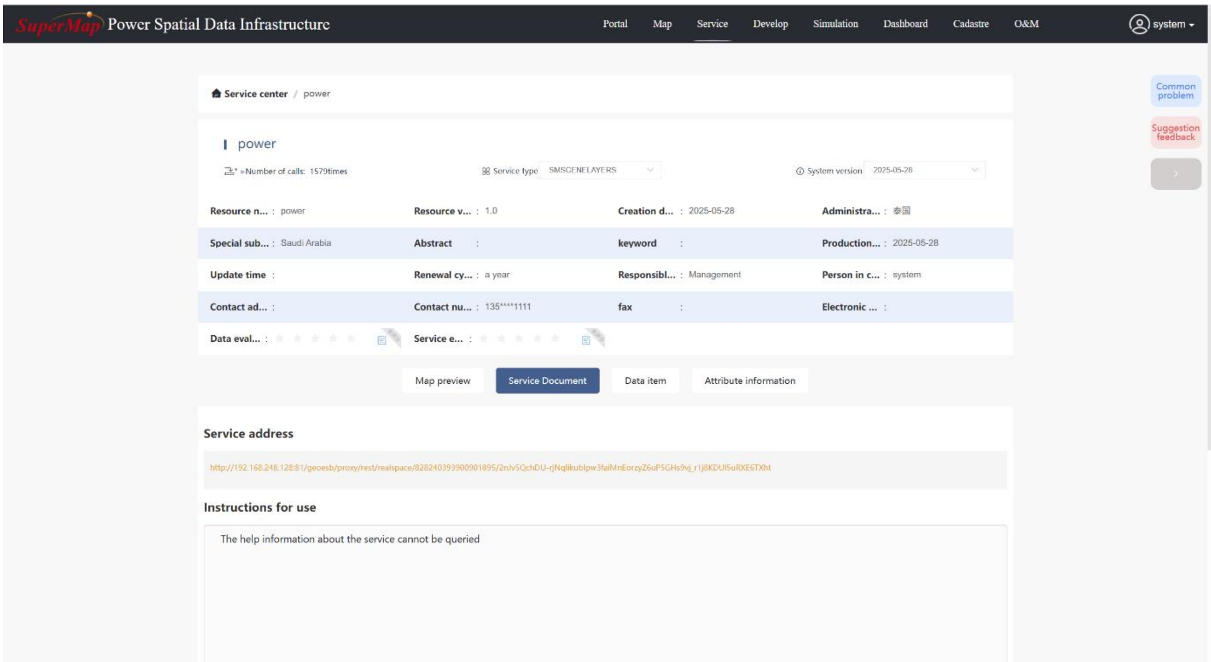
6.2 Service Centre

Service Search: Supports keyword and multi-condition filtering.

Publication Configuration: Visualised workflow guidance, supporting bulk publication of 3D models and 2D geographic data.

6.2.1 Service List

During service registration, services can be categorised into corresponding directories based on their metadata attributes, facilitating user retrieval.



Service Search: Users input keywords (e.g., service name, keywords, data type). The system employs fuzzy matching and semantic analysis to rapidly retrieve services.

View Basic Information: Clicking a service entry displays its fundamental details (name, address, description, tags).

View Service Documentation: Displays the service endpoint, request methods, parameters, and response examples.

View Attribute Information: For data services, supports viewing database field details.

Map Preview: For map services, preview the visual presentation of the map display.

Enable/Disable: Service administrators may enable or disable services based on maintenance schedules or resource utilisation. Services default to disabled or may be labelled as suspended.

Edit Service Resources: Supports editing non-critical service details such as name and description; enables custom tag configuration (default tags cannot be manually altered); facilitates image legend attachment; active services must be deactivated prior to modification.

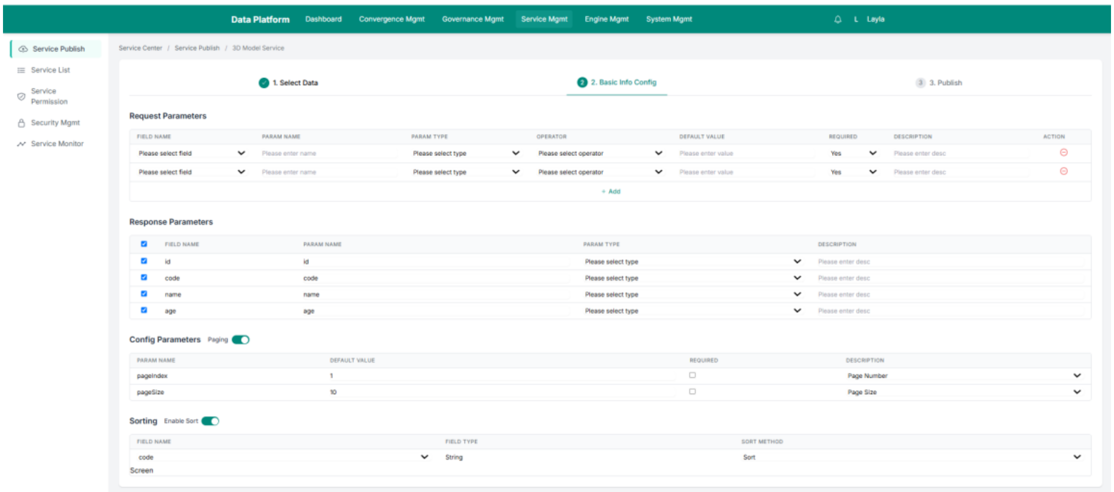


Figure 18 : Edit Service Resources

6.2.2 Service Publication

Adherence to OGC standards and industry specifications (such as the S3M Model Publishing Standard and RESTful interface specifications)

Service registration information must include complete metadata (service type, data source, interface protocol)

Publication of three-dimensional models and geospatial data.

Results data loading: By default, loads a list of results data already in S3M format for data selection and association prior to service publication.

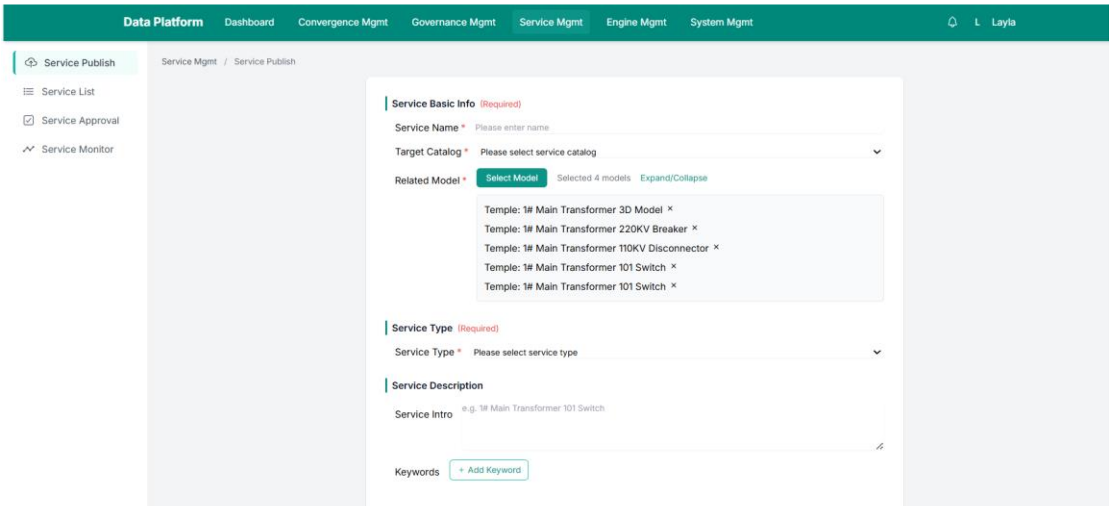


Figure 19 : Service Publication

Service information registration: Complete service registration details, including basic service information, type information, resource descriptions, etc.

3D model service publication: Publication of meticulously constructed 3D equipment models, building models, terrain models, etc., in accordance with industry-standard modelling specifications.

2D/3D Data Service Publication: Process and integrate 2D/3D geospatial data (e.g., 3D terrain data, underground space data) for publication via RESTful or similar interfaces.

Third-Party Interface Service Publication: Adhering to OGC (Open Geospatial Consortium) standards, uniformly register and proxy forward map service interfaces (e.g., WMTS, WFS) and geoprocessing interfaces.

Publication Progress Display: Show the backend execution status of published output data and third-party interfaces converted into service APIs.

6.2.3 Service Permissions

Authorisation Dashboard: Supports searching by service/user/department, displaying organisational structure in a tree format. Permission Configuration: Visualised selection of operational permissions. Upon authorisation completion, users automatically receive relevant notification messages.

Permissions Dashboard: Displays authorised users per service.

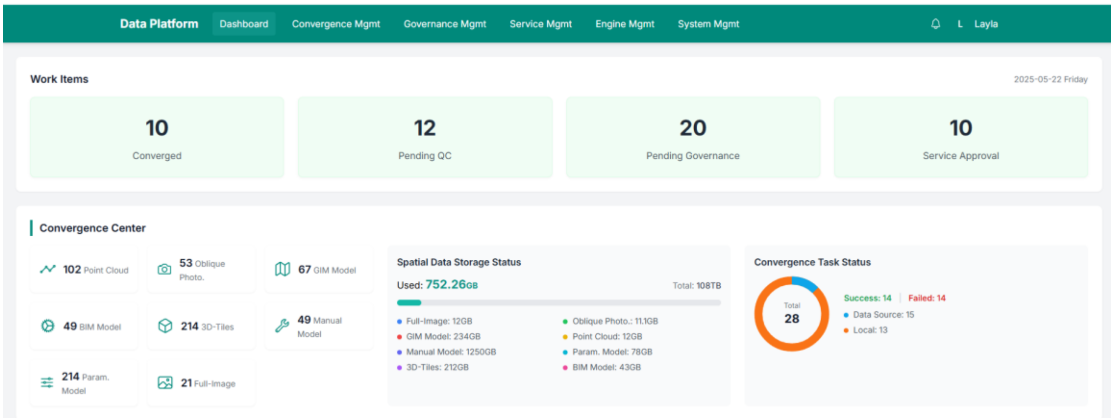


Figure 20 : Conceptual Diagram - Authorisation Workbench

Service Authorisation: Grant service access authorisation to users for offline service requests.

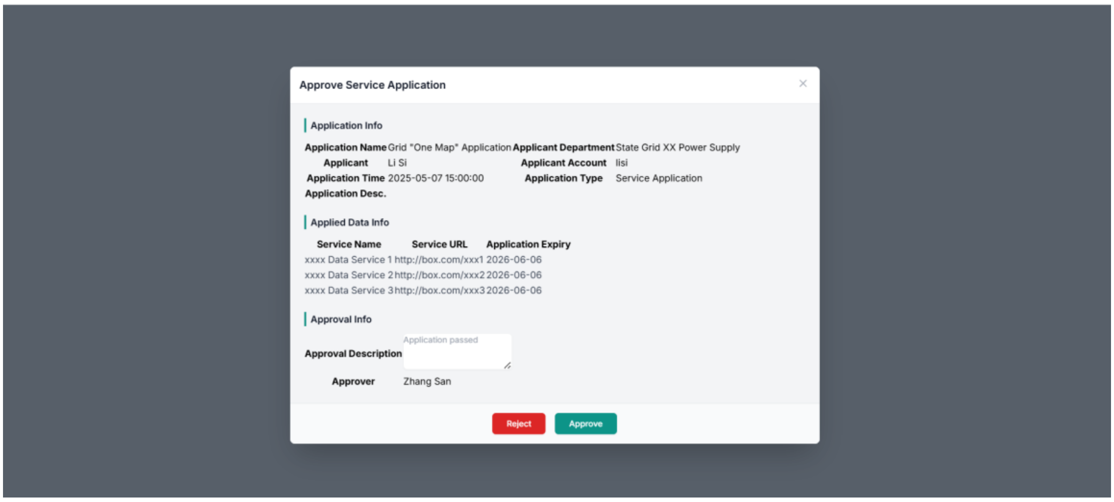


Figure 21 : Service Review

Service External Sharing: Enable external service sharing through parameterised configuration, supporting batch operations. Supports CRUD operations for shared services.

6.2.4 Tag Management

Supports custom date range selection and fuzzy search by service name; displays service access status in list format.

6.2.5 Security Policies

Create new security policies or edit existing ones; load service lists and support batch association.

Access Policies: Establish access rules, such as configuring IP access whitelists.

Default Policy: Configure a universal default policy covering fundamental rules for service access and permission allocation.

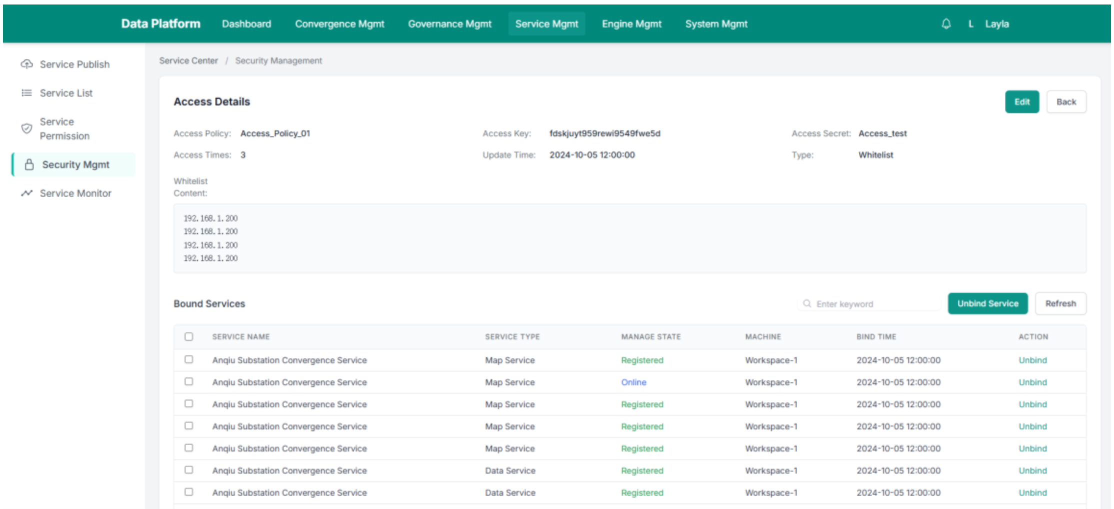


Figure 22 : Security Policies

6.2.6 Map Centre

Load various types of maps and map operation tools published by the service centre, along with map analysis tools, to showcase diverse map data types and API capabilities.

6.2.7 Map Directory

Supports loading and displaying the map catalogue in a tree structure, with fuzzy search by catalogue name.

6.2.8 Basic Map Operations

Pan: Users may freely navigate and explore the geographic scene via mouse dragging, keyboard arrow keys, or similar methods.

Zoom In: Gradually increase the display scale of the map or scene around the current viewpoint by scrolling the mouse wheel forward or clicking the zoom-in button, revealing finer details.

Zoom Out: Reduce the display scale of the map or scene by scrolling the mouse wheel backwards or clicking the zoom-out button. This allows viewing a broader geographical area to grasp the overall spatial layout.

Pan: Hold down the left mouse button and drag, or use the arrow keys on the keyboard to move the map or scene view horizontally.

6.2.9 3D Auxiliary Tools

Provides commonly used auxiliary tools for map operations, such as compass, panoramic view, and split-screen comparison functions.

Directory Search: Supports querying and searching the map directory.

Open Map: Select a map name to overlay it on the base map for display.

Attribute Query: Search based on geographic feature attribute information.

Spatial Query: Enables searches based on the spatial location and spatial relationships of geographic features

Layer Control (Legend): Users may select to display or hide specific layers as required, such as terrain, roads, or buildings. The Layer Manager enables rapid toggling of layer visibility.

Scene Switching: Rapidly transition between different geographic scenes (e.g., different regional maps, different temporal dimensions, 2D/3D scenes)

3D Annotation: Add annotations within 3D scenes to describe specific geographic features

Figure 23 : Conceptual Map - 3D Annotations

Full View: One-click adjustment to display the entire geographic scope of the map or scene view

Sky Colour Switch (Morning/Midday/Evening): Simulate sky colours at different times of day

Bird's-eye view: Display a thumbnail of the entire geographical area in a small window, with the current main view's display range annotated within the thumbnail

Panoramic View: Enables users to rotate 360 degrees around a specific point or their own location to observe the 3D scene

Flight Mode: Simulates an aerial perspective, allowing users to set flight paths and speeds for free navigation within the 3D scene

Measurement: Provides distance measurement (measuring straight or curved distances between two or more points), area measurement (measuring polygonal areas), and elevation measurement (measuring terrain or object height differences)

Split-Screen Comparison: Divides the map or scene into multiple windows on the screen, enabling simultaneous display of different data resources

Curtain Comparison: Utilises a curtain-like sliding operation to drag a curtain within the same view, switching between different data layers or data states.

Buffer Analysis: Creates buffer polygons around point, line, or area features at specified distances, revealing data contained within the buffer zone

Overlay Analysis: Processes geographic data from multiple layers through operations such as intersection, union, and difference to visualise analytical results.

Field of View Analysis: Calculates the observable area in two- or three-dimensional space from a specific vantage point.

Shadow Analysis: Simulates shadow conditions at specific times (e.g., different moments on the winter and summer solstices) by integrating solar illumination models with 3D geographic models (e.g., buildings, terrain).

Line-of-sight analysis: Assesses visibility between two points.

Skyline Analysis: Analysis of skyline characteristics within a specific area.

Height Control Analysis: Assessing height restrictions for buildings within a designated area.

Flood inundation analysis: Simulating the extent of inundation during flood events and other disasters.

Openness Analysis: Analysing the openness characteristics within a specific area.

6.3 GIS Data Processing Tools

6.3.1 GIS Workflow Design

Leveraging SuperMap GPA's geographic processing toolset and model-building capabilities, it supports the visual design of industry-specific workflows for the power sector, achieving deep integration between data processing steps and organisational business rules.

6.3.1.1 Industry-Specific Workflow Modelling

Based on power industry data management standards, SuperMap GPA's drag-and-drop "Model Builder" interface enables data processing tasks to be linked into closed-loop workflows according to role-based division of labour. For example:

- **Database Creation and Update Workflow**: Integrating GPA tools such as "Dataset Creation", "Attribute Structure Definition", "Data Import", and "Topological Relationship Construction", this workflow builds a process: "Field Data Import → Format Validation (invoking GPA's Format Conversion Tool) → Attribute Integrity Check (invoking GPA's Attribute Query Tool) → Topological Relationship Construction (invoking GPA's topology processing tools) → database update → version archiving." Each node is assigned to a specific role (e.g., "format validation" assigned to data entry personnel, "topology construction" assigned to GIS engineers), ensuring compliance with power utility database construction standards.
- **Business-Matching Data Processing Workflows**: For core power operations (e.g., line relocation data processing, substation asset association), combine GPA's spatial analysis tools to build customised processes. For example, the "Line Relocation Data Processing" workflow: "Import GIS data for relocation scope → Compare with existing line topology (utilising GPA's spatial overlay analysis tools) → Identify affected equipment (using GPA's buffer analysis tools) → Update attribute information (via GPA's field calculation tools) → Review and confirmation → Store results in database". Process nodes correspond directly to power business stages (e.g., design, construction, acceptance).

- **Deep Integration of SuperMap GPA Toolset**:

Built-in SuperMap GPA full suite of geoprocessing tools (encompassing data conversion, attribute processing, spatial analysis, topology construction, 3D data processing, etc.) enables direct invocation and parameter configuration within workflows (e.g., invoking GPA's "Topology Error Check" tool in the "Line Topology Verification" node, setting power-specific topology rules such as "Lines must connect to towers" and " equipment must not overlap" and other power-specific topology rules), enabling automated execution of data processing steps and reducing manual intervention.

6.3.2 Task Allocation and Progress Tracking

Leveraging SuperMap GPA's task scheduling and status monitoring capabilities, this enables precise allocation of power data processing tasks, visualised workflow progression, and real-time progress tracking.

6.3.2.1 Task Management

- **Multi-mode task initiation**: Supports manual triggering (e.g., an administrator initiating the "Monthly GIS Data Update" task within the tool) or automatic triggering (e.g., when GPA detects new data uploaded from field collection terminals, automatically launching the "Data Ingestion Verification" workflow). Upon initiation, it can associate power business parameters (e.g., equipment type, voltage level, affiliated region).
- **Role-Based Task Assignment**: Workflow node tasks are automatically assigned to corresponding role-based users based on power industry job divisions (e.g., inspectors, data reviewers, GIS administrators). For instance, the "Field Data Collection" node is assigned to inspectors (who may only upload data for equipment within their designated area), while the "Topology Verification" node is assigned to GIS engineers. Task notifications are simultaneously pushed during assignment (including GPA tool usage guidance, e.g., "Please use the 'Batch Attribute Editing' tool to correct incorrect equipment

model entries").

6.3.2.2 Progress Tracking

- **Visualised Process Display**: Utilising SuperMap GPA's process visualisation engine, workflow node relationships are presented via BPMN standard process diagrams (e.g., "Pending → In Progress → Review → Completed"). Each node is annotated with associated GPA tools (e.g., "Data cleansing" node marked "Invoke GPA 'Attribute filtering' tool"), responsible personnel, and processing deadlines. Embedded within the workflow diagram ( ) are Power GIS map thumbnails (displaying the spatial scope of involved equipment/lines).
- **Real-time progress monitoring**: Display workflow status in real time via the tool dashboard, showing node statuses ("Pending", "In Progress", "Completed", "Anomaly") and linking to GPA processing logs (e.g., "Topology validation node: 3 line segments found unconnected to towers, error ID: XXX"). Supports drill-down to view individual task details (e.g., an inspector's "Transformer District Equipment Data Collection" task is 80% complete, with coordinates for 2 remaining poles yet to be uploaded).

6.3.3 Management and Reporting Capabilities

Leveraging SuperMap's spatial permission management and GPA data analytics capabilities to achieve granular control over power GIS data processing and quantitative analysis of outcomes.

6.3.3.1 Data Editing Permissions Management

Leveraging SuperMap's spatial permission controls, define GIS data editable zones for specific user accounts (linked to power personnel's jurisdictional areas). For example:

- Assign the "East City Operations Team" user spatial editing permissions for

"XX Street 10kV and below equipment". This permits them to use GPA tools (such as "attribute modification" and "coordinate adjustment") solely within this designated area for processing equipment data. Operations exceeding this scope will be blocked.

- Grant provincial GIS administrators full regional data structure editing permissions (e.g., adding the "Smart Device Identifier" field via the GPA "Data Structure Modification" tool), whilst restricting their ability to alter specific operational parameters of individual devices to ensure "alignment of responsibilities with spatial scope".

6.3.3.2 Work Progress Reporting

Generate multi-dimensional work progress reports by role/individual based on GPA processing logs and user operation records, incorporating electricity business-specific metrics:

- **Task Volume Statistics**: e.g., "Inspector Li Si completed equipment data collection for 20 transformer districts this month, utilised the GPA 'Data Import' tool 15 times and the 'Coordinate Calibration' tool 8 times, achieving a 95% completion rate";
- **Data Quality Metrics**: e.g., "Topology verification tasks processed by GIS Engineer Wang Wu achieved a 92% error correction rate (correcting 28 of 30 original errors) across three 110kV lines";
- **Spatial Distribution Analysis**: Embed SuperMap GIS maps within reports to visualise task completion density across user-assigned areas via heatmaps (e.g., "Task completion rate in the southern urban area exceeds that of the northern area by 12%");
- Reports support export to PDF/Excel formats or integration into power management platforms, aiding managers in evaluating team efficiency and data

processing quality.

6.4 Power Network Data Construction Tool

6.4.1 Power Network Management

Establishes a unified multi-level power network framework centred on voltage levels, enabling coordinated management across different voltage tiers.

- **Multi-level network creation**: Supports defining at least three voltage levels within the same network model (High Voltage: e.g., 220kV and above; Medium Voltage: e.g., 10-110kV; Low Voltage: e.g., 0.4kV). Each level independently configures fundamental parameters (rated voltage, frequency, number of phases, maximum transmission capacity, etc.), with cross-level associations established via "voltage conversion nodes" (e.g., transformers). Examples include: "220kV substation main transformer connects to 110kV outgoing lines" and "10kV distribution transformer connects to 0.4kV low-voltage network".
- **Network Topology Management**: Employing a "node-edge" model to describe network structure, where nodes represent substations, switching stations, transformer districts, etc., and edges denote lines (e.g., transmission lines, distribution lines). Supports manual drawing or importing GIS topology data to generate network topology. Node positions and line routes can be adjusted via drag-and-drop, with network connection relationships updating in real time.
- **Hierarchical Association Rules**: Ensures logical closed-loop relationships where high-voltage networks supply medium-voltage networks and medium-voltage networks distribute loads to low-voltage networks. Examples include: "The power source for the 110kV medium-voltage network must be traceable to a 220kV high-voltage substation" and "The load of the 0.4kV low-voltage network must be associated with a 10kV distribution transformer", thereby preventing network

topology islands.

6.4.2 Connection Rule Management

Achieve precise association at the grid data layer through standardised rule definitions, safeguarding network logical consistency and accuracy.

6.4.2.1 Connection Rule Definition

Precisely define associative relationships between grid objects, encompassing both spatial and logical dimensions, to support the digital mapping of grid topology structures.

- **Spatial Connection Rules**: Based on the GIS spatial coordinate system, define the association between equipment and geographic space ( ), such as the coordinate binding between utility poles and tower locations. Establish spatial positional relationships between equipment (e.g., "lines are strung along utility poles," "switchgear is located in area X of the substation"). Supports validating connections through spatial parameters like distance and azimuth.
- **Power Grid Logical Connection Rules**: Define logical associations between equipment based on electrical connection characteristics of power systems (e.g., "Busbar connects to current transformer"; "Circuit breaker series-connected at line sectioning point"). Supports setting connection constraints (e.g., "Rated current matching between switches and instrument transformers within the same circuit") and automatically validates logical conflicts (e.g., "Redundant connections in closed-loop networks").
- **Connection Rule Library Management**: Preserves common connection patterns (e.g., the typical "transformer - busbar - feeder switch" sequence) as templates, enabling rule reuse, modification, and access control (e.g.,

administrators may edit rules while library creators can only invoke them).

6.4.2.2 Connection Rule Configuration

6.4.2.2.1 Numerical Ranges and Grouping

- Define numerical ranges for critical parameters (e.g., "Circuit breaker rated current range: 630A–4000A"; "Conductor cross-sectional area standards: 16mm², 25mm²…240mm²") to restrict data entry and prevent invalid values;
- Supports grouping assets by dimensions such as "Function Type", "Material", or "Supplier" (e.g., "Group '10kV Vacuum Circuit Breakers' by 'Manufacturer' into 'Brand A Group' and 'Brand B Group'"), facilitating bulk queries and management.

6.4.2.2.2 Association of Non-Electrical Assets with Electrical Assets

For assets not directly involved in power transmission but providing grid support, establish dedicated connection rules while linking full lifecycle information to achieve integrated asset-grid management.

- **Non-operational asset connection rules**: Define physical connection relationships for non-operational assets (e.g., poles, crossarms, insulators, earthing rods), clarifying the load-bearing logic of non-electrical assets (e.g., poles, crossarms, insulators) supporting electrical assets (e.g., conductors, switches, instrument transformers). Examples:
  - "Crossarms fixed at 2.5 metres above ground level on poles", "Insulators installed at both ends of crossarms", "Earthing rods welded to pole bases". Supports assembly structures via parent-child hierarchical relationships (e.g., "Poles as parent nodes, crossarms and insulators as child nodes").
  - "Conductors must be strung across the crossarms of the pole" (linking pole ID, crossarm installation height, and conductor model compatibility);
  - "Insulators must be installed at both ends of the crossarm, with at least two

insulators corresponding to each conductor segment";

- Associated information synchronises to asset attributes (e.g., pole fields such as "Supported Conductor Model" and "Number of Insulators" update automatically).

- **Asset attribute association**: Bind asset management fields (model, material, supplier, installation date, inspection records, scrapping lifespan, etc.) to non-operational assets, supporting linkage with connection rules (e.g., "Automatically verify crossarm load-bearing compatibility when pole model changes").
- **Asset condition tracking**: By linking assets to grid operational data through connection rules (e.g., associating earth rod resistance test results with the inspection records of their corresponding poles), this supports asset health assessment and lifespan prediction.

6.4.2.2.3 Substation and Internal Component Association

Define the electrical connection logic within substations to establish hierarchical associations of "Substation - Bay - Equipment". For example:

- "High-voltage bays within substations must contain circuit breakers, current transformers, and voltage transformers, connected in the sequence: busbar → voltage transformer → circuit breaker → current transformer → outgoing line";
- "The 10kV low-voltage busbar must connect to the high-voltage sides of at least two distribution transformers";
- Supports visualisation of relationships via topology diagrams, with clicking substation nodes expanding their internal component connection structures.

6.4.2.3 Generation of logical connection diagrams and single-line diagrams

- Following import of GIS spatial data (equipment coordinates, line routes), automatically extracts network topology to generate logical connection diagrams (displaying electrical interconnections between equipment while disregarding geographical scale);

- Supports manual editing of logical diagrams to streamline redundant nodes (e.g., merging identical equipment types), generating single-line diagrams compliant with power industry standards (e.g., 10kV distribution line single-line diagrams, substation main connection single-line diagrams), and associating equipment parameters (e.g., annotating conductor type and current-carrying capacity alongside lines).

6.4.2.4 Rule Validation

An embedded rule engine performs real-time validation of data editing operations against established rules, such as:

- "Customer meters must connect to low-voltage conductors (0.4kV), with each meter linked to only one low-voltage conductor" — if a meter is connected to a medium-voltage line, the system prevents saving and displays "Error: Meter must connect to 0.4kV low-voltage conductor";
- "The high-voltage side of a transformer must connect to a busbar of the corresponding voltage rating (e.g., a 10kV transformer's high-voltage side requires a 10kV busbar)" — If incorrectly connected, a warning triggers displaying "Voltage rating mismatch. Please verify transformer parameters against busbar rating";
- Error logs are recorded, containing error type, operator, and time, with support for filtering queries by device or rule type.

6.4.3 Network Query and Analysis Functionality

Deliver diverse query methods and professional analytical capabilities to unlock the operational value of network data.

- **Basic query functions**:

- Query by "Equipment Attributes" (e.g., "Query all 110kV circuit breakers with rated current ≥1250A");
- Query by "Connection Relationships" (e.g., "Query all conductors and associated insulators supported by a specific pole"; "Query all distribution transformers connected to the low-voltage side of a specific substation");
- Query by "Voltage Level / Area" (e.g., "Query the switch status of all 10kV lines within Area XX").

- **Professional analysis functions**:

- Topological Path Analysis: Tracing the complete path from "power source to load point" (e.g., "supply route from 220kV substation to XX distribution area"), identifying critical nodes (e.g., sectionalising switches, transformers);
- Supply Area Analysis: Calculate the supply zones of substations/lines based on network topology (e.g., "Medium-voltage supply area of 110kV Substation A"), overlaid on GIS maps for visualisation;
- Load Correlation Analysis: Quantify the associated load of a specific line/transformer (e.g., "total load of all low-voltage distribution areas connected to 10kV Line B"), supporting load variation analysis by time dimension (daily/monthly/annual);
- Fault Impact Analysis: Simulates the impact of equipment failure (e.g., circuit breaker tripping) on downstream networks and loads (e.g., "Three transformer districts and 500 households affected after the 10kV C line switch tripped").

6.4.4 Data Visualisation

Through two-dimensional and three-dimensional integration, achieve multi-dimensional, intuitive presentation of power grid network data.

6.4.4.1 Three-dimensional Network Data Model Construction

- Construct a three-dimensional model library based on equipment parameters (dimensions, materials) and GIS coordinates (e.g., three-dimensional solid models of utility poles, transformers, and substations);
- Associate 3D models according to network topology to form complete three-dimensional network scenarios (e.g., "3D models of high-voltage lines erected along GIS paths, connecting 3D models of substations at both ends");
- Supports importing BIM models (e.g., substation building BIM) and merging them with network equipment models to construct integrated three-dimensional scenes encompassing "buildings – equipment – lines".

6.4.4.2 Two-dimensional and three-dimensional visualisation capabilities

- 2D Visualisation: Overlay network topology (lines, equipment locations) onto GIS maps, annotate key equipment parameters (e.g., transformer capacity, line current-carrying capacity), with support for zooming, panning, and layer control (e.g., displaying only the 10kV line layer);
- 3D Visualisation: Enables scene navigation and perspective switching (bird's-eye view / side view / first-person view). Supports clicking 3D equipment to view detailed attributes (e.g., clicking a utility pole displays "Model, Installation Date, Supported Conductors");
- 2D-3D Synchronisation: Selecting equipment on the 2D GIS map automatically locates and highlights the corresponding equipment in the 3D scene. Selecting an area in the 3D scene synchronously marks the area's boundaries and associated network elements on the 2D map.

6.4.5 Asset Data Management

Integrates comprehensive grid asset data, enabling visualisation and value extraction of asset information through charts and reports.

6.4.5.1 Aggregated Asset Query

Correlates fundamental asset attributes (model, specification, supplier), operational data (load factor, fault frequency), maintenance records (inspection dates, replaced components), and spatial information (installation location, associated equipment). Supports data aggregation by dimensions such as "Asset Type", "Voltage Level", and "Service Duration" (e.g., "Aggregate 'Capacity - Load Factor - Fault Frequency' data for all 10kV distribution transformers"). - Failure Counts' data").

6.4.5.2 Chart and Report Generation

- Chart Types: Provides bar charts (e.g., comparison of fault frequency across different manufacturers' circuit breakers), line charts (e.g., annual load trend for a specific line), pie charts (e.g., material composition ratio of low-voltage equipment in a region), and heatmaps (e.g., GIS-based distribution of equipment fault density);
- Report Templates: Pre-built standardised reports (e.g., "Monthly Asset Health Report", "Voltage Level Network Asset Statistics Report"), supporting customisable report dimensions (e.g., adding an "Asset Full Lifecycle Cost Analysis" module);
- Output formats: Supports export to PDF, Excel, and image formats. Report data automatically links to datasets, ensuring real-time updates.

6.5 GIS Data Quality Assurance Tool

Accurately identifies various errors within power GIS data, providing verification mechanisms and correction tools to achieve a closed-loop process of "detection - verification - correction".

6.5.1 Data Quality Inspection

6.5.1.1 Data Quality Inspection

Covers spatial error types in power GIS data, such as abnormal equipment positioning ("pole coordinates located at river centre", "substation boundaries overlapping roads") and broken topological relationships ("lines not connected to poles or substations at both ends", "switchgear not associated with any circuit");

6.5.1.2 Data Quality Inspection Report

The tool supports generating data quality inspection reports, enabling users to manually correct data based on the output reports.

6.5.2 Attribute Information Quality Inspection

Provides comprehensive verification of attribute information for elements such as equipment and lines within power GIS data, ensuring attribute data complies with power industry standards.

6.5.2.1 Attribute Quality Inspection

Supports comprehensive validation of core attributes in power GIS data (e.g., equipment ID, model, voltage level, installation date, owning organisation, operational status), including:

- **Completeness checks**: Verifies mandatory attributes are not missing (e.g., "Transformers must specify rated capacity"; "Lines must be linked to associated substation IDs");
- **Standardisation Verification**: Validates attribute formats against power standards (e.g., equipment numbers must follow the "voltage level + area code + equipment type + serial number" convention, such as "10kV-XX Area - T-001"; date formats must be "YYYY-MM-DD");
- **Consistency Check**: Verify logical compatibility of associated attributes (e.g.,

"Circuit breaker rated current must match maximum current-carrying capacity of associated line"; "Distribution transformer low-voltage side voltage must be 0.4kV").

6.5.2.2 Quality Inspection Report

The tool supports generating attribute quality inspection reports. Users manually correct the data in the file based on the output quality inspection report.

6.5.2.3 Attribute Information Correction

Supports batch operations on multiple spatial features (e.g., all towers within the same line, all switchgear within the same substation) to enhance processing efficiency:

- **Batch Replacement**: For scenarios involving incorrect attribute values or updates, replace specified attributes with a single click (e.g., "Uniformly replace all 'Pole Material' attributes marked as 'Concrete' within the XX area to 'Reinforced Concrete'"; "Batch-correct formatting errors in all equipment 'Installation Date' entries").
- **Reallocation**: Rule-based automated assignment of attributes to multiple features (e.g., "Segment by line: Reallocate 'Responsible Crew' to 'East City Operations Team' for pylons 1-10 on Line L123, and to 'South City Operations Team' for pylons 11-20"; "Automatically assign 'Responsible Substation ID' to equipment based on GIS coordinates").

6.5.3 Validation Rule Management and Configuration

Supports customisation and management of industry-specific validation rules tailored to meet diverse business scenario data quality standards.

6.5.3.1 Rule Customisation and Industry Adaptation

Provides a visual rule configuration interface, enabling users to define validation rules based on power industry standards or internal corporate requirements:

- **A ttribute Rules**: Configure mandatory fields (e.g., "Switchgear must specify protection rating"), numeric value ranges (e.g., "Conductor cross-sectional area for 110kV lines must be 50-400mm²"), and enumerated value lists (e.g., "Equipment status permitted only as 'Operational', 'Standby', 'Under Maintenance', 'Decommissioned')";
- **Spatial rules**: Configure spatial constraints (e.g., "Distance between pylons and lines must ≤0.5 metres"; "Substation boundaries must encompass all internal equipment") and topological relationships (e.g., "Distribution lines must form a tree topology; closed loops are prohibited");

6.6 Real-time data processing tools

6.6.1 Data aggregation

Adapted to the diverse data sources within the power industry, ensuring efficient and accurate real-time data ingestion, covering scenarios involving real-time data stream inputs.

6.6.1.1 Directory-monitored data collection

Supports real-time monitoring of local directories or network-shared directories. Precisely identifies newly created files through mechanisms such as file creation time and checksum values, collecting only unprocessed new data to avoid redundant processing. Supports configuration of monitoring policies according to power business rules, adapting to the hierarchical storage management standards for power data.

6.6.1.2 Network Protocol and Format Adaptation

- Supports dual-mode access via Web protocols (HTTP/HTTPS) and WebSocket protocols: Web protocols suit periodic data reporting (e.g., distribution terminals uploading 5-minute interval voltage/current data via), while WebSocket protocols handle high-frequency real-time streaming data (e.g., substation telemetry/telecontrol data, instantaneous waveform data from line faults), catering to diverse real-time requirements within the power sector.

- Native support for parsing core power industry data formats: Directly ingests JSON (device status parameters, operational logs), GeoJSON (fault locations with spatial coordinates, line topology change data), and XML (traditional SCADA system telemetry frame data). Built-in format validation rules (e.g., GeoJSON coordinate integrity checks, XML tag compliance with power industry standards) ensure input data structural conformity.

6.6.2 Real-time data processing

- **Rapid real-time processing**:

Processing commences immediately upon data ingestion. Initial steps include format standardisation (e.g., converting XML to JSON for unified parsing) and field mapping (e.g., mapping "telemetry value" to the power industry standard field "active_power"). This is followed by multi-dimensional filtering:

- **Attribute filtering**: Data screening based on core attributes of electrical equipment (equipment ID, voltage level, asset number, operational status, etc.), e.g., "Process only transformer data with a voltage level of 220kV and status marked as 'abnormal'";
- **Spatial Location Filtering**: Combines GIS spatial information with geographical rules (latitude/longitude ranges, administrative boundaries, substation/line protection zones) for filtering. For example: "Process only line temperature data for the line within the XX transmission corridor (latitude range N30°-N31°, longitude range E116°-E117°)".

6.6.3 Intelligent Alarms

Enables real-time data processing and dynamic analysis based on power utility business rules, triggering precise alerts to support rapid response. Features a dedicated industry-specific rule engine supporting combined analysis of events, conditions, locations, and geographic zones based on live data to initiate alerts aligned with operational logic:

- **Event-triggered**: Alerts when specific status change events occur (e.g., "Circuit breaker status changes from 'Open' to 'Closing Anomaly'", "Photovoltaic inverter status changes from 'Operating' to 'Island Operation'");
- **Condition-triggered**: Alarms when monitored parameters exceed preset thresholds (e.g., "Transformer oil temperature >85°C", "Line load factor >90%", "Cable joint temperature change >10°C/min");
- **Location/Area Triggered**: Alerts when the spatial location associated with data matches sensitive area rules (e.g., "Fault point within 500 metres of critical user supply radius"; "External force damage monitoring point located within transmission line protection zone");
- Alarms support classification according to power industry standards (general, critical, emergency) and include trigger details (e.g., "Trigger condition: Line L123 load factor = 92% > threshold 90%; Associated equipment: 110kV XX line"), enabling rapid issue identification by operations personnel.

6.6.4 Data Export

P rocessed data is distributed on demand to power business systems, storage media, or front-end applications, forming a data processing closed loop.

6.6.4.1 Real-time Database Writing

- Supports inserting or updating records (e.g., real-time equipment status, alarm event logs) into relational databases (e.g., MySQL, PostgreSQL), ensuring operational systems (e.g., OMS, PMS) receive the latest data in real time;
- Supports storing georeferenced data (e.g., fault point GeoJSON, line topology spatial relationships) in spatial databases (e.g., PostGIS, MongoDB Spatial Edition), providing real-time spatial data sources for GIS systems.

6.6.4.2 File-based Output

Automatically generates standardised files and stores them in designated paths, supporting CSV (device operational parameter statistics), JSON (alarm details), and GeoJSON (spatially-related events) formats. This fulfils requirements for data archiving, offline analysis, or file import into third-party systems (e.g., exporting daily 10kV line fault data as CSV for reporting system statistics).

6.6.4.3 Real-time Data Streaming Service

Establish standardised real-time data streams (e.g., based on Kafka or MQTT protocols) to push processed data in stream format to grid dispatch systems and real-time monitoring platforms, supporting dynamic dispatch decisions (e.g., pushing real-time load flow data to EMS systems for power flow calculations).

6.6.4.4 Web-based data push

Instantly push JSON or equivalent data files ( ) to web browsers (e.g., operations monitoring dashboards, mobile applications) to visualise alert information and equipment status (e.g., real-time updates of fault locations and details on monitoring interfaces).

6.7 Mobile Development Components

6.7.1 Mapping Services and Spatial Data Module

This module provides spatial positioning fundamentals for field data collection in the power sector, supporting integration with existing industry-specific map resources to fulfil location-related requirements for field operations.

- Map Display Capabilities: Supports 2D map switching, enabling loading of specialised power industry map layers (e.g., substation distribution, transmission line routes, transformer station boundaries), alongside fundamental operations including zooming, panning, distance measurement, and area calculation.
- Map Service Integration: Compatible with mainstream OGC map services while supporting access to internal power industry map services, fulfilling field queries for specific regional spatial information.
- OGC Standard Compliance: Strict adherence to OGC (Open Geospatial Consortium) standards enables integration with OGC-compliant data services including WMS (Web Map Service) and WFS (Web Feature Service), facilitating data interoperability with existing power sector GIS systems.

6.7.2 Object Attribute Editing Module

Provides flexible attribute editing capabilities for core objects collected at power sites (e.g., transformers, utility poles, switchgear), ensuring data compliance with power industry standards.

- Object Selection and Association: Supports locating target power network objects ( ) via map point selection or list selection, automatically associating the object's fundamental attributes (e.g., equipment number, model, installation date).
- Attribute Editing Operations: Offers editing controls including text input, dropdown selections, date pickers, and photo uploads (e.g., for equipment defect

documentation). Supports customisable attribute fields (e.g., adding "Inspection Results" or "Fault Severity" based on power operation types).

6.7.3 Offline Data Processing Module

Resolves network instability issues at remote power sites (e.g., remote mountainous areas, underground substations), ensuring uninterrupted operations during offline periods with full data synchronisation upon reconnection.

- Offline Data Storage: Supports storing designated area map data, fundamental power object data, and collected data locally on the device. Utilises local encrypted storage to safeguard power data security.
- Offline Operation Support: Enables normal map viewing, object attribute editing, and new data collection (e.g., adding fault point records) during network outages. All operation records are saved in real-time to the local database.
- Data Synchronisation Mechanism: Automatically detects unsynchronised local data upon network reconnection, supporting incremental synchronisation (synchronising only modified/new data). A progress bar displays during synchronisation. Should synchronisation fail, a retry function is provided alongside failure cause logging for subsequent troubleshooting.

6.7.4 Multi-format data support module

Covers common data types collected at power sites, ensuring data from diverse sources and formats can be viewed and utilised seamlessly.

- Basic format support:
  - Vector data: Supports formats including SHP and GeoJSON, enabling loading of vector layers such as power lines and equipment distribution ( ). Layer visibility control is supported.
  - Raster Data: Supports formats including TIFF and PNG, enabling viewing of

raster maps such as satellite imagery and aerial photographs to meet detailed site survey requirements.

- Text Data: Supports TXT and CSV formats. Enables import of equipment ledgers, inspection task lists, and other textual data. Also allows export of collected data into text format.

- Specialised Format Support: Primarily supports KML format data, enabling loading of KML files for power inspection route planning and key monitoring area annotations. KML layers can be overlaid with other map layers to assist field operation positioning.

7 Digital Power Smart Application System

7.1 Web Application System

7.1.1 Integrated System Management Subsystem

7.1.1.1 System Parameter Configuration Function

System parameter configuration is responsible for centrally managing all parameters required for system operation, ensuring stable functioning according to predefined rules. It also records the impact of parameter changes on the system, providing a basis for troubleshooting.

7.1.1.1.1 Management Configuration List

1. Parameter Classification System

System parameters are categorised into three main groups based on their functionality and scope of influence:

System Foundation Parameters: Including system name, version number, time zone, language, log retention period, etc., which determine fundamental operational attributes;

Performance Optimisation Parameters: Including database connection pool size, cache expiry time, request timeout threshold, concurrent thread count, etc., used to regulate system operational performance;

Security Control Parameters: encompass password complexity requirements, session timeout duration, IP access whitelists, and operation log recording levels, ensuring secure system operation.

2. Visualised List Display

The frontend employs a table component (based on Element UI/Vue3) to display the parameter list. Core fields include: Parameter ID, Parameter Name, Parameter Category, Parameter Type (String / Numeric / Boolean), Current Value, Default Value, Last Updated, Operator, Parameter Status (Enabled / Disabled). Supports pagination (default 10 entries per page, customisable between 5-50 entries) and fixed columns (Parameter ID, Parameter Name) for rapid parameter location.

3. Search and Filtering Functionality

Multi-condition filtering: Supports filtering by parameter category, parameter status, and update time range (last 1 day / last 7 days / custom range).

Fuzzy search: Enables keyword searches by parameter name or ID, with real-time highlighting of search results;

Advanced filtering: Enables precise targeting by parameter type (e.g., query numeric parameters only) or parameter value range (e.g., parameters where "concurrent threads > 100").

Batch Operations

Batch enable/disable: Enable or disable multiple parameters simultaneously with a single click (disabled parameters require a reason, e.g., "Parameter pending optimisation, temporarily disabled");

Batch Export: Supports exporting filtered parameter lists to Excel format. Exported content includes all list fields for offline analysis and backup.

7.1.1.1.2 Configuration Details Management

1. Parameter Detail Display

Clicking the "View Details" button in the parameter list opens the parameter details page, displaying the following information:

Basic Information: Parameter ID, Name, Category, Type, Current Value, Default Value, Status, Creation Date, Last Updated Date, Operator;

Description: Parameter functionality explanation (e.g., "Database connection pool size: Controls the number of simultaneous connections to the database to prevent connection overload"), applicable scenarios (e.g., "Applies only to the primary database; secondary databases require separate configuration"), modification recommendations (e.g., "During peak business hours, set to 50-100; during off-peak hours, set to 20-50").

Associated Information: System modules dependent on this parameter (e.g., "Concurrent Thread Count" associated with "Data Acquisition Module" and "Report Generation Module"), parameter change history (records of the last five modifications, including pre- and post-change values, operator, and timestamp).

2. Parameter Modification Process

Permission Verification: Only roles designated as "System Administrator" or "Parameter Administrator" may modify parameters; standard users are restricted to viewing only.

Modification Operation: Click the "Modify" button to open the modification form. Supports editing the "Current Value" and "Parameter Status" (Enable/Disable). A modification reason must be provided (e.g., "Increased business volume necessitates expanding the connection pool size").

Effect Control: Different effect mechanisms are set based on parameter type:

Immediate Effect: e.g., "IP Access Whitelist" synchronises to the system security interception module immediately after modification, requiring no restart;

Restart-triggered: For parameters like "Database connection pool size", changes are marked as "Pending activation". A system prompt states "Requires application restart to take effect", with a restart reminder task logged;

Scheduled Effectiveness: For example, "Log storage retention period" supports setting an effective time (e.g., "Next day at 00:00"). Changes take effect automatically upon schedule, avoiding disruption during peak operational periods.

3. Parameter Comparison and Restoration

Supports comparison between "Current Value" and "Default Value", highlighting discrepancies (e.g., current value "60", default value "30", with differences marked in red);

Provides a "Restore Default Value" function. Clicking this resets the current value to the default, requiring secondary confirmation (e.g., "Confirm restoring to default value 30? Changes will take effect according to the activation mechanism after restoration") to prevent accidental operations.

7.1.1.1.3 Manage Impact History: Enable traceability for parameter changes

1. Content of Impact History

Design the sys_param_history table to log every parameter change. Core fields include:

Basic change details: History ID, Parameter ID, Parameter Name, Operator (Username + User ID), Operation Time, Operation Type (Add / Modify / Delete / Restore Default);

Change Details: Previous Value, New Value, Reason for Change, Effect Mechanism (Immediate / Restart / Scheduled), Effect Status (Pending / Applied /

Expired);

Scope of Impact: Associated system modules (e.g., "Data Collection Module", "User Authentication Module"), affected operations (e.g., "Parameter changes may cause delays in report generation"), risk level (Low / Medium / High, e.g., modifying "Password Complexity Requirements" is classified as high risk).

2. Historical Record Query and Filtering

Multi-dimensional Query: Supports filtering by parameter ID/name, operator, operation time range (accurate to the hour), operation type, and risk level;

Associative Query: Entering "Data Collection Module" retrieves all parameter change records affecting that module;

Pagination and Sorting: Default reverse chronological order by operation time (most recent changes first), with support for ascending/descending sorting by "Risk Level" (e.g., prioritising high-risk changes).

3. History Export and Archiving

Export Functionality: Supports exporting filtered historical records to Excel/PDF format. Exported content includes all fields. PDF format supports adding watermarks (e.g., "Power System Parameter Change Log – Do Not Distribute Outside ").

Archiving Policy: Historical records are retained for 3 years. Records older than 3 years are automatically archived to an offline database (e.g., PostgreSQL archive repository). Archived records remain retrievable via the "Archive Query" function (requires administrator privileges), preventing data redundancy in the online database.

Historical Record Analysis

Statistical Reports: Generate "Monthly Parameter Change Statistics" reports displaying: - Quantity of different operation types (Additions / Modifications /

Deletions) - Proportion of high-risk changes - Top 5 operators (most frequent changes)

Trend Analysis: Utilises line charts to display "Parameter Change Frequency Over the Past 6 Months", assisting administrators in identifying periods of high change activity (e.g., increased changes prior to service launches) to refine parameter management strategies.

7.1.1.2 Organisational Chart Management Function

7.1.1.2.1 Manage Unit Lists

1. Unit Information Framework

Defines core attributes of power units, covering all dimensions of information required for management:

Basic Information: Unit ID, Unit Name (e.g., "North China Power Dispatch Centre", "East China Power Operations and Maintenance Branch"), Unit Code (generated per power system coding rules, e.g., "HD-001"), Unit Type (Headquarters / Branch / Subsidiary / Operations and Maintenance Station), Affiliated Region (e.g., "North China", "East China", "South China");

Responsible Person Information: Name, Position, Contact Details (Mobile + Office Phone), Email Address, Date of Employment;

Operational Information: Date of establishment, registered capital (subsidiaries only), scope of business (e.g., "power dispatch", "equipment operation and maintenance", "power sales"), unit status (operating normally / under preparation / deregistered / suspended operations), remarks (e.g., "under preparation October 2024, commencing formal operations January 2025").

Unit List Operations

Basic Operations: Supports "Add", "Edit", "Delete", and "View Details" for entities. Action buttons dynamically display based on entity status (e.g., "View

Details" only appears for "Deregistered" entities, while "Edit" and "Delete" are hidden).

2. New Entity Creation Process:

Form completion: Enter basic unit information, responsible person details, operational information, and upload unit qualification documents (e.g., scanned business licence; supports PDF/JPG formats, size ≤10MB);

Submit for Review: Upon completion, submit the form to the "Regional Administrator" for review. Review status (Pending Review / Approved / Rejected) is displayed in real-time within the list;

Review processing: Regional administrators review the form and qualification documents. Upon approval, the unit status is set to "Operating Normally" (units in preparation are set to "In Preparation"). If rejected, the reason must be provided (e.g., "Unit code format incorrect; must follow 'Region - Sequence Number' rule").

Batch Operations: Supports bulk import of entities (via Excel template, which includes mandatory field descriptions and examples), bulk export (exported to Excel containing all entity information), and bulk status changes (e.g., changing multiple "Under Preparation" entities to "Operating Normally" requires uploading operational licence documents).

3. Unit List Filtering and Search

Multi-criteria filtering: Supports filtering by unit type, affiliated region, unit status, and establishment date range;

Precise search: Enables searching by unit ID, unit name, or unit code keywords, with matching fields highlighted in search results ;

Advanced Filtering: Supports complex queries such as "Business scope includes 'equipment operation and maintenance'" or "Manager's mobile prefix is

138".

7.1.1.2.2 Manage departments and information within organisations

Supports department creation, adjustment, and information maintenance. Clearly defines department functions and responsible persons to achieve transparent hierarchical control ("organisation - department"), providing departmental-level support for subsequent user affiliation and permission allocation.

1. Department Information Attributes

Define core departmental information to ensure completeness and association with the organisation:

Basic Information: Department ID, Department Name (e.g., "Scheduling and Operations Department", "Equipment Maintenance Department", "General Administration Department"), Department Code (generated as "Unit Code - Department Sequence Number", e.g., "HD-001-001"), Parent Unit (select from approved units via dropdown, linked to Unit ID), Department Type (Business Department / Functional Department / Support Department);

Head Information: Department Head Name, Position (e.g., "Department Manager", "Supervisor"), Contact Details, Email Address, Areas of Responsibility;

Functional Information: Department function description (e.g., "Responsible for daily operation, maintenance, and fault resolution of power dispatch equipment in the North China region"), primary responsibilities (listed as bullet points, e.g., "1. Equipment inspections; 2. Fault troubleshooting; 3. Generation of operation and maintenance reports"), associated business systems (e.g., "Power Monitoring System", "Equipment Management System");

Status Information: Department status (Active / Cancelled / Merged), creation date, last modification date, reason for modification (e.g., "Merged with

'Equipment Inspection Department' due to business integration").

2. Department Operational Functions

Basic Operations: Supports "Add", "Edit", "Delete", "View Details"; operation permissions controlled by role (e.g. unit administrators may add departments within their unit, system administrators may operate on all unit departments);

Add Department: Select affiliated unit from dropdown menu, complete department details, submit for immediate effect (no review required as departments belong to units already approved), simultaneously generating department code (automatically concatenating unit code and sequence number);

3. Department Adjustments:

Affiliation Adjustment: Supports transferring a department from Organisation A to Organisation B (requires Organisation B's status to be "Operational"). The department code automatically updates post-adjustment (e.g., from "HD-001-001" to "HD-002-001"), synchronously updating organisational tree hierarchy;

Status Adjustments: Department dissolution/merger requires specifying the reason for adjustment. Upon dissolution, users under the dissolved department are automatically assigned to "Pending Assignment" status (requiring administrator reassignment to other departments). Mergers require selecting the target department (merging the current department's users and functions into the target department).

Batch Operations: Supports bulk export of department lists (filtered by unit before export) and bulk adjustment of department heads (e.g., replacing all department heads within a unit by importing new head details via Excel).

4. Department Information Maintenance and Synchronisation

Information Updates: Changes to department heads, functional descriptions, etc., synchronise in real-time with the "User Account Management" module (e.g., when a department head changes, the "Direct Supervisor" field for that department's users is automatically updated).

Associated Synchronisation: Changes to business systems associated with a department are synchronised to the "Application Management" module, ensuring that users within that department can only access the associated business systems ( );

Logging: All department operations (additions/adjustments/deletions) generate activity logs detailing the operator, timestamp, and changes made. Logs are retained for one year and support querying and exporting.

7.1.1.2.3 Enable collaborative management of components and departments

Define the relationship between "components" (functional teams/specialised task forces within the power system) and departments. Support component creation, affiliation adjustments, and list management to achieve comprehensive coverage of the three-tiered "unit-department-component" structure. This fulfils team management requirements for specialised power system operations (e.g., fault repair, equipment inspection).

1. Component Definition and Attributes

A component is a temporary or permanent team established within the power system to execute specific specialised operations (e.g., "High-Voltage Equipment Inspection Team", "Typhoon Fault Repair Team"). Core attributes include:

Basic Information: Component ID, Component Name, Component Code (generated as "Department Code - Component Sequence Number", e.g., "HD-001-001-001"), Component Type (Permanent Component / Temporary Component; temporary components require validity period configuration), Affiliated

Department (select from active departments via dropdown, linking to department ID);

Responsible Person Information: Component Responsible Person Name, Position (e.g., "Team Leader", "Deputy Team Leader"), Contact Details, Affiliated Department (matches the component's affiliated department and cannot be modified);

Member Information: Component members (multiple selection of users belonging to the department, supports bulk addition/removal), member role (Team Leader/Deputy Team Leader/Ordinary Member), member joining date;

B usiness Information: Component function (e.g., "Responsible for quarterly inspections of 110kV and above high-voltage equipment in the North China region"), associated business (e.g., "Equipment Inspection Business", "Fault Repair Business"), status (Active / Dissolved), validity period (for temporary components only, e.g., "25 October 2025 to 31 December 2025").

2. Component and Department List Management

List Display: The front-end employs a hierarchical "Department - Component" list display. Department lists (grouped by affiliated organisation) appear first; clicking a department expands its component list. Component list fields include: Component ID, Name, Code, Type, Responsible Person, Status, Validity Period.

Filtering: Supports filtering by department name, component type, component status, and validity period range.

Search Functionality: Enables keyword searches by component name, code, or responsible person's name, with search results highlighted.

3. Component Operations

Basic Operations: Supports "Add", "Edit", "Delete", "Dissolve", and "View

Details" for components. When adding a new component, select the affiliated department and generate a component code;

Member Management: Clicking the component's "Member Management" button opens a pop-up window supporting:

Batch Add: Select users from the department via dropdown (only displays users in normal status within that department), assign member roles;

Batch Removal: Select members and remove them with one click. A reason must be provided (e.g., "Member transferred to another component");

Role Adjustment: Modify member roles (e.g., changing a regular member to deputy group leader). Changes synchronise with user permissions (e.g., deputy group leaders gain approval rights within the component);

4. Status Management

Temporary Components: Seven days prior to expiry, the system automatically sends reminders (SMS/email) to the component lead and department administrator. Upon expiry, the status automatically changes to "Dissolved", with members reverting to their original departments.

Permanent Components: Dissolution requires specifying a reason. Upon dissolution, members revert to their original departments, the component status changes to "Dissolved", and component information is retained (read-only, not editable).

5. Component-Department Synergy

Permission Coordination: Component members' permissions = Departmental base permissions + Component-specific permissions (e.g., members of the "High-Voltage Equipment Inspection Team" possess "High-Voltage Equipment Inspection Data Viewing" permissions in addition to their departmental operational maintenance rights);

Business Collaboration: Business data associated with components (e.g., inspection reports, emergency repair records) is automatically linked to the affiliated department. Department administrators can view business data for all components within their department.

Statistical Collaboration: Supports generation of "Department - Component" statistical reports displaying component counts per department, proportions of temporary/permanent components, and component member numbers, assisting administrators in optimising component configuration.

7.1.1.2.4 Visualised organisational structure management

Presents the three-tiered "Unit - Department - Component" structure as a visual tree diagram. Supports hierarchical adjustments, node operations, exporting, and printing of the organisational tree, enabling "clear at a glance, intuitive management" of the organisational structure. Provides visual support for user affiliation and permission allocation.

1. Hierarchical Structure of the Organisation Tree

The organisational tree employs a fixed three-tier hierarchy:

Level 1 nodes: Units (only displays units with status "Operating normally" or "Under preparation"; units with status "Deregistered" or "Ceased operations" are hidden);

Secondary Nodes: Departments (only displays departments belonging to primary nodes with status "Normal"; departments with status "Revoked" or "Merged" are not displayed);

Level 3 Nodes: Components (only displays components belonging to Level 2 departments with status "Active"; components marked "Dissolved" are not displayed);

Node Display Information:

Unit Node: Unit Name (with unit type in parentheses, e.g., "North China Power Dispatch Centre (Headquarters)"), Name of Responsible Person;

Department node: Department name (with department type in brackets, e.g., "Dispatch Operations Department (Business Department)"), responsible person's name;

Component node: Component name (with component type in parentheses, e.g., "High-Voltage Equipment Inspection Team (Fixed Component)"), responsible person's name, number of members (e.g., "(5 persons)").

Organisational Tree Operations Functionality

Basic Operations: Supports "Expand/Collapse" (default fully collapsed; click the node's preceding "+" to expand, "-" to collapse; provides "Expand All" and "Collapse All" buttons), "Node Click" (clicking a node displays its details on the right—e.g., unit nodes show organisational information, department nodes display departmental details);

Node Editing: Supports direct node name editing within the organisational tree (double-click node name to open edit box; submit after modification). Only names can be edited here; other details require entering the node's information page.

Node Movement: Supports dragging nodes to adjust hierarchy (only permitted between nodes of the same level or adjacent levels):

Unit nodes: Non-movable (top-level nodes are fixed with no parent);

Department Nodes: May be reordered within the same unit (e.g., moving "Scheduling & Operations Department" from position 1 to position 2 under the unit), or transferred to other units (provided the target unit's status is "Operating Normally");

Component Nodes: May be rearranged within the same department or transferred to another department (provided the target department status is

"Normal");

Upon dragging, the system automatically updates the node's parent ID (e.g., when a department moves to a new unit, the unit_id in the org_department table is updated) and its code (e.g., the department code changes from "HD-001-001" to "HD-002-001");

Node deletion: Supports removal of organisational tree nodes (departments and component nodes only; unit nodes cannot be deleted). Requires double confirmation before deletion (e.g., "Deleting 'Equipment Inspection Department' will synchronously remove all subordinate components. Confirm?"). Post-deletion, node status changes to "Revoked" (department) or "Dissolved" (component) and is no longer displayed in the organisational tree.

2. Visual Enhancements to the Organisational Tree

Node Styling: Distinct colours and icons denote different statuses/types:

Unit nodes: Headquarters (red icon + red text), Branch offices (blue icon + blue text), Subsidiaries (green icon + green text), Operations stations (yellow icon + yellow text);

Department nodes: Business departments (orange icon), functional departments (purple icon), support departments (grey icon);

Component Nodes: Fixed Components (black icon), Temporary Components (pink icon);

H ighlighting: When hovering over a node, its background colour fades (e.g., light grey) to facilitate identification of the currently selected node;

Search and navigation: A search bar at the top of the organisational tree supports keyword searches by unit/department/component name. Matched nodes are automatically highlighted and their parent nodes expanded (e.g., searching for "Scheduling" highlights all nodes containing "Scheduling" in their names, while their parent unit/department nodes automatically expand).

3. Organisation Tree Export and Printing

Export Functionality: Supports exporting the organisational tree as an image (PNG/JPG) or PDF format:

Image Export: Exports based on the currently displayed scope of the organisational tree (all expanded nodes are shown; collapsed nodes display only the top level). Supports configuring image resolution (default 1920×1080, optional 1280×720 or 2560×1440).

Export PDF: Automatically paginate to display the complete organisational tree (preventing node truncation). The PDF header displays "Power System Organisational Structure Diagram", while the footer shows the export date and exporter.

Printing Functionality: Supports direct printing of the organisational tree. During print preview, users may configure print scope (all nodes / currently displayed nodes), paper size (A4/A3), and orientation (portrait / landscape). Printed content mirrors the exported PDF.

4. Organisational Tree Permission Control

Viewing Permissions: Control organisational tree visibility by role:

System Administrator: View all organisational units, departments, and component nodes;

Regional Administrator: View all units, departments, and component nodes within their assigned region;

Unit Administrator: View their own unit and subordinate departments/component nodes;

Department Administrator: View their department and subordinate component nodes;

Standard Users: View only their own department and component nodes;

Operational Permissions: Only System Administrators, Regional Administrators, and Unit Administrators possess permissions to edit, move, or delete nodes. Department Administrators only possess operational permissions for their department's component nodes. Regular Users possess no operational permissions.

7.1.1.3 Functionality for managing role lists and user account lists

Role and user account management implements a permission model of "role-based authorisation and user-to-role mapping" through standardised role definitions and centralised user control. This ensures users possess only the minimum privileges required for their duties, thereby safeguarding system security.

7.1.1.3.1 Manage Role Lists

Establishes a standardised role framework for power systems, supporting role creation, permission allocation, and status management. Enables flexible adaptation to either "one role per position" or "multiple roles per position" models, providing a standardised framework for user permission assignment.

1. Role Classification and Attributes

Roles are categorised into four major groups based on power system functional responsibilities, with core attributes defined as follows:

Core role attributes include:

System Management: e.g., "System Administrator", "Parameter Administrator", "Security Administrator" – responsible for underlying system configuration and security controls;

Organisational Management: e.g., "Regional Administrator", "Unit Administrator", "Department Administrator", responsible for organisational structure and user affiliation management;

Operational Role: e.g., "Operations and Maintenance Operator," "Dispatcher," "Equipment Inspector," responsible for daily operational tasks;

Read-Only Query: e.g., "Report Viewer", "Log Viewer", "Data Analyst", possessing solely data viewing permissions without operational privileges.

Basic Information: Role ID, Role Name (named according to "Category - Function", e.g., "System Management - System Administrator", "Business Operations - Operations Maintenance Operator"), Role Code (generated according to "Category Code - Sequence Number", e.g., "XM-001", "YW-001"), Role Category (select from four main categories via dropdown).

Permission Information: Permission description (e.g., "System Administrator: Possesses operational permissions for all modules"), associated permissions (permission items linked to the "Delegation of Authority" module, such as "System Parameter Modification Permission" and "User Deletion Permission");

Status Information: Role status (Enabled / Disabled), creation date, last permission update date, creator (default: current logged-in user), remarks (e.g., "For headquarters system administration only; not to be used by branches").

2. Role Operations

Basic Operations: Supports "Add", "Edit", "Delete", "Enable/Disable", "View Details"; Permission-controlled operations (only "System Administrators" may manage system administration roles; "Regional Administrators" may manage organisational administration roles within their designated region);

Role Creation Process:

Complete basic information: Select role category, enter role name and remarks; the system automatically generates a role code.

Assign Permissions: Navigate to the permissions allocation page. The left pane displays the permissions tree (categorised by module, e.g., "System Parameter

Settings," "Organisational Chart Management"), while the right pane shows selected role permissions. Tick desired permissions and submit.

Submit for activation: New roles default to "Enabled" status and take effect immediately upon submission, ready for user role assignment;

Permission update: Click the role's "Permission Update" button to re-enter the permission allocation page. Modify selected permissions (supports adding/removing permissions). Changes take effect immediately upon submission, automatically synchronising user permissions for roles assigned to this role;

Role Duplication: Supports replicating existing roles (click "Duplicate", enter new role name, other details default to original role). Permissions may be modified post-duplication to reduce repetitive configuration (e.g., duplicate "Operations Technician" role, modify select permissions to create "Senior Operations Technician").

Status Management: Disabling a role requires specifying a reason (e.g., "Role function obsolete, replaced by 'Senior Operations Operator'"). Once disabled, the role cannot be assigned to new users, though existing users retain their permissions (requiring manual role adjustment). Re-enabling a disabled role requires no reason and takes effect immediately.

3. Role Batch Operations and Queries

Batch Operations: Supports batch enabling/disabling roles (select multiple roles and click "Batch Enable"/"Batch Disable"), and batch exporting role lists (exported to Excel, including all role attributes and associated permission names);

Query and Filtering: Supports filtering by role category, role status, and creation time range. Enables searching by role name, code, or keywords. Search results are grouped by role category (e.g., System Management, Organisation Management, etc.).

7.1.1.3.2 Manage Account List

Establishes a unified ledger for all users within the power system, supporting user account creation, status management, role assignment, and bulk operations. Enables full lifecycle control of users "from creation to deactivation", ensuring account security and permission compliance.

1. User Account Attributes

Define core user account information covering identity, affiliation, permissions, security, and other dimensions:

Identity Information: User ID, Username (generated as "Department Code - Initials of Full Name", e.g. "HD-001-LS"; customisation permitted, must be unique), Full Name, Gender, Date of Birth, National ID Number (optional, used for identity verification), Contact Details (Mobile Number, must be unique and format verified), Email Address (must be unique and format verified);

Affiliation Information: Affiliated Organisation (select from normal status organisations via dropdown), Affiliated Department (select from normal departments under affiliated organisation via dropdown), Affiliated Component (optional, select from normal components under affiliated department via dropdown), Direct Supervisor (select from users in affiliated department via dropdown, used for approval workflows);

Permission Information: Associated Roles (multiple selection of enabled roles; user permissions = union of all role permissions), Permission Scope (data access rights, e.g. "View only departmental data", "View all data within assigned region", "View system-wide data");

Security Information: Account Status (Active / Locked / Disabled / Deactivated), Password Status (Initial Password / Modified), Last Login Time, Last Login IP, Last Login Device (e.g., "Windows Chrome"), Account Expiry Date (optional, e.g., "25 October 2025 to 25 October 2026", automatically disabled upon expiry);

Additional Information: Creation date, creator, remarks (e.g., "Newly recruited operations personnel in 2025, 6-month probationary period").

2. User Account Management Functions

Basic operations: Supports "Add", "Edit", "Delete", "View Details", "Enable/Disable", "Unlock". Operational permissions are role-based (e.g., system administrators can manage all users, while unit administrators can only manage users within their unit);

New User Creation Process:

Complete identity details: Enter full name, mobile number, and email address. The system automatically generates a default username (editable) and sets an initial password (default "Power@123", which users must change upon first login).

Select affiliation details: Select organisation and department from dropdown menus; optional selection of component affiliation and direct supervisor;

Assign roles and permission scope: Select multiple enabled roles and choose data access permissions (e.g., "View only departmental data");

Configure security settings: Optionally set account validity period. Default account status is "Normal", password status is "Initial Password";

Submit for activation: Upon submission, the user account is successfully created. The system automatically sends an SMS/email notification to the user (containing username, initial password, and login address);

Status Management:

Lock: Account automatically locks after 5 consecutive incorrect password attempts (default lock duration: 1 hour, configurable at). Administrators may manually unlock (click "Unlock" button, no reason required);

Disable: Administrators may disable user accounts (requiring a reason, e.g., "User has left the organisation, temporarily disabled"). Disabled accounts cannot be logged into, but account information is retained;

Deactivation: Upon employee departure, administrators may deactivate accounts (requiring a deactivation reason, e.g., "Employee has left the company, permanently deactivated"). After deactivation, the account status changes to "Deactivated", cannot be reactivated, and only account information can be viewed.

Role Adjustment: Click the user's "Role Adjustment" button to reselect associated roles. Upon submission, user permissions update in real time (synchronously updating user permissions cached in Redis).

Affiliation Adjustment: Supports modifying a user's affiliated unit/department/component (provided the target unit/department/component status is active). Following adjustment, the user's data permission scope automatically synchronises (e.g., transferring from Department A to Department B changes data permissions to "View Department B data only").

3. Batch User Account Operations

Bulk Import: Supports importing multiple users via Excel template (template includes mandatory field descriptions and examples, e.g., username, full name, mobile number). The system validates data legitimacy prior to import (e.g., username uniqueness, mobile number format). Upon successful validation, users are created in bulk; failed entries generate error reports (e.g., "Mobile number 13800138000 already exists, import failed").

Bulk Export: Supports filtering users by affiliated organisation/department/role before exporting in bulk to Excel. Exported content includes all user attributes;

Batch operations: Supports batch role assignment (select multiple users, choose role, assign in bulk), batch deactivation (select multiple users, enter unified deactivation reason, deactivate in bulk), and batch validity period setting (select multiple users, set unified validity period, update in bulk).

4. User Account Query and Filtering

Multi-dimensional filtering: Supports filtering by affiliated unit, affiliated department, account status, role, and account validity period range;

Precise Search: Enables keyword searches by username, full name, mobile number, or user ID with real-time results display;

Advanced filtering: Supports filtering by "Last login time > 3 months" (long-inactive users), "Password status = Initial password" (users who haven't changed their initial password), and "Permission scope = Full system data" (high-privilege users), helping administrators identify risky accounts.

7.1.1.3.3 Manage Detailed Account Information

Provides a "comprehensive information view" for each user, enabling viewing, editing, and supplementing of user profiles. Records user operation logs and security information to ensure data completeness and accuracy, serving as a basis for identity verification and permission tracing.

1. Account Details Display

Clicking the "View Details" button in the user list opens the account details page. Tabs are used to organise multiple sections displaying comprehensive information:

Basic Information Tab: User ID, username, real name, gender, date of birth, ID number (partially masked, e.g., "110101******** 1234"), Contact Details (mobile number, email address partially obscured, e.g. "ls****@power.com"), Emergency Contact (name, mobile number, optional), Start Date, Position Title (e.g. "Operations Engineer", "Dispatch Specialist");

Affiliation Information Tab: Affiliated Unit (Name + Code), Affiliated Department (Name + Code), Affiliated Component (Name + Code, displays "None" if absent), Direct Supervisor (Full Name + Username), Departmental Role (e.g., "Department Head", "Regular Staff"), Affiliation Adjustment History (Last 5 adjustments, including Pre-adjustment Affiliation, Post-adjustment Affiliation, Adjusting Party, Adjustment Date, Reason for Adjustment);

Permissions Information Tab: Associated Roles (Role Name + Category; clicking the role name displays detailed role permissions) Permission Scope (Data access scope, e.g., "View only departmental data", with permission details such as "May view departmental equipment maintenance data and fault records; may not view other departments' data") Special Permissions (e.g., "Temporary Permission: Emergency Device Operation Permission, valid until 25 November 2025"), Permission Change Log (last 5 permission modifications, including pre-change role, post-change role, operator, and modification time);

Security Information Tab: Account status, password status, last login time, last login IP, last login device, login logs (last 10 login records including time, IP, device, outcome), password modification history (last 5 changes including time, operator (user/administrator)), account lockout history (last 3 lockouts including time, unlock time, unlock operator) ;

Other Information Tab: Creation date, creator, notes, attachments (e.g. employment verification, scanned qualification certificates; supports upload/download/delete, administrator-only access).

2. Account Information Editing Functionality

Editing Permissions: Permissions vary by tab:

Basic Information: Users may edit contact details, emergency contacts, and job title; administrators ( ) may edit all basic information (excluding username and user ID);

Affiliation Information: Only administrators may edit affiliated organisation/department/unit, direct supervisor, and departmental role. Edits generate affiliation adjustment records;

Permissions Information: Only administrators may edit associated roles, permission scopes, and special permissions. Edits generate permission change records.

Security Information: Only administrators may edit account status (enabled/disabled/deactivated) and unlock accounts. Users may view security details but cannot edit them;

Other Information: Users may edit notes themselves; administrators may edit notes and upload/delete attachments;

Editing Process: Click the "Edit" button on the tab to enter edit mode. Modify the relevant fields and submit. Upon submission, the details page information is updated in real-time, and an operation log is generated (recording the editor, edit time, and change content).

Field validation: Field validity checks occur during editing (e.g., mobile number format, email format, ID number format). Failed validation triggers error messages (e.g., "Invalid mobile number format. Please enter 11 digits") and prevents submission.

3. Account Information Linking Functionality

Identity Verification Linkage: ID numbers and mobile numbers in basic information are used for "password recovery" and "identity verification" (e.g., mobile verification codes for sensitive operations).

Permission Association: The department affiliation in ownership details and the associated role in permission details jointly determine the user's data access and functional permissions (e.g., a user belonging to Department A with the Operations Operator role can only perform operations within Department A's maintenance functions and view Department A's maintenance data);

Log Association: All account data operations (edits, affiliation adjustments, permission changes) are linked to the "System Operation Log" module. This supports querying all operation records by user ID, enabling end-to-end traceability.

4. Account Information Export and Printing

Export Functionality: Supports exporting account details to PDF format. PDFs are paginated by tabs, displaying "User Account Details - Username: XXX" in the header and the export date/user in the footer.

Printing Function: Supports direct printing of account information. During print preview, selectable tabs (e.g., printing only basic information or attribution details) are available, with configurable paper size and orientation.

7.1.1.4 Decentralised Permissions

Permission Delegation (Authorisation Allocation) Through a three-tier mapping relationship of "Permissions - Roles - Users", precise allocation and control of permissions are achieved. This ensures users possess only the minimum privileges required for their tasks, adhering to the "Principle of Least Privilege" to safeguard system security.

7.1.1.4.1 Delegating permissions to roles

1. Permissions Framework Definition

A four-tier permission system is established according to the power management subsystem modules, encompassing "Module - Submodule - Function - Operation" to cover all system functionalities:

Core permission attributes include:

Level 1 Permissions (Module): e.g., "System Parameter Configuration", "Organisational Chart Management", "Role/User Management" , "Delegation of Authority", "Application Management", "Session Management";

Level 2 Permissions (Submodule): e.g., "Manage Configuration List", "Manage Configuration Details", "Manage Impact History" under "System Parameter Settings";

Tier 3 Permissions (Function): e.g., under "Manage Configuration List": "View Parameters", "Filter Parameters", "Export Parameters";

Level 4 Permissions (Operations): e.g., under "Parameter Viewing": "List View", "Detail View"; under "Parameter Filtering": "Multi-condition Filtering", "Fuzzy Search".

Permission ID, Permission Name (named according to "Module - Submodule - Function - Operation", e.g., "System Parameter Settings - Manage Configuration List - View Parameters - List View"), Permission Code (generated according to "Module Code - Submodule Code - Function Code - Operation Code", e.g., "CS-001-001-001");

Permission Type (Function Permission / Data Permission; Function Permission controls whether functions can be operated, while Data Permission controls which data can be operated upon);

Associated Module (the application/subsystem linked to the "Application Management" module, e.g., "System Parameter Settings" linked to the "Power Management Subsystem");

Permission Description (e.g., "List View: Permits viewing the system parameter configuration list"); Status (Enabled / Disabled; permissions cannot be assigned when disabled); Creation Date.

2. Permission Delegation (Assignment) Functionality

Permission Allocation Interface: Adopts a "left-hand role list + right-hand permission tree" layout. The left pane displays enabled roles (supporting filtering and searching by role category).

7.1.1.4.2 Manage permissions for other applications

1. Application Permission Registration: All applications requiring integration with the subsystem must register "Permission Interfaces" within the application management module. This defines functional permissions (e.g., "Switch Status Control" for SCADA systems) and data permissions (e.g., "Area Load Data" for EMS systems).

2. Permission mapping: The subsystem associates application permission interfaces with internal role permissions. For instance, the "Load Control" permission for the "Dispatcher" role is automatically mapped to the "Load Command Issuance" interface permission in the EMS system;

3. Single Sign-On (SSO): Upon logging into the subsystem, users receive a unified session token (JWT format, containing user ID, role permissions, and validity period). When accessing other applications, users need not re-authenticate but merely present the token. Applications verify the token's validity and permission scope by calling the subsystem's "Token Verification Interface"; upon successful verification, access is granted directly;

4. Permission Synchronisation Updates: When role permissions within the subsystem are adjusted (e.g., adding "Energy Storage Dispatch" permission for "Dispatchers"), these changes are automatically synchronised to associated applications, ensuring consistent cross-application permissions.

7.1.1.5 Application Management Functionality

Application Management establishes a unified three-tier directory structure of "Application - Subsystem - Function", enabling end-to-end lifecycle management from development to decommissioning. It also facilitates internal collaboration through a shared website.

7.1.1.5.1 Shared Website Development

Application Portal: Displays all deployed Web/App applications categorised by subsystem (e.g., Dispatch, Operations, Marketing). Users view accessible applications based on permissions and access them via SSO ( ) without repeated credentials entry.

Notifications & Announcements: System administrators publish operational notices (e.g., maintenance schedules, system upgrade announcements) and security alerts (e.g., cybersecurity risk advisories). Supports targeted distribution by department or role. Users may review historical notifications and mark items as read.

Document Sharing: Supports uploading technical documentation (e.g., equipment operating procedures, dispatch protocols, training manuals) and operational forms (e.g., maintenance work permit templates, fault report templates). Documents are categorised by type (technical, administrative, training) with configurable access permissions (e.g., "Public", "Department-only", "Designated roles only").

Version Management: Automatically logs version numbers upon document upload. Generates new versions upon updates (retaining historical versions). Users may download historical versions for comparison. Supports document commenting functionality — operations personnel may pose queries under equipment manuals, with technical experts providing online responses to build knowledge reserves.

Search and Analytics: Supports resource searches by document name or keywords, alongside analytics features (e.g., application access rankings, document download rankings), providing IT operations teams with insights for application optimisation.

7.1.1.5.2 Application List Management

1. Application Registration: Application developers (internal IT departments or external suppliers) log into the subsystem to complete application details: application name (e.g., "Power Inspection APP V2.0"), application type (Web/Android/iOS), development language (Java/Python), functional description (e.g., "Supports photographing and uploading equipment defects, inspection route planning"), interface documentation (data exchange specifications with other systems), and security compliance certificates (e.g., Level 3 Information Security Certification report).

2. Review Process: Upon receiving a registration application, the system administrator conducts a three-stage review:

Security Review: Verifies compliance with power system security standards (e.g., data encryption, SQL injection prevention, access controls), with penetration testing conducted where necessary;

Functional Review: Verifies whether application features align with business requirements and identifies potential functional overlaps (e.g., duplication with existing inspection systems);

Interface Review: Verify that interfaces with subsystems and other core systems comply with unified standards to ensure data interoperability;

3. Deployment and Release: Upon approval, the application enters a "Pending Deployment" status. The IT Operations department uploads the application package (APP) to the application portal on the shared website or configures the web application's access address, setting the application's "Visibility Scope" (e.g., visible only to the Operations department);

4. Operational Management: Supports application version updates (new

versions submitted by developers undergo repeated review before release), fault monitoring (real-time tracking of application access success rates and response times, with automated alert SMS to operations staff upon anomalies), and user feedback (users may submit usage issues via the application portal, with operations staff handling and replying online);

5. Decommissioning Process: When an application becomes obsolete (e.g., replaced by a new system) or poses significant security risks, the system administrator initiates a decommissioning request. Following confirmation by the business department, the application status is changed to "Decommissioned" and hidden from the application portal. Historical application data (e.g., user access logs) is retained for subsequent auditing.

7.1.1.5.3 Subsystem List Management

1. Subsystem Classification: Based on core power system operations, subsystems are categorised into six major groups:

Dispatch Management Subsystem: Incorporates load forecasting, dispatch instructions, grid topology analysis, and related functions;

Operations and Maintenance Management Subsystem: Includes equipment inspection, fault repair, maintenance planning, and related functions;

Renewable Energy Management Subsystem: Includes photovoltaic/wind power output monitoring and generation schedule reporting;

Marketing Management Subsystem: Incorporates functions including customer electricity metering, tariff settlement, and demand response;

Security Management Subsystem: Incorporates cybersecurity, operational auditing, and emergency response functions;

Integrated Management Subsystem: Includes functions such as human resources, financial reimbursement, and document circulation;

2. Subsystem Information Maintenance: Maintain core details for each subsystem: subsystem name, business domain affiliation, responsible officer (name + contact details), launch date, associated applications (e.g., Operations Management Subsystem linked to "Power Inspection APP" and "Equipment Management System"), data interfaces (e.g., load data interface with Dispatch Management Subsystem);

3. Association Management: Supports configuration of inter-subsystem dependencies. For instance, setting the "Operations Management Subsystem" to rely on the load data interface from the "Dispatch Management Subsystem". Should the dispatch subsystem's interface address change, it automatically synchronises with the operations subsystem, preventing data exchange failures. Additionally, supports permission inheritance. For example, the "New Energy Management Subsystem" can inherit the "Operational Audit" permission from the "Security Management Subsystem", eliminating duplicate configuration.

7.1.1.5.4 Function List Management

1. Function Definition: Maintain detailed information for each functional unit: function name (e.g., "Equipment Defect Registration"), affiliated subsystem (Operations Management Subsystem), function type (Query-based / Operational / Configuration), interface address (e.g., http://xxx/operation/defect/register), and operational logging requirements (whether to record operator, operation time, and operation content).

2. Enable/Disable Control: Upon completion of new feature development, initially set to "Test" status. Test personnel verify functionality and security. Upon successful verification, change to "Enabled" status to formally grant permissions. When a feature contains vulnerabilities or is superseded, change to "Disabled" status. This automatically unbinds

permissions for all roles, preventing erroneous operations.

3. Permission Binding: Once enabled, functions may be associated with role permissions. Within the decentralisation module, select corresponding functions for roles (e.g., bind "Equipment Defect Registration" and "Defect Handling Tracking" functions to the "Substation Operations and Maintenance Officer" role). Upon binding, users gain functional access rights through their assigned roles.

4. Dependency Management: For functions with dependencies (e.g., "Defect Handling Tracking" depends on "Equipment Defect Registration"), configure "Function Dependency Rules" — roles lacking "Equipment Defect Registration" permission cannot bind "Defect Handling Tracking" permission, preventing chaotic permission configurations. Additionally, when a dependent function is disabled, the dependent function automatically transitions to "Pending Approval" status, requiring re-evaluation before reactivation.

7.1.1.6 Session Management Functionality

7.1.1.6.1 System Login Management

1. Diversified Login Methods:

Basic Authentication: Username/password + SMS verification code (default for standard users). Verification codes remain valid for 5 minutes, with a maximum of 3 codes sent per mobile number within 1 hour.

Two-factor authentication: For critical roles such as administrators and dispatchers, login requires additional verification via Ukey (hardware token) or WeCom QR code scanning. Ukey supports domestic cryptographic algorithms (SM4) to ensure identity authenticity ( ).

Quick Login: Supports WeCom/DingTalk quick login (internal staff only). Integrates with WeCom/DingTalk via OAuth 2.0 protocol, eliminating the need to remember credentials. Automatically synchronises department information upon login.

2. Login Security Policies:

Password Strength Validation: Verifies passwords against policy requirements during login (minimum 8 characters, containing uppercase/lowercase letters, numbers, and special characters, and differing from the previous three passwords). Login is denied if criteria are not met.

Failed Login Lockout: Accounts automatically lock for one hour after five consecutive failed login attempts (manually unlockable by administrators) to prevent brute-force attacks.

Geolocation Login Detection: Based on the user's historical login IP (e.g., primary IP in Shanghai), if a login from an unusual location (e.g., Beijing IP) is detected, two-factor authentication is immediately triggered (requiring entry of a verification code sent to the bound mobile number), and an SMS alert is sent to the user;

3. Login Logging and Alerts:

Logging: Detailed records of each login including "User ID, login time, IP address, device information (operating system, browser version), login method, login result (success/failure reason)" are retained for one year for audit purposes.

Anomaly Alerts: Upon detecting high-frequency logins (multiple account attempts from the same IP within 10 minutes) or abnormal device logins (e.g., using unregistered devices), the system automatically pushes alert notifications to security administrators. Administrators can view alert details in real-time and block anomalous IPs if necessary.

7.1.1.6.2 System Logout Management

1. Active Logout:

When a user actively clicks the "Logout" button, the subsystem immediately terminates the current session (deleting session information from Redis), clears browser cookies (including session IDs), and records the logout time.

Support for "Simultaneous Multi-Device Logout": When a user initiates logout from a mobile device after logging in via computer, the system automatically synchronises and terminates all sessions across all terminals, preventing session persistence.

2. Passive logout:

Session timeout logout: Differentiated timeout settings by role — Administrator: 30 minutes, Dispatcher: 60 minutes, Standard User: 120 minutes. Sessions are automatically terminated upon expiry, requiring users to log in again;

Account Status Triggered Logout: Should an administrator set a user account to "Locked" or "Disabled" status, the system immediately logs out all the user's active sessions and rejects new login requests;

Abnormal Operation Triggered Logout: Upon detecting abnormal session activities (e.g., simultaneous operations from multiple IP addresses, high-frequency permission modifications), the system automatically initiates "Forced Logout", sends SMS alerts to the user, and logs the abnormal operations.

7.1.1.6.3 Password Management

1. Password Creation Policy:

Initial Password: Upon first login, the system sends a random initial password (8 characters, including uppercase letters, lowercase letters, and numbers) via SMS. Users must immediately change this initial password to use the system;

Password Strength Verification: During password modification, real-time strength indicators (Weak / Medium / Strong) are displayed. Only "Strong" passwords (e.g., Abc123!@#) may be submitted.

2. Password Usage Controls:

Password Encrypted Storage: User passwords are not stored in plaintext. Instead, they are encrypted using the BCrypt algorithm (with salt) before storage. Even if the database is compromised, passwords cannot be decrypted.

Prohibition of Plaintext Transmission: Passwords are transmitted via HTTPS encryption during login and modification to prevent man-in-the-middle attacks.

3. Password reset process:

Self-service reset: Forgotten passwords can be reset via verification code sent to the user's bound mobile number or email address. After successful verification, the password is reset, requiring re-login.

Administrator-assisted reset: Should users be unable to receive verification codes (e.g., due to mobile service suspension), they may submit a reset request (requiring submission of a staff ID photo). Upon administrator approval, a temporary password (valid for 24 hours) is generated and sent via the official work email address;

4. Password expiry management:

Periodic Renewal: Set password validity periods (90 days for administrators, 180 days for standard users). Seven days prior to expiry, the system will notify users via SMS/system messages to update their password.

Expiration Lockout: Accounts automatically lock if passwords remain unchanged after expiry. Unlocking requires password modification.

7.1.1.6.4 Session Lifecycle Management

1. Session Creation: Upon successful user login verification, the system generates a unique session ID (32-bit random string generated by ` `) and stores session details (session ID, user ID, role, creation time, timeout, status) in Redis. Simultaneously, a JWT token (containing session ID, user permissions, and

validity period) is returned to the user.

2. Session Maintenance:

Heartbeat Mechanism: When the user interacts with the application, the frontend sends a "heartbeat request" to the subsystem every 30 seconds. Upon receiving the request, the system updates the session's timeout value (resetting it to the initial timeout), preventing premature session expiry.

Session State Synchronisation: During multi-device logins, session status synchronises in real-time (e.g., extending the timeout on a desktop device automatically extends it on mobile devices);

Session Timeout: When user inactivity reaches the timeout threshold, the system automatically marks the session as "expired" and destroys session data (deleting Redis records and invalidating tokens). Upon receiving the timeout notification, the frontend automatically redirects to the login page;

3. Session destruction:

Active Destruction: Sessions are immediately destroyed upon user logout or administrator-enforced disconnection;

Batch Destruction: During system version updates or security vulnerability fixes, administrators may initiate a "Batch Destroy Sessions" operation, forcing all online users to re-authenticate to ensure system updates take effect.

4. Session Monitoring: Administrators may view real-time online session listings within the subsystem's "Session Monitoring Centre", displaying details including "User ID, Role, Login Time, IP Address, Device Information, and Session Remaining Time". Supports filtering by department or role, with the ability to enforce "Forced Logout" on anomalous sessions (such as remote logins or prolonged inactivity).

7.1.1.6.5 Account Authentication

1. Sensitive Operation Verification: When users perform sensitive operations (e.g., modifying role permissions, issuing dispatch instructions, altering device protection thresholds), the system automatically triggers secondary verification. Verification methods are risk-tiered: "Password Verification" (medium risk) or "Ukey Verification" (high risk). Operations proceed only upon successful verification.

2. Identity Information Maintenance Verification: When users modify personal details (e.g., binding mobile numbers or email addresses) or reset passwords, they must first verify the authentication code sent to the previously bound mobile number/email address. This prevents unauthorised individuals from modifying account information.

3. Cross-scenario identity verification: When users transition from non-sensitive scenarios (e.g., data viewing) to sensitive scenarios (e.g., device operation), the system automatically verifies the validity of the current session's permissions. If session permissions are insufficient, users must reapply for permissions and undergo identity verification.

7.1.1.6.6 Session Identification Tokens and Permission Management

1. Token Generation: Upon successful login, the system generates a JWT token. The token payload contains the following information:

Basic Information: User ID, Username, Department ID;

Permission Information: Role ID, Permission Scope (functional permission list, data permission scope);

Session Information: Session ID, token validity period (aligned with session timeout), issuance time;

The token employs RSA asymmetric encryption (private key issuance, public key verification) to ensure tamper-proof integrity;

2. Token Transmission: The token is stored locally in the frontend's localStorage (not via cookies, to prevent CSRF attacks). Upon each application access or action execution, it is transmitted via the HTTP request header (Authorisation: Bearer {token}) with all transmissions encrypted over HTTPS;

3. Token Verification: Upon receiving the token, the application invokes the subsystem's "Token Verification Interface". The verification process is as follows:

Decryption Verification: Decrypts the token using the public key to validate the signature's legitimacy (preventing tampering);

Validity Period Verification: Checks whether the token's current timestamp falls within its validity period (access denied if expired);

Permission Verification: Checks whether the requested operation (e.g., "Modify Device Parameters") falls within the token's authorised scope; if not, returns "Insufficient Permissions";

4. Token Refresh: When the token nears expiry (e.g., 10 minutes remaining), the frontend automatically invokes the "Token Refresh Interface". After verifying the current session's validity, the system generates a new token (resetting its validity period), immediately invalidating the old token to prevent frequent user logins;

5. Token Revocation: Upon user logout, account lockout, or session anomalies, the system adds the token to the "Revocation List" (stored in Redis with the same validity period as the original token). Even if the token remains unexpired, access is denied during verification if it is detected in the revocation list.

7.1.1.7 Grid and Telecommunications Network Map Management Functionality

Map management serves as the system's foundational support, integrating diverse base map data to construct a clear-layered, comprehensive geographic information foundation. Through base map layer functions, it enables operations such as loading, unloading, overlaying, and updating various layers, ensuring precise alignment between geographic information and specialised network data.

7.1.1.7.1 Base Map Layer Types and Data Characteristics

1. Raster Administrative Base Map Layer

Raster administrative base maps utilise a pixel matrix as their data carrier, encompassing multi-tiered administrative divisions including provinces, cities, counties, townships, and villages. They feature fundamental information such as administrative names, government seat locations, and boundary lines. Data originates from standard administrative maps published by the National Administration of Surveying, Mapping and Geoinformation, with resolution support ranging from 5 metres to 100 metres for multi-level adaptation. This accommodates administrative area positioning requirements across various scales. The layer supports dynamic loading, automatically retrieving raster tiles of corresponding precision based on the user's current viewport to ensure smooth display performance.

2. Vector Geospatial Base Layer

The vector geographic base layer employs point, line, and polygon vector data structures, encompassing elements such as roads (national, provincial, county, and rural roads), water systems (rivers, lakes, reservoirs), settlements (cities, villages, residential areas), and landmark buildings (hospitals, schools, large enterprises). Data formats are dual-supported in GeoJSON and Shapefile. Road features include attributes such as name, width, and classification, while settlement features are linked to foundational data like population size and building density. Vector layers support seamless zooming: higher zoom levels automatically display finer-grained features (e.g., internal residential roads), while lower zoom levels aggregate to macro-level area identifiers, preventing information overload.

3. Raster Geographic Base Layer

The raster geographic base layer emphasises natural geographic features, incorporating satellite remote sensing imagery and aerial photography. This layer visually presents topography (e.g., mountains, plains, basins), vegetation cover (forests, farmland, deserts), and surface building distributions. Data resolution is tiered according to regional significance: core urban areas support 0.5-metre high-definition imagery, while remote regions utilise 5-metre base imagery. Efficient storage and rapid retrieval are achieved through tile pyramid technology. This layer is primarily employed in scenarios requiring consideration of natural environments, such as power line route selection and base station siting.

4. Terrain Base Map Layer

Constructed from a Digital Elevation Model (DEM), this layer displays elevation and topographic contours through contour lines, gradient colour scales, and 3D rendering. Supporting 10-metre to 100-metre grid resolutions, it includes elevation values, gradient, and slope aspect attributes. This layer facilitates analysis of power line installation challenges (e.g., mountainous route construction cost estimation) and telecommunications signal coverage gaps (e.g., valley shadowing areas). It supports 2D/3D switching, with the 3D mode enabling intuitive viewing of terrain topography through perspective rotation.

5. National and Administrative Boundary Map Layer

The boundary layer employs high-precision vector data strictly adhering to national surveying standards, encompassing multiple tiers of boundary lines including national, provincial, municipal, and county borders. Line feature attributes record boundary type, approval document numbers, and managing authorities. To ensure data authority, boundary information interfaces directly with the National Geographic Information Public Service Platform for regular synchronised updates. The layer supports boundary highlighting, enabling users to query basic administrative area information (such as area, population, and economic data) by clicking on boundary lines. It also incorporates a boundary protection mechanism that prohibits unauthorised editing operations.

6. Transport Map Layer

The Transport layer focuses on transport features relevant to power grid and telecommunications network operations, including motorways, railways, waterways, bridges, and tunnels. Feature attributes cover traffic flow, access restrictions (e.g., height/weight limits), and maintenance status. Data interfaces in real-time with transport authority APIs, dynamically updating information on roadworks and congestion to provide route guidance for emergency vehicle dispatch. For instance, during power grid failures, the system can automatically bypass congested sections using the transport layer to reduce repair response times.

7. Population Map Layer

The population layer displays data such as population density, age structure, and electricity/telecommunications demand at a vector grid resolution of 1km × 1km. It visually presents population distribution characteristics through heatmap rendering (red indicating high density, blue indicating low density). Data is derived from integrated analysis of census results and operator user data, with foundational data updated annually and dynamic population flow information (e.g., holiday migration patterns) refreshed monthly. This layer primarily supports grid load forecasting (requiring increased supply capacity in densely populated areas) and telecommunications base station planning (enhancing base station density in high-demand zones).

7.1.1.7.2 Core functions for base map layer management

1. Layer Loading Function: Supports batch loading of layers by region, accuracy, and type. Preset scenario-based layer combinations such as "Power Grid Operations" and "Telecom Planning" enable one-click access to commonly used layers.

2. Layer Overlay Function: Enables hierarchical overlay of different layer types (e.g., vector administrative base map + raster remote sensing imagery), with adjustable layer transparency (0-100%) to prevent feature masking;

3. Layer update function: Integrates with real-time data source interfaces. Automatically detects and incrementally updates when base map data changes (e.g., new roads, administrative boundary adjustments), ensuring data timeliness;

4. Layer Caching Function: Locally caches frequently accessed layer data (e.g., core urban base maps) to reduce redundant downloads and enhance loading speed (cache validity configurable, default 7 days);

5. Layer query function: Supports querying layer features by spatial location (e.g., box selection, point selection) or attribute conditions (e.g., "Find roads containing 'XX Road' in their name"), returning feature details and associated data.

7.1.1.7.3 Power Grid and Telecommunications Network Layer Functionality

The power grid and telecommunications network layer serves to display the physical structure, operational status, and relevant service data of electricity and communications networks, enabling "network visualisation" management. Layer data integrates with real-time monitoring systems and service management systems, supporting dynamic updates and multi-dimensional analysis.

7.1.1.7.3.1 Power Grid Data Layer

1. High-Voltage Grid Data Layer

Covers power grid facilities at 110kV and above voltage levels, including substations (name, capacity, commissioning date), transmission lines (type, length, transmission power), pylons (type, height, coordinates), and circuit breakers (status, model). Transmission lines are represented by red line features, while substations are shown as blue point features. Line width differentiates transmission capacity (greater width indicates higher capacity). This layer interfaces with SCADA (Supervisory Control and Data Acquisition) systems to display real-time operational parameters including line current, voltage, and power factor. When parameters exceed thresholds, affected lines automatically flash to indicate an alert.

2. Medium-voltage grid data layer

Focuses on the 10kV-35kV voltage level distribution network, encompassing distribution substations, ring main units, branch boxes, distribution lines, and other elements. Element attributes include line installation method (overhead/cable), user type (industrial/residential), and load factor. Medium-voltage lines are represented by yellow line features, while ring main units are indicated by green point features. Supports display range segmentation by supply transformer district. The layer interfaces with distribution automation systems to display real-time load distribution. Upon detecting transformer district overloads, it automatically flags affected areas and issues alert notifications.

3. Low-voltage grid data layer

This layer displays the user-side grid at 0.4kV and below, encompassing low-voltage lines, distribution boxes, meter boxes, and user access points ( ). It links to user information (name, address, electricity consumption) and line loss rates. Grey line features denote low-voltage lines, while black point features represent meter boxes. Display can be refined by street or residential area. This layer primarily serves meter reading route planning and low-voltage fault location (e.g., determining user power outage scope). Clicking on an electricity meter box enables rapid retrieval of user electricity consumption history and payment status.

4. Grid Operational Status Layer

This layer dynamically renders the grid's real-time operational status using colour-coded indicators. Status levels are defined by metrics including load factor, voltage compliance rate, and supply reliability: green denotes "Normal" (load factor < 70%), yellow indicates "Alert" (70% ≤ load factor < 90%), and red signifies "Emergency" (load factor ≥ 90% or voltage anomalies). The layer updates data every 5 minutes and supports time-based playback (e.g., reviewing status changes over the past 24 hours), aiding dispatchers in analysing load fluctuation patterns. Additionally, it can overlay meteorological layers (e.g., high temperatures, heavy rainfall) to assist in assessing the impact of extreme weather on grid operations.

5. Grid Fault Layer

Displays real-time grid fault information, including fault type (short circuit, broken line, equipment damage), occurrence time, affected area, and resolution progress. Unresolved faults are indicated by flashing orange dots, faults under resolution by blue dots, and resolved faults by grey dots. The radius of fault points expands proportionally to the number of affected users. This layer interfaces with the fault repair system, automatically synchronising repair personnel locations and estimated restoration times. Clicking a fault point reveals detailed information (such as protection action logs and on-site images) alongside the associated repair work order, enabling end-to-end visualisation from fault detection to closure.

6. Grid Operations Personnel Layer

Displays real-time locations, assigned teams, contact details ( ), and current tasks for grid operations personnel (e.g., repair technicians, patrol officers). Different coloured human icons distinguish personnel types (red for repair personnel, blue for patrol officers). This layer interfaces with personnel positioning systems (GPS/BeiDou), achieving 5-metre accuracy. It supports querying personnel trajectories (past 24-hour movement paths) and work statuses (idle/busy). During faults, the system rapidly filters the nearest available personnel via this layer, automatically dispatching task notifications to enhance repair response efficiency.

7.1.1.7.3.2 Telecommunications Network Layer

1. Optical Cable Routing Layer: Displays trunk and access fibre optic cable routes, annotated with cable model (e.g., GYTA-24B1), core count, installation method (duct/direct burial/aerial), and operator ownership. Cable types are distinguished by line feature colour (blue for trunk cables, grey for access cables).
2. Base Station Layer: Includes macro base stations, micro base stations, and indoor distribution systems. Displays location data alongside base station model, coverage radius (500m–3km), signal strength (4G/5G), and operational status (active/decommissioned). Represented by signal tower icons, with decommissioned stations highlighted by flashing red indicators.
3. Equipment Room / Data Centre Layer: Displays locations, floor areas, power supply methods (mains / backup power), and supported services (core network / transport network) for telecommunications equipment rooms and data centres. Supports viewing equipment inventories (e.g., switches, servers) and real-time temperature/humidity data;
4. Telecom Service Layer: Displays broadband and 5G user coverage by grid cell, using heatmap colour intensity to indicate service density, aiding prioritisation of service expansion.

7.1.1.7.4 Professional Layer Interaction Features

1. Layer Interlinking: Supports synchronised display of power grid and telecommunications layers. For instance, when viewing high-voltage lines in a specific area ( ), telecommunications base stations within a 500-metre radius are automatically displayed to analyse potential signal interference risks from the lines;

2. Feature-linked Query: Clicking any power grid/telecom feature (e.g., substation) automatically displays associated facilities (e.g., incoming/outgoing lines, adjacent base stations) and historical data (e.g., fault records from the past three years);

3. Custom layers: Users may create temporary layers (e.g., "Key Inspection Areas") based on operational requirements, supporting manual polygon drawing and annotation. Temporary layers can be saved to personal workspaces or shared with teams.

7.1.1.7.5 Standard Map Operations

7.1.1.7.5.1 Map Zoom Control

Multi-level zooming: Supports seamless scaling from 1:500 to 1:1,000,000 scale. Quick-access buttons for common scales (e.g., 1:10,000, 1:50,000) enable instant navigation to corresponding views.

Zoom Methods: Four methods provided to suit different scenarios: mouse wheel scrolling, double-click zoom, box selection zoom (automatically enlarges selected area to full screen), and gesture zoom (pinch/spread gestures supported on touchscreen devices);

Zoom Restrictions: Scaling range configurable based on layer data precision (e.g., raster remote sensing imagery supports up to 1:2000 zoom), preventing data distortion from excessive magnification;

Zoom memory: Automatically records the user's last 10 zoom operations, supporting one-click jumps to "Return to previous view" and "Return to initial view".

7.1.1.7.5.2 Rotation Control

Rotation Methods: Supports mouse drag rotation (right-click and drag), keyboard shortcuts (left/right arrow keys for counterclockwise/clockwise rotation), and angle input (directly enter rotation angles 0-360°);

Rotation Assistance: Displays a true north indicator (permanently oriented towards the top of the screen) during rotation. Includes a "Reset to True North" button for rapid restoration of the default perspective.

Adaptive Optimisation: During rotation, layer features (e.g., lines, text annotations) automatically orient with the view to ensure displayed direction aligns with actual geographic orientation, preventing visual confusion.

7.1.1.7.5.3 Measurement Controls

- Distance Measurement: Supports straight-line distance (between two points) and path distance (multi-point connection) measurement. Units switchable between metres, kilometres, and feet. Accuracy up to 0.1 metres. Measurement results automatically annotated alongside the path.
- Area Measurement: Calculates area by selecting polygonal regions, with units in square metres, hectares, or mu. Suitable for scenarios such as estimating substation land acquisition requirements or calculating base station coverage areas.
- Elevation Measurement: Integrates with topographic base maps to measure elevation differences between two points, displaying gradient values (percentage/degrees) to assist in assessing terrain difficulty for line laying;

- Measurement Tools: Results can be saved as text or images, exported locally (in TXT or PNG formats), or directly added to map annotations.

7.1.1.7.5.4 Printing Controls

- Printing Scope: Supports full-screen printing, selected area printing, and printing by administrative region (e.g., selecting "XX County" automatically prints that county's boundaries);
- Format Settings: Selectable paper size (A4, A3, custom), orientation (landscape/portrait), and resolution (150dpi/300dpi). 300dpi is recommended for high-precision hardcopy output.
- Content Configuration: Prior to printing, select required layers (e.g., only print power grid layer + administrative base map), annotations (e.g., survey results, fault point markers), legends, scales, titles, etc., to avoid space wastage from irrelevant information;
- Output Methods: Supports direct printing (via printer connection), exporting to PDF (editable), or exporting as images (PNG/JPG). PDF files automatically incorporate layer attribute data (click images to view feature details).

7.1.1.7.5.5 Data Rendering Tools

- Rendering Methods: Offers five rendering modes—single colour, gradient colour, classification colour, heatmap, and symbol size—adapted to different data types (e.g., gradient colour for numerical data, classification colour for categorical data).
- Colour configuration: Features built-in professional colour schemes (e.g., grid load rate displayed via green-yellow-red gradient), with support for user-defined colour thresholds (e.g., setting 60% load rate as yellow threshold);
- Dynamic Rendering: Visualisations refresh instantly upon layer data updates (e.g., fault handling status changes), eliminating manual redrawing;

- Rendering Save: User-configured rendering schemes can be saved as templates (e.g., "Summer Load Rendering Template") for direct recall during subsequent use, reducing repetitive operations.

7.1.1.7.6 Advanced Map Features

Route Finding Functionality: Leveraging power grid and telecommunications network topologies alongside real-time status data, this provides precise route planning services, supporting path analysis requirements across multiple scenarios.

- Route Visualisation: Planned routes are displayed on the map with highlighted lines (e.g., solid red lines), marking key nodes along the path (e.g., turns, toll stations, pylon locations). Distance information is shown beside nodes (e.g., "1.2 km to next station").
- Multi-route Comparison: The system presents three candidate routes labelled "Shortest Distance", "Fastest Time", and "Lowest Cost". Each route displays total length, estimated duration, and key constraint fulfilment (e.g., "No construction zones on this route");
- Route Export: Supports exporting routes as navigation files (GPX format, compatible with Amap and Baidu Maps), printing route maps (including node details), and sharing with team members (via internal system messaging);
- Route Simulation: Offers route simulation functionality, animating the journey from start to finish to visually demonstrate route details and help users familiarise themselves with the path in advance.

7.1.1.7.7 Map Data Optimisation Feature

Map data optimisation dynamically adjusts data display strategies to balance precision and system performance, ensuring a smooth user experience across diverse scenarios (e.g., low bandwidth, small-screen devices, restricted permissions).

7.1.1.7.7.1 Zoom-Based Optimisation

- Level of Detail (LOD) Control: Automatically adjusts the display precision of map layers based on the current zoom level. For example:
- Small scales (e.g., 1:1,000,000): Displays only macro-level features such as high-voltage power grid trunk lines, provincial administrative boundaries, and major base stations, while hiding fine-grained data like low-voltage lines and neighbourhood-level roads;
- Medium scale (e.g., 1:10,000): Displays medium- and high-voltage power grids, county boundaries, major roads, and base station coverage areas, with feature attributes showing only core information (e.g., line names, voltage levels);
- Large scale (e.g. 1:500): Display all features (including low-voltage meter boxes and fibre optic splice closures), with feature attributes showing full details (e.g. equipment model, installation date);
- Feature aggregation: At lower zoom levels, densely distributed features (e.g., meter boxes and micro-base stations within urban areas) automatically aggregate into clustered icons, with annotations indicating the number of features within the cluster (e.g., "5 base stations"). Clicking a cluster zooms into the area and disperses individual features to prevent interface clutter.

7.1.1.7.7.2 User Permission-Based Optimisation

- Permission Hierarchy: Users are categorised into four levels: Administrator, Dispatcher, Operations & Maintenance Personnel, and Visitor. Each level corresponds to distinct data access permissions:
- Administrator: Access to all layer data (including classified information such as base station passwords and power grid load forecasting models), with layer

editing privileges;

- Dispatchers: Can view grid/telecom network operational status, fault data, and operator locations, but cannot access confidential attributes (e.g., detailed user information);
- Maintenance Personnel: May only view layer data within their assigned area (e.g., a repair technician can only see the low-voltage grid for their county), with permission to view basic equipment attributes but not to edit them;
- Visitors: Permitted to view only public layers (e.g., administrative base maps, high-voltage grid trunk lines) with no operational privileges;
- Dynamic Permission Adaptation: Upon user login, the system automatically filters layer data based on permissions, concealing inaccessible features (e.g., the low-voltage grid layer remains unloaded for visitors). Simultaneously, it restricts sensitive operations (e.g., non-administrators cannot print maps containing fault details).

7.1.1.7.7.3 Optimisation based on display settings

- Resolution Adaptation: Automatically detects device display resolution (e.g., 1920×1080, 2560×1440, mobile 720×1280), adjusting feature display size (e.g., text annotations automatically scaled up by 1.2x on high-resolution screens) and icon precision (loading high-definition icons on large screens, simplified icons on smaller screens);
- Screen Size Adaptation: Optimises interface layout for different device types (PC, tablet, mobile), e.g.:
- PC: Display full toolbar (zoom, rotate, measure buttons), layer list expanded as a sidebar;
- Mobile: Collapsing the toolbar into floating buttons, enabling layer switching via a bottom swipe bar, and prioritising core operations.

- Performance optimisation: Adjust data loading strategies based on device capabilities (such as CPU and memory). Low-specification devices employ an 'on-demand loading' mode (loading only data within the current viewport), while high-specification devices utilise a 'preloading' mode (loading surrounding area data in advance). Concurrently, limit the number of layers loaded simultaneously (maximum of six) to prevent lag.

7.1.1.8 Shared Usage Category Management Functionality

Shared category management encompasses six core foundational lists. Each list requires a comprehensive functional framework built around "data design - management operations - permission control".

7.1.1.8.1 Position List Management

The Position List focuses on standardised management of all roles within the power system, covering the entire position hierarchy from decision-making and dispatch levels to frontline operations and maintenance. It serves as the basis for human resources staffing, permission allocation, and remuneration calculation.

1. Precise Addition and Editing:

When adding positions, the system automatically validates "unique position codes" (preventing duplicate codes) and "valid department affiliation" (displaying only active departments). Editing supports batch attribute modifications (e.g., uniformly adjusting permission associations for a position category) while retaining modification history (recording modifier, modification time, and original attribute values) for traceability.

Multi-dimensional Query and Filtering:

Supports combined filtering by "Department, Position Level, Status" (e.g., querying all positions under "Maintenance & Repair Department - Technical Role - Enabled"). Simultaneously provides fuzzy search functionality (e.g., entering

"Dispatch" matches "Power Grid Dispatcher", "Distribution Network Dispatch Specialist", etc.). Results can be sorted by "Position Code" or "Established Staff Quota".

2. Staffing Alerts and Statistics:

Real-time statistics on the ratio of "Current Staff / Authorised Quota" for each position. Triggers a yellow alert when the ratio ≥90% (e.g., "Substation Maintenance Engineer" with 14 current staff / 15 authorised quota), and a red alert when the ratio = 100% . Alert notifications are synchronously pushed to the Human Resources department.

3. Data Export and Template Import:

Supports exporting position lists to Excel (including all fields) for offline review. Provides standardised import templates (with field descriptions and example values) for batch importing new positions (e.g., adding multiple "New Energy Operations & Maintenance Roles" during power system expansion). The system automatically validates data formats prior to import, generating separate "error reports" for invalid entries.

7.1.1.8.2 Professional List Management

The specialisation list facilitates personnel-specialisation matching (e.g., aligning emergency repair personnel skills with fault types), training programme development, and talent recruitment screening. It ensures specialisation classifications remain synchronised with the power industry's technical framework.

1. Professional-Position Linkage:

When adding new specialisations, applicable positions may be linked in bulk (e.g., when adding the "New Energy Science and Engineering" specialisation, link it to "Photovoltaic Operations and Maintenance" and "Wind Power Dispatch" positions). Should a position be decommissioned, the system automatically prompts: "The XX specialisation associated with this position requires synchronous adjustment of applicable positions," thereby preventing data inconsistencies.

2. Programme Statistics and Analysis:

Provides "Major - Position Matching Rate" statistics (e.g., "Power Systems and Automation" major matches 12 positions with highest compatibility) and "Departmental Major Distribution" charts (e.g., "Relay Protection" specialists constitute 30% of Operations & Maintenance Department). This supports talent acquisition planning (e.g., targeted recruitment for "New Energy" specialists in departments with shortages).

3. Industry Standard Synchronisation:

Reserve an interface for integration with the "National Energy Administration's Power Industry Major Directory," synchronising the latest major classifications (e.g., adding "New Power System Engineering") on a regular basis (every six months). After synchronisation, data must undergo administrator review before activation to ensure compliance.

7.1.1.8.3 National List Management

1. Automatic Synchronisation of International Standards:

Interface with the official ISO database to synchronise country codes and name changes in real time (e.g., adjustments to a country's name). Upon synchronisation, the system generates a "Change Notification". Data is updated after administrator approval, ensuring alignment with international standards.

2. Frequently Used Countries Quick Access:

Frequently used countries are pinned to the top of the list, supporting "one-click filtering of common countries". When overseas business modules (e.g., overseas operations management) call the country list, frequently used countries are loaded by default to enhance operational efficiency.

3. Electrical Standards Query:

Clicking a country name displays its detailed power standard system (e.g., Pakistan's voltage levels include 11kV, 220kV, 500kV). Standard documents can be exported (PDF format) for overseas project equipment selection and O&M plan formulation.

7.1.1.8.4 List Management for Provinces, Cities, Districts, and Towns

1. Hierarchical Linkage Operations:

When adding a new administrative division, the parent unit must first be selected (e.g., adding "Kunshan City" requires selecting the parent "Suzhou City"). The system automatically validates the parent code's validity. When deleting an administrative division at any level (e.g., abolishing a district), the system prompts: "XX associated towns and XX distribution network lines under this region require prior adjustment," preventing cascading data errors.

2. National Administrative Division Synchronisation:

Interface with the National Bureau of Statistics Administrative Division Database to automatically synchronise the previous year's administrative boundary adjustments (e.g., newly established municipal districts, counties converted to cities) each January. Following synchronisation, generate an Adjustment List (containing newly added/deleted/renamed regions). After administrator review, perform batch updates whilst simultaneously synchronising to modules such as Distribution Network Management and Operations & Maintenance Scheduling (e.g., automatically creating distribution network management sub-zones for newly added regions).

3. Regional electricity data association:

Supports binding electricity service data to each administrative division (e.g., associating three maintenance sites and twelve 10kV lines with "Yushan Town"). Querying a region enables instant viewing of its power facility distribution and user scale, supporting regional load forecasting (e.g., predicting next year's load demand based on town-level user growth).

7.1.1.8.5 Ward and Commune List Management

1. Critical Facility Marking and Alerts:

Within the ward list, primary load wards are marked in red and secondary load wards in yellow. The system supports "one-click filtering for primary load wards". When planned power outages affect areas containing such wards, the system automatically triggers a "Critical Load Power Outage Alert", prompting advance verification of backup power status. Within the commune list, communes with ≥50,000 users are marked as "Key Service Communes" and receive priority allocation of maintenance resources.

2. Data Integration and Operational Triggers:

When adding a new ward, the system automatically associates it with the power supply line in its designated area (e.g., "ICU Ward" linked to "10kV Medical Dedicated Line") and pushes an "Important Load Registration" task to the distribution network management module. When adding a new community, it automatically assigns a power service site and synchronously updates the site's service coverage to prevent service blind spots.

3. Rapid Information Query and Export:

Supports filtering wards by "Administrative Division + Power Supply Level" (e.g., "Suzhou City Gusu District - Class 1 Load Wards") and communes by "Power Usage Type + Number of Users" (e.g., "Industrial-Dominant - Communes with ≥30,000 Users"). Query results can be exported to Excel for outage notifications and service planning.

7.1.2 Equipment Full Lifecycle Information Management Subsystem

7.1.2.1 System Function Description

The architecture of the Equipment Full Lifecycle Information Management Subsystem is illustrated below:

The overall application architecture of the management system comprises three layers:

(1) Application Presentation Layer: PC and mobile terminals

(2) Business Service Layer: Primarily encompassing equipment asset management, facility maintenance, spare parts management, facility leasing, facility upkeep, facility refurbishment, contingency planning, situational awareness, statistical analysis, and mobile application functionality.

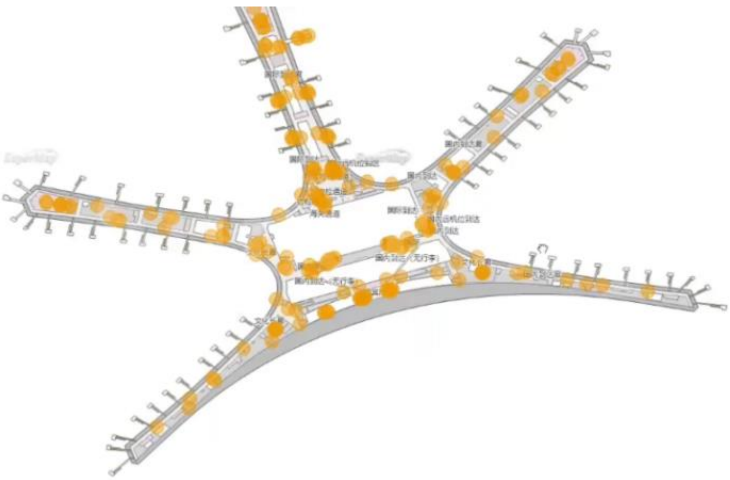
(3) Data Layer: Facility equipment data, operational data, maintenance records, status data, servicing records, contingency plan data.

7.1.2.2 Equipment Asset Management

7.1.2.2.1 Equipment Ledger Management

(1) Supports ledger management for equipment assets, enabling: - 3D visualisation-based recording of fundamental equipment/facility data - Automatic coding - Code management - Goods area recording - Barcode printing - Item category definition - Multi-level category creation - Implementation of equipment/facility cycle records - Dynamic usage management - Concise statistical reports - Usage duration alerts - Alert threshold configuration

Users may view equipment ledger lists through the system and navigate to corresponding locations on the map by selecting specific equipment.



(2) Supports cross-referencing within equipment ledgers to retrieve full lifecycle data including maintenance, modifications, and spare part replacements.

The system enables viewing of equipment-related data including inspection, maintenance, and servicing records.

(3) Supports the archiving and management of system equipment from two dimensions: static information and dynamic data, enabling comprehensive lifecycle management of equipment.

(4) Facilitates integration and transfer of asset information with the BIM5D integrated management platform. Features include customisable ledger attributes, bulk import of equipment inventories, upload of supporting documentation, lifecycle traceability management, and expiry alerts. This establishes a comprehensive equipment archive (linked to maintenance and repair records) and supports integration with financial systems, pushing asset ledger data for valuation and depreciation calculations.

(5) Supports updatable information for vehicle and equipment maintenance, repairs (overhauls), modifications (technical upgrades), and system installations, with data integration capabilities across systems. Enables modification/installation reporting for vehicles and equipment, supporting bulk import/export of maintenance records with automatic updates to the vehicle and equipment database.

7.1.2.2.2 Equipment Identity Identification

(1) Equipment asset identification management provides a standardised coding system for equipment ledger identities. This system complies with facility equipment classification and coding standards, meeting internal airport management requirements for data categorisation and coding. It ensures the uniqueness and consistency of the airport information model, providing unified foundational data for airport construction and operations.

(2) Supports dedicated interfaces and associated data tables for unified classification and centralised management of all models within scenarios. Enables automatic equipment coding based on customised rules, facilitates model retrieval and categorised queries via codes, generates corresponding QR code labels, and permits user-defined label template settings for on-demand printing. This ensures alignment between system-encoded data and physical site labels. The coding system supports logical topology representation across specialist systems. Supports the use of RFID electronic radio frequency identification tags as management and tracking identifiers.

7.1.2.2.3 Equipment Positioning Management

Enables real-time location tracking and management of valuable terminal equipment assets via positioning tags. Supports real-time visualisation of asset locations on interactive maps, with retrospective movement trajectory analysis. The visualisation interface facilitates switching between 2.5D and 3D display modes, featuring animated trajectory replays and timestamped movement data on the map. Supports alerts for abnormal equipment events, notifying administrators promptly via push notifications when equipment exceeds designated spatial boundaries. Enables one-click inspection of all location tags, automatically generating equipment asset inventory reports to enhance managerial efficiency and reduce inventory management costs.

7.1.2.2.4 Equipment Change Management

(1) Records equipment changes including relocation, sealing, unsealing, and decommissioning. Functions encompass capitalisation, transfer (relocation), deactivation, sealing, and idling. Supports customisable form interfaces and approval workflows according to management requirements.

(2) For scenarios such as reactivating decommissioned equipment, commissioning new equipment, relocating equipment, or altering critical components, supports triggering the upload of equipment risk assessments/reports. Equipment may only be reactivated upon approval.

7.1.2.2.5 Equipment Inventory Management

Equipment inventory management involves creating inventory plans based on operational requirements, obtaining approvals, generating inventory forms, processing inventory surpluses/shortfalls, and maintaining inventory records. Supports mobile and offline inventory using RFID technology, and enables creation of equipment asset maps displaying location, hierarchical asset types, status, and anomalies.

Device Inventory > Inventory List Details

Close

Basic Info
Inventory No. DEVPD2019030700001 Inventory Scope All Devices Inventory Time 2019-03-07 Inspector Yanjin Zhang Remarks 0

Inventory Data Info
Total Quantity: **17** Inventoried Quantity: **13**

Inventory Info

No.	ID	Name	Category	Brand	Department	Person in Charge	Storage Location	Inventoried?	Remarks
1	JQ80013	Office Desk	Office Equip.	Longxing	Production	Wu Jingjing	Warehouse A	☑	
2	DEV2019022600003	Test223	Welding Equip.	Xinliangtian	Production		Workshop B	☐	
3	DEV2019022600001	Test123	Production Equip.	Kangkangshi	Production		Cabinet 2	☑	
4	12333	Gate	Production Equip.	Xinliangtian	Production		Workshop B	☑	
5	abc0001	Automatic Cart	Office Equip.	Xinliangtian		Zhang San	Cabinet 2	☐	
6	DEV2019000001	Drilling Machine	Heavy Equip.	Fengbo	Quality	Ning Bin	Haidian	☑	
7	JQ10083-OLD	Laser Cutting	Heavy Equip.	Ouwei	Equipment	Zhi Haoke	Heavy Equip.	☑	
8	DEV2018000009	Label Printer	Office Equip.	Fengbo			Zhongri	☑	
9	DEV2018000003	FC Slicer	Heavy Equip.	Zhibite	Engineering	Wu Jingjing	Workshop B	☐	
10	DEV2018000002	Concrete Line	Heavy Equip.	Xinliangtian	Quality	Ning Bin	Heavy Equip.	☑	

Items per page: 10 Showing 1 to 10 of 17 records Prev 1 2 Next

(1) Procurement Contracts and Financial Ledgers

- Define procurement contract details for facilities and equipment, including model, quantity, price, delivery schedule, and other critical information, ensuring contractual terms align with airport requirements.
- Establish detailed financial ledgers to record expenditure incurred during procurement, installation, and commissioning processes, facilitating financial reconciliation and audit compliance.

(2) Equipment Asset Labelling

- Assign a unique asset label to each piece of facility equipment. The label contains basic information such as equipment serial number, model, and production date.
- Employ RFID technology to link asset tags with equipment information, enabling rapid identification and tracking.

(3) Post-installation Asset Inventory

- Conduct regular physical inventories of facilities and equipment to ensure quantities, locations, and other details align with ledger records.
- Update equipment details in real time to guarantee the accuracy and timeliness of asset data.

7.1.2.2.6 Equipment Disposal Management

Facilitate the disposal of equipment through the creation of a decommissioning form. This form captures details including the decommissioning date, responsible individual, department, original value of the equipment, reason for decommissioning, previous management status, and accumulated depreciation. Supports the import of decommissioned equipment ledger information and the submission of decommissioning records. Provides alerts when equipment approaches its decommissioning deadline.


Device Scrapping Form

Basic Info

APPROVED

Document Date	2022-07-12	Scrap No.	2022107012
Device Name *	Flatbed Cart	Model	HZ117-01
Unit	Set	Applicant *	Jin Wei
Department *	Guiyang Project Dept.	Application Date	2022-07-12
Scrap Date	2022-08-01	Est. Scrap Cost	2,424.00
Document Creator	Huang Yi		
Reason for Scrapping	Basic components damaged, no longer meets standards after repair.		
Usage Instructions	Cannot be used after the date of scrapping.		
Remarks			

7.1.2.2.7 Equipment Transfer Management

Facilitates equipment transfer processing. Import ledger information for equipment awaiting transfer, edit details including receiving department/unit/enterprise, disposal notes, total original value, transfer type (uncompensated transfer, contractual transfer), etc. Supports submission of transfer forms and automatic updating of equipment information upon approval confirmation.

7.1.2.3 Facilities and Equipment Maintenance

7.1.2.3.1 Fault Reporting

Supports maintenance reporting for facility and equipment faults across the entire site. Includes manual reporting and system-triggered alerts. Manual reporting allows fault conditions to be documented via photo uploads or data entry, generating fault records containing descriptions, occurrence times, reporters, and submission dates. Maintenance requests can be automatically triggered based on fault data from IoT-connected equipment.

7.1.2.3.2 Fault Report Feedback

Enables online feedback of fault assessment information to the reporting party. Upon receiving a report, the system conducts preliminary verification to confirm the completeness and accuracy of the submitted details. Should information be incomplete or non-compliant, users are notified to supplement or rectify the data.

7.1.2.3.3 Maintenance Plan Formulation

Supports online formulation of facility and equipment repair plans. The system retrieves maintenance information from the knowledge base based on facility/equipment type, pushing historical solutions for similar faults and the device's fault history. External repair plans may also be uploaded.

Repair plans include objectives, scope, and step-by-step procedures. Identify required repair items alongside necessary materials, tools, and spare parts. Establish timelines by estimating duration for each step to ensure timely completion. Account for spare part procurement and logistics to guarantee plan feasibility.

7.1.2.3.4 Generation of Maintenance Tasks

Generate maintenance tasks based on the repair plan, specifying task resources, scheduled times, and regional allocations. Distribute tasks online to maintenance personnel, notifying them to attend the site for resolution.

Assign maintenance tasks to appropriate personnel or teams, ensuring each individual understands their responsibilities and duties.

7.1.2.3.5 Maintenance Records

(1) Document the execution and completion status of maintenance tasks. Support video and photo uploads via handheld terminals, with the system automatically updating task status to "Completed".

(2) Supports recording maintenance costs alongside associated spare parts and procurement prices.

7.1.2.3.6 External Repair Request

Submit external maintenance requests online. Such requests typically arise when equipment, machinery, or systems malfunction and internal maintenance capabilities prove insufficient to resolve the issue, necessitating engagement with external specialist maintenance service providers.

Complete the external repair request form via the system, including the equipment's basic details (such as model, serial number, etc.), fault description, diagnostic results, and the desired repair time and location.

Please indicate any special requirements or considerations within the request form to enable the external maintenance service provider to better understand the requirements.

7.1.2.3.7 External Repair Approval

Online approval of external repair requests. Following online submission, requests are automatically routed to senior management or relevant departments for authorisation. Once approved by the responsible manager, external repair work may proceed.

During the approval process, communication with superiors or management may be required to explain the necessity of external repairs and the anticipated outcomes.

7.1.2.3.7.1 Supervision Records

Monitor the execution and completion of repair tasks undertaken by external contractors. Support the upload of videos and photographs via handheld terminals to generate supervision records.

Conduct regular inspections of external contractors' progress against the maintenance task schedule. Compare actual progress with planned timelines, analyse potential deviations, and implement necessary corrective actions.

Conduct on-site supervision of critical repair stages to ensure operations comply with specifications, are conducted safely, and are efficient. Communicate with on-site maintenance personnel to understand operational challenges and difficulties, providing necessary support and guidance.

7.1.2.3.8 Repair Acceptance

Upon completion of maintenance tasks, conduct quality inspections and acceptance checks. Verify that the maintenance outcomes meet contractual requirements, are complete, and fulfil expectations. Record acceptance comments, inspector details, and acceptance dates via handheld terminals or web interfaces.

7.1.2.4 Spare Parts Management

7.1.2.4.1 Spare Parts Inventory Count

Spare parts inventory stocktaking is conducted to accurately calculate monthly and annual operational status, ensure stored goods remain intact and that physical stock matches recorded inventory, thereby safeguarding normal production operations.

The system records spare parts inventory count details, including counted quantities, inventory levels, and spare part types. When the inventory level of any spare part falls below the warehouse's designated quantity, the system automatically issues an alert.

7.1.2.4.2 Spare Parts Procurement Request

The spare parts procurement request process ensures production or operational continuity and stability. It enables requests to the procurement department for purchasing when inventory is insufficient or when spare parts require updating or upgrading.

Submit spare parts procurement requests online, including procurement purpose, applicant, and description. Edit procurement details within the request, such as part type, quantity, and name. This function interfaces with the group's centralised procurement system for execution. Submit completed procurement requests to superiors or relevant departments for approval.

7.1.2.4.3 Spare Parts Procurement Approval

Approval of spare parts procurement requests; this function utilises the Group's centralised procurement system.

Approvers review the application, verifying the reasonableness and necessity of the procurement requirements. They may communicate with the applicant or request supplementary materials.

Depending on the approval outcome, the application may be approved or rejected. If approved, the application proceeds to the next procurement stage; if rejected, the applicant will adjust the application based on the rejection reasons or resubmit it.

7.1.2.4.4 Spare Parts Procurement Acceptance

Upon completion of procurement, the applicant or relevant department shall inspect the procured spare parts to ensure compliance with procurement requirements and quality standards.

Receipt and acceptance information shall be recorded based on the procurement application details and receipt status, including acceptance comments, acceptance status, acceptor, and acceptance date; this function shall be executed via the Group's centralised procurement system.

7.1.2.4.5 Spare Parts Warehouse Entry/Exit Records

(1) Supports real-time inventory recording with comprehensive data query capabilities, enabling multiple in/ out methods (e.g., maintenance, scrapping, routine, repair, metrology). Functions include inventory queries, exporting spare parts inventory data, printing inventory records, querying in/out transaction histories, exporting transaction logs, printing transaction records, archive management, and inventory statistical reports.

(2) Supports fundamental inventory management configurations, enabling dynamic warehouse management, stock level alerts, item categorisation, and warning threshold settings.

(3) Supports staff operations for registering item receipts and issues, enabling barcode scanning for receipt and issue registration. Upon successful submission, automatically generates spare parts receipt/issue records and allows viewing of associated maintenance records.

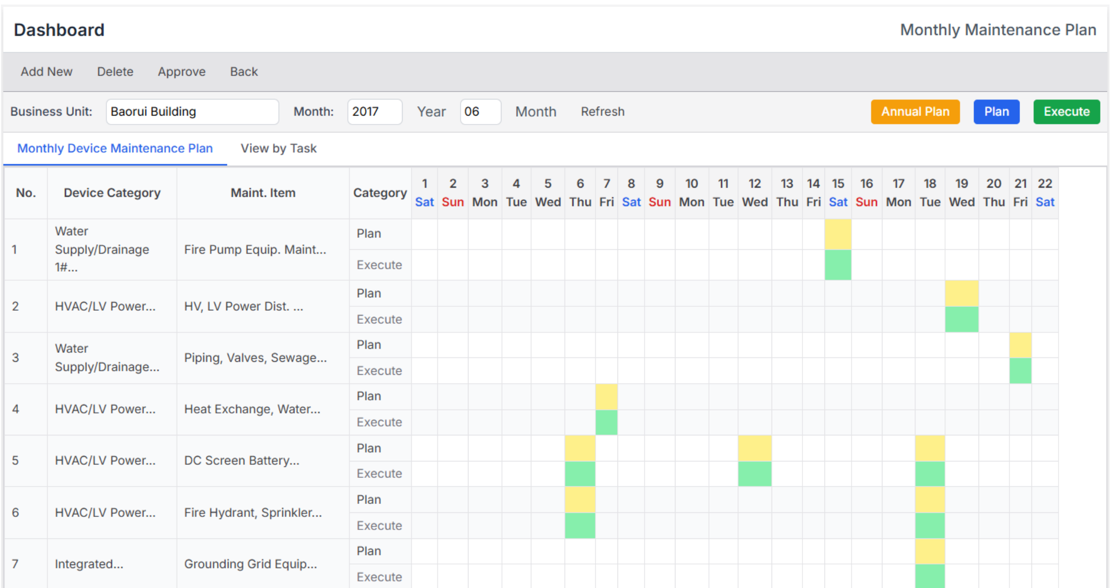
7.1.2.5 Facility and Equipment Maintenance

7.1.2.5.1 Maintenance Plan Formulation

Establishing facility and equipment maintenance plans is a crucial measure to ensure proper operation, extend service life, and reduce malfunctions. The system supports uploading and editing maintenance schedules for facilities and equipment.

Appropriate maintenance cycles are determined based on the type of facility/equipment, usage frequency, and manufacturer recommendations, such as daily, weekly, monthly, quarterly, or annual maintenance. For each facility/equipment item, specific maintenance tasks are listed, including cleaning, lubrication, tightening, inspection, and replacement. Maintenance tasks are prioritised according to the importance of the facility/equipment and its impact on production or operations.

Arrange maintenance tasks chronologically to create a detailed maintenance schedule.



7.1.2.5.2 Maintenance Plan Review

Reviewing the maintenance plan is a crucial step to ensure facility and equipment maintenance proceeds smoothly according to established objectives and requirements. The system supports online review of facility and equipment maintenance plans, enabling approval, rejection, and comment submission.

Verify that the maintenance plan covers all facilities and equipment requiring upkeep, along with each item's critical maintenance points. Confirm that the plan details maintenance tasks, frequencies, methods, and required materials/tools.

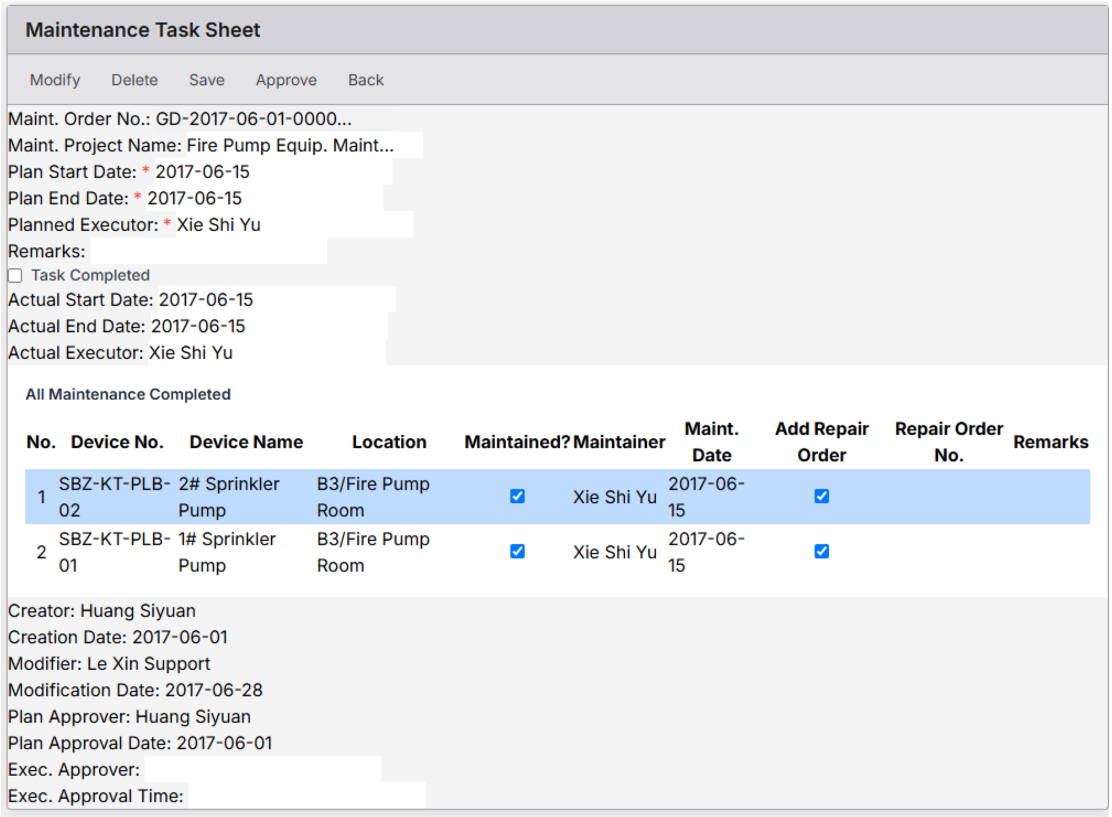
Evaluate whether the maintenance plan is grounded in the equipment's actual operating condition, manufacturer recommendations, and industry standards. Consider the equipment's usage frequency, working environment, and expected lifespan to determine the plan's reasonableness. Assess whether the required resources (such as personnel, time, and materials) are adequate and whether the plan can be executed smoothly under existing conditions.

Analyse whether the maintenance plan adequately addresses potential risk factors, such as equipment failure, downtime , and other associated risks. Evaluate the cost-effectiveness of the maintenance plan to ensure that resource investment aligns with the anticipated maintenance outcomes.

7.1.2.5.3 Maintenance Task Generation

Generating maintenance tasks is a critical step in executing facility and equipment maintenance plans, involving the conversion of the plan into specific, actionable tasks. Tasks are generated based on the maintenance plan, with resources and timelines scheduled accordingly. Tasks are then assigned to staff members in line with the maintenance plan; the system supports advance reminders and overdue alerts for maintenance tasks.

Assign maintenance tasks to designated personnel or teams, clearly defining their responsibilities and authorisations. Simultaneously, liaise with relevant parties to ensure they comprehend task requirements and execution schedules, enabling timely completion.



Maintenance Task Sheet

Modify Delete Save Approve Back

Maint. Order No.: GD-2017-06-01-0000...
Maint. Project Name: Fire Pump Equip. Maint...
Plan Start Date: * 2017-06-15
Plan End Date: * 2017-06-15
Planned Executor: * Xie Shi Yu
Remarks:
Task Completed
Actual Start Date: 2017-06-15
Actual End Date: 2017-06-15
Actual Executor: Xie Shi Yu

All Maintenance Completed

No.	Device No.	Device Name	Location	Maintained?	Maintainer	Maint. Date	Add Repair Order	Repair Order No.	Remarks
1	SBZ-KT-PLB-02	2# Sprinkler Pump	B3/Fire Pump Room	☑	Xie Shi Yu	2017-06-15	☑		
2	SBZ-KT-PLB-01	1# Sprinkler Pump	B3/Fire Pump Room	☑	Xie Shi Yu	2017-06-15	☑		

Creator: Huang Siyuan
Creation Date: 2017-06-01
Modifier: Le Xin Support
Modification Date: 2017-06-28
Plan Approver: Huang Siyuan
Plan Approval Date: 2017-06-01
Exec. Approver:
Exec. Approval Time:

7.1.2.5.4 Maintenance Implementation Records

Maintenance implementation records are a critical component in ensuring the correct execution and effective oversight of facility and equipment maintenance. These records document the execution and completion status of maintenance tasks. Support is provided for uploading videos and photographs via handheld terminals to generate task execution records, describing the maintenance situation and recording the completion time. The system automatically changes the task status to "Completed".

(1) Equipment Information: Record basic details such as the name, model, and location of the maintained equipment to clearly identify the maintenance subject.

(2) Maintenance Date and Time: Detailed recording of the commencement and completion times of maintenance work to ensure timely fulfilment.

(3) Maintenance Items: Document the specific maintenance tasks performed according to the maintenance schedule, such as cleaning, lubrication, or component replacement.

(4) Materials and Tools Used: Document the materials, spare parts, and tools employed during maintenance to ensure correct items were utilised.

Maintenance Content

Modify Save Complete All Back

No.	Task Content	Standard Requirement	Completed	Problem Description	Abnormal
1	Check pump & valve flanges for leakage		☐		☐
2	Check if pump inlet/outlet valves open/close normally		☐		☐
3	Check test bleed valve for flexible opening/closing...		☐		☐
4	Check if pump pressure gauge & pressure sensor are...		☐		☐
5	Check if pump mechanical seal is good or leaking		☐		☐
6	Check pipeline, valve open/close identification signs...		☐		☐
7	Check motor, pump flexible coupling operation...		☐		☐
8	Motor, pump body, valves, and base...		☐		☐

(5) Maintenance Personnel: Record the name of the individual or team responsible for performing the maintenance work to enable accountability.

(6) Maintenance Outcomes: Document the equipment's post-maintenance condition, performance improvements, or identified issues to evaluate maintenance effectiveness.

(7) Anomalies and Resolution: Document any anomalies or issues encountered during maintenance, detailing the resolution method and outcome.

7.1.2.5.5 Maintenance Acceptance

Maintenance acceptance is a crucial step in ensuring the quality and effectiveness of facility and equipment maintenance. Supports online completion of maintenance acceptance information. This includes importing maintenance task execution records, editing acceptance time, acceptance recommendations, acceptance personnel, and other details, with support for online submission of acceptance forms.

(1) Visual Inspection: Observe whether the equipment surface is clean, free from obvious stains or oil marks. Check that all components are securely installed with no signs of looseness. Note any visible damage or wear.

(2) Functional Inspection: Test whether the equipment starts and stops normally, and whether it operates smoothly without abnormal noises. Verify that all functions and operations are normal and fault-free. Simultaneously, confirm that safety protection devices are functioning correctly and are undamaged.

(3) Performance Metrics Testing: Conduct performance metrics testing in accordance with the equipment's specific requirements and maintenance manual. This may involve measuring operational parameters such as temperature, pressure, and flow rate, and comparing these against stipulated standards. Ensure the equipment's performance post-maintenance meets or exceeds expected requirements.

7.1.3 Power Monitoring and Management Subsystem

The core objectives of the Power Monitoring and Management Subsystem are to achieve real-time power status, hierarchical power supply management, efficient fault resolution, and intelligent security prevention. This can be broken down as follows:

Comprehensive Data Integration: Covering grid power sources, backup power sources, energy storage systems, and other power types, it collects core parameters such as current, voltage, load, and equipment status to establish a unified data platform.

Multi-voltage monitoring: Addressing differentiated requirements across high, medium, and low-voltage grids, it enables visualisation and granular management of power supply status throughout transmission, distribution, and consumer-side networks;

Rapid fault response: Establishes a closed-loop process of "power outage identification – location – dispatch – restoration – analysis" to reduce fault resolution time and enhance supply reliability;

Safety risk prevention: Continuously monitors grid corridor hazards (tree obstructions, construction intrusions) while integrating environmental data (icing, lightning) for risk alerts, safeguarding physical grid security;

Statistical Reporting Loop: Automatically generate multi-dimensional power supply statistical reports, supporting scheduled submissions and customised exports to provide data support for grid planning and operational decision-making.

7.1.3.1 Comprehensive Power Source Status Information Function

This function serves as the subsystem's "data hub", responsible for integrating multi-source power data including grid power, backup power, and energy storage. Through end-to-end management encompassing "collection - processing - display - alerting", it enables real-time monitoring of power status and anomaly warnings.

7.1.3.1.1 Data Acquisition Scope and Methods

Focusing on "all power source types + full parameter coverage", it clearly defines collection targets and technical solutions:

Power Source Types	Collection Targets	Core Acquisition Parameters	Collection Frequency	Collection Technology

Grid Power Supply	High/Medium/Low Voltage Lines, Substations, Distribution Transformers	Current, voltage, power factor, active power, reactive power, line loss rate, equipment temperature (main transformer / circuit breaker)	High Voltage: 1–5 seconds; Medium Voltage: 10–30 seconds; Low Voltage: 1–5 minutes	Remote Telemetry (RTU/FTU/DTU), Smart Meters, Sensors
Standby power supply	UPS, diesel generator, emergency power supply	Output voltage/current, battery capacity (SOC), operating mode (automatic/manual), number of starts, fault codes	Normal: 5-minute resolution; Fault: 1-second resolution	Device-integrated monitoring interface (RS485/Modbus), IoT module
Energy Storage Power Supply	Power Conversion System (PCS), battery cluster	Charge/discharge power, battery voltage/temperature, SOC, charge/discharge cycles, energy efficiency ratio	10-second resolution	PCS monitoring system, Battery Management System (BMS)
Distributed Power Sources	Photovoltaic inverters, wind power converters	Output power, generation output, grid connection point	1-minute interval	Inverter Monitoring Interface, IoT Gateway

		voltage/current, power factor		

Data acquisition employs a hybrid "wired + wireless" approach: high-voltage equipment prioritises transmission via the Power Dispatch Data Network (SPDnet); medium- and low-voltage equipment utilises 4G/5G/NB-IoT wireless transmission; satellite communications supplement coverage in remote areas (such as the mountainous wind farms in), ensuring no gaps in the acquisition chain.

7.1.3.1.2 Data Processing and Status Recognition

Multi-tiered data processing facilitates the transformation from "raw data → cleaned data → status determination → anomaly alerts":

Data Cleaning Layer: Automatically removes outliers (e.g., jump data caused by offline acquisition terminals), completes missing values (using linear interpolation/mean filling; missing data exceeding 30 minutes triggers terminal fault alerts), and verifies data consistency (e.g., prompts "Data Inconsistency" when the sum of substation incoming currents deviates over 5% from the sum of outgoing currents).

Status Analysis Layer: Assesses power supply status based on predefined rules and algorithms:

Threshold assessment: e.g., high-voltage line current exceeding rated value by 10% triggers "Alert", exceeding 20% triggers "Fault"; UPS battery SOC below 20% triggers "Low Power Warning";

Trend Analysis: Utilises sliding window algorithms to analyse load variation trends (e.g., predicting "overload risk" if medium-voltage line load increases by over 30% within one hour);

Correlation Analysis: Integrates meteorological data (e.g., heavy rainfall) with equipment status (e.g., outdoor circuit breaker tripping) to determine "weather-induced faults";

Status Grading: Classifies power supply status into four levels corresponding to different response priorities:

Status Level	Definition	Colour Indicator	Action Priority
Normal	Parameters within rated range, no abnormalities	Green	Low
Warning	Parameter approaching threshold, risk present	Yellow	Medium
Fault	Parameter exceeds threshold, equipment abnormality	Red	High
Offline	Data acquisition terminal disconnected, data transmission interrupted	Grey	Extremely high

7.1.3.1.3 Status Display and Alert Management

Multi-dimensional display:

Overview Dashboard: Displays network-wide power health (percentage of operational equipment), fault distribution (by voltage level/region), backup power utilisation rate, and energy storage charge/discharge status. Supports "one-click drill-down" for detailed insights.

Device Detail Page: Clicking a main transformer/inverter displays real-time parameter curves (current/voltage changes over past 24 hours), historical fault records, and maintenance cycle reminders;

Mobile Adaptation: Developed dedicated apps/mini-programs enabling field personnel to monitor equipment status and receive alert notifications;

Tiered alerting:

Alarm Triggering: Faults/offline status automatically trigger alarms; warning status only pushes notifications to operations personnel.

Alarm Methods: Audible and visual alerts (flashing on dispatch centre display + audible alarm), SMS/app notifications (tiered distribution based on permissions, e.g., high-voltage faults alert dispatchers + operations managers), email alerts (scheduled summaries sent at);

Alarm closure loop: Alarm acknowledgement (recipients must confirm within 15 minutes), resolution tracking (linked to repair work orders), closure upon restoration (automatic or manual closure after equipment returns to normal). Unresolved alarms trigger daily escalation reminders.

7.1.3.2 Comprehensive Grid Power Supply Status Mapping Functionality

7.1.3.2.1 Map foundation and layer design

Establish a layered architecture of "base map + business layers" to ensure map accuracy and operational alignment

Base Map Layer:

Administrative Base Map: Utilises the National Survey and Mapping Administration's standard administrative base map (province/city/district/township boundaries), resolution ≥ 1:10,000, supporting infinite zoom;

Topographic Base Map: Overlaid with Digital Elevation Model (DEM) data to display terrain features such as mountains and plains, facilitating analysis of line-laying environments (e.g., icing risks for mountainous routes);

Transportation Base Map: Integrates motorway, railway, and waterway data for emergency repair route planning;

Operational Layers (stratified by voltage level and operational type, supporting on-demand overlay/hide):

Layer Name	Display Content	Style Design
High-Voltage Grid Layer	110kV and above transmission lines, substations, pylons, cable chambers	Lines: Solid red (normal)/Orange (alert)/Black (fault); Substations: Blue rectangle (normal)/Flashing red (fault)
Medium-voltage grid layer	10-35kV distribution lines, ring main units, distribution transformers, fault indicators	Lines: Solid yellow (normal) / Orange (overloaded) / Black (faulted); Distribution transformers: Green dots (load rate <80%) / Red (> 100%)
Low-voltage grid layer	0.4kV lines, meter boxes, charging points, user access points	Lines: Grey solid line; Meter boxes: Blue dots (normal)/Red (power off); Charging points: Green (operational)/Grey (offline)
Power Supply Status Thermal Layer	Regional load density, voltage compliance rate, number of users without power	Heatmap Gradient: Blue (low load / high compliance rate) → Yellow → Red (high load / low

		compliance rate / high number of power-cut users)
Emergency Repair Resources Layer	Emergency repair team locations, spare parts warehouses, maintenance stations	Repair teams: red human icons (busy) / green (idle); warehouses: orange triangles

7.1.3.2.2 Spatialised real-time status display

Dynamic rendering: Map data synchronises with real-time monitoring, refreshing status every 30 seconds:

Automatic fault zone highlighting: e.g., if a medium-voltage line fails, the affected segment turns black on the map; impacted distribution transformers and meter boxes in the vicinity are simultaneously marked red, displaying "Number of affected users: XX households";

Load overload alerts: High-load zones (e.g., industrial parks) appear red on heatmaps. Clicking displays "Current load: XX MW, rated load: XX MW, overload rate: XX%" with recommended actions like "Transfer load to XX line";

Spatial Query and Localisation:

Point query: Click on a specific tower to display information such as "tower number, voltage level, current, last maintenance date, and associated lines";

Box Selection Query: Drag the mouse to select an area, automatically calculating the "number of operational/faulty equipment, total load, and number of users without power" within that region;

Fuzzy Search: Enter "XX Substation" or "XX Residential Area" to automatically locate the target on the map and display surrounding power supply status;

Historical Trajectory Playback: Supports selecting time ranges (e.g., past 12 hours, past 7 days) to replay power supply status changes within a region (e.g., load fluctuations, fault recovery processes). Playback speed is adjustable (1x, 5x) for fault cause tracing (e.g., identifying patterns in recurring power outages within a specific area).

7.1.3.3 High-Voltage Grid Power Supply Management Functions

For high-voltage grids at 110kV and above (primarily undertaking transmission tasks), focus on "safe and stable operation, power flow optimisation, and equipment condition monitoring" to achieve refined management.

7.1.3.3.1 Core Monitoring Objects and Metrics

Monitoring Objects	Core Monitoring Metrics	Normal Threshold Range	Warning Threshold Range	Failure Threshold Range
Transmission Line	Current, Voltage, Power Factor, Line Loss Rate, Conductor Temperature, Ice Thickness on Conductor , Sway Amplitude	Current < 90% of rated value; Line loss < 5%	Current 90%-100%; Line loss 5%-8%	Current > 100%; Line loss > 8%; Ice accumulation > 15mm
Substation Main Transformer	Oil temperature, winding temperature, load factor, insulating oil dielectric loss, tap changer position	Oil temperature < 65°C; Load factor < 80%	Oil temperature 65-75°C; Load factor 80%-90%	Oil temperature > 75°C; Load factor > 90%; Dielectric loss exceeds standard

Circuit Breaker	Operating status, number of operations, mechanical characteristics (tripping time, closing bounce), SF6 gas pressure/temperature	Status consistent with command; SF6 pressure normal	Operating cycles approaching lifespan threshold (90%)	Status inconsistent with command; low SF6 pressure
Busbar	Voltage deviation, frequency, three-phase imbalance, harmonic content	Voltage deviation ±5%; Frequency 50±0.2Hz	Voltage deviation ±5% to ±7%; frequency ±0.2 to ±0.5 Hz	Voltage deviation >±7%; Frequency >±0.5Hz

7.1.3.3.2 Key Management Functions

Real-time Power Flow Monitoring and Optimisation:

Power Flow Calculation: Based on node power balance algorithms, calculates network-wide power flow distribution every 5 seconds. Displays line power flow direction and magnitude on maps using arrows, with red arrows indicating heavy load (>90% rated power);

Overload Management: When lines/main transformers experience overload, the system automatically generates a "load shedding plan" (e.g., disconnecting interruptible loads from industrial users) and forwards it to dispatchers. Upon confirmation, remote commands can be issued.

Voltage Regulation: Monitors busbar voltage deviations, automatically recommending actions such as "adjusting main transformer tap settings" or "engaging/disengaging reactive power compensation units" ( ). For instance, when

220kV busbar voltage is low, it prompts: "Engage three parallel capacitor banks, projected voltage increase of 2kV";

Equipment Status Diagnosis and Prediction:

Main Transformer Status Diagnosis: Integrates oil temperature, winding temperature, and oil dielectric loss data using a BP neural network model to assess transformer health (Excellent/Good/Fair/Poor). At "Fair" health, prompts "Arrange oil sample testing";

Circuit Breaker Lifespan Prediction: Fitting lifespan curves based on operation counts and mechanical characteristic data to forecast remaining service life (e.g., "Circuit breaker has 500 remaining operations; replacement recommended within 6 months");

Line Icing Forecasting: Integrating meteorological station icing data and conductor temperature sensor readings to predict 24-hour icing thickness. Triggers an "Icing Alert" when exceeding 10mm, advising "Arrange de-icing operations";

Fault Isolation and Restoration:

Fault Location: Utilising line longitudinal protection and fault recorder data to precisely pinpoint fault locations on maps (error ≤500 metres), e.g., "Short circuit at tower #123 on 110kV XX line";

Isolation Operations: Automatically generate fault isolation plans (e.g., "Disconnect circuit breakers at towers #122 and #124 to isolate the faulty section"), supporting remote operation by dispatchers or prompting on-site maintenance personnel to execute;

Power restoration: Following fault clearance, the system recommends "closing the bus-side circuit breaker first, followed by the line-side circuit breaker," whilst monitoring post-closure current and voltage to prevent energising with faults present.

7.1.3.3.3 Safety and Stability Control

Transient Stability Control: During major disturbances (e.g., line tripping), real-time calculation of system power angle stability ( ) margin. When margin is insufficient, automatically triggers "generator shedding / load shedding" commands to prevent system collapse;

Low-Frequency/Low-Voltage Load Shedding: Monitors system frequency and voltage. When frequency < 49.5Hz or voltage < 0.9 pu, sequentially sheds loads according to preset rotation to maintain system stability.

Black Start Procedures: Stores substation black start protocols (e.g., using a specific gas turbine as power source with phased load restoration). During outages, displays black start pathways and steps on maps to guide dispatcher operations.

7.1.3.4 Medium-voltage grid supply status management functions

For 10-35kV medium-voltage grids (serving as the backbone of distribution networks), the focus is on load balancing, rapid fault location, and distribution automation, tailored to the radial/ring network topologies characteristic of distribution systems.

7.1.3.4.1 Core Monitoring Objects and Metrics

Monitoring Targets	Core Monitoring Metrics	Normal Threshold Range	Warning Threshold Range	Failure Threshold Range
Distribution lines	Current, Voltage, Load Factor, Line Loss Rate, Three-Phase Unbalance, Fault Indicator Status	Load factor < 80%; Line loss < 8%; Unbalance < 2%	Load factor 80%-90%; Line loss 8%-12%; Unbalance 2%-5%	Load factor > 90%; Line loss > 12%; Fault indicator tripped

Ring Main Unit / Branch Box	Switch status, cabinet temperature, SF6 gas pressure (ring main unit), incoming/outgoing line current	Switch status consistent with command; temperature < 40°C	Temperature 40-50°C; Switch operation count approaching end-of-life	Switch status abnormal; temperature > 50°C; low SF6 pressure
Distribution Transformer (Distribution Transformer)	Load factor, oil temperature, output voltage, three-phase imbalance, insulation condition	Load factor < 80%; Voltage deviation ±7%	Load factor 80%-95%; Voltage deviation ±7%-±10%	Load factor > 95%; Voltage deviation > ±10%; Insulation breakdown
Reactive Power Compensation Unit	Engaged capacity, power factor, compensation effect	Power factor 0.9–1.0; compensation without overcompensation	Power factor 0.85-0.9; slight overcompensation	Power factor < 0.85; Severe overcompensation

7.1.3.4.2 Key Management Functions

Load Balancing Management:

Load Monitoring: Statistics on medium-voltage line load distribution by transformer district, colour-coded on maps to indicate heavily loaded districts (red) and lightly loaded districts (green), e.g. "10kVXX Line #3 Transformer District Load Rate 92%, #5 Transformer District Load Rate 50%";

Load Transfer: For ring network structures, automatically calculates "load transfer paths", e.g. "Transfer load from #3 transformer district to #2 transformer district on 10kVYY line, transfer capacity XX kVA", and generates operational steps (e.g. "Disconnect #3 transformer district branch switch, close interconnection switch");

Dynamic Voltage Regulation: Monitors distribution transformer output voltage. When voltage is low (e.g., <200V), automatically commands the distribution transformer tap changer to increase voltage or activates the transformer district's reactive power compensation device to restore voltage to normal range;

Rapid Fault Location and Resolution:

Fault Indicator Interlocking: Utilising line fault indicator data (flip-card/current surge detection), fault segments are marked on maps (e.g., "Short circuit between poles #5-#6 on 10kVXX line"), with positioning accuracy ≤100 metres;

Distribution Automation (DA) Control: For lines equipped with DA functionality, automatically triggers the "Fault Detection - Isolation - Restoration" process upon fault occurrence. Example: "Upon detecting pole #5 fault indicator activation, automatically de-energises switches at poles #4 and #6, restoring supply to poles #1-#4 via tie switch"; restoration time ≤ 5 minutes;

Automatic Work Order Dispatch: For non-DA line faults, the system automatically assigns the nearest repair team based on fault location (e.g., "XX Operations Station, 3 kilometres from fault point") and pushes fault location, line parameters, and surrounding user information to the repair team's mobile application;

Refined distribution transformer management:

Load factor monitoring: Daily/weekly statistics on distribution transformer load factors. For transformers with load factors >90% for three consecutive days, prompt: "Require capacity expansion or substation division"; for transformers with load factors <30%, recommend: "Merge substations to reduce losses";

Three-phase balance adjustment: Monitor transformer phase currents. When imbalance exceeds 5%, the system prompts "Adjust customer wiring" (e.g., "Reroute 20 customers from Phase A to Phase B in Zone #3") and generates an adjustment checklist;

Abnormal Consumption Detection: By correlating distribution transformer load curves with consumer meter data, the system identifies anomalies such as "electricity theft" or "unauthorised capacity increases". For instance: "Suspected electricity theft where distribution transformer load curve shows sudden night-time spikes without corresponding consumer meter data".

7.1.3.5 Low-voltage grid supply management functions

For the 0.4kV low-voltage grid (directly serving end-users), focus on "voltage quality, user reliability, and distributed load management ( )" to achieve end-to-end monitoring "from grid to user".

7.1.3.5.1 Core Monitoring Objects and Metrics

Monitoring Targets	Core Monitoring Metrics	Normal Threshold Range	Warning Threshold Range	Failure Threshold Range
Low-voltage lines	Voltage deviation, three-phase imbalance, line loss rate, total harmonic distortion (THD)	Voltage 220±7%; Unbalance < 10%; THD<5%	Voltage 220±7% to ±10%; Unbalance 10% to 20%; THD 5% to 8%	Voltage <198V or >242V; Unbalance >20%; THD >8%
Transformer	Total current, phase	Switch closed; current	Current 90%-100%	Switch open; current > 100%

District Meter Box	currents, voltage, switch status	< 90% of rated value		
User Electricity Meter	Electricity consumption, voltage, current, power factor, outage duration	Voltage normal; outage duration = 0	Power factor < 0.85	Power outage duration > 1 hour; voltage abnormal
Distributed loads (charging points / photovoltaic)	Output power, grid connection point voltage, connection capacity, operational status	Voltage normal; power < 90% of connection capacity	Power 90%-100%; Voltage fluctuation ±5%	Voltage anomaly; equipment offline

7.1.3.5.2 Key Management Functions

Voltage Quality Control:

Real-time Monitoring: Statistics on low-voltage line voltage compliance rates by transformer district (e.g., "Transformer District XX today's voltage compliance rate 98.5%, below target value 99%"), locating districts with abnormal voltage (e.g., "Transformer District #8 15:00- 16:00 voltage 195V, classified as low");

Voltage Regulation Measures: For low-voltage distribution areas, recommend "adjusting the tap changer of the distribution transformer" or "replacing with larger-cross-section conductors"; for high-voltage distribution areas (e.g., during high PV output), prompt "engaging the distribution area reactor" or "guiding adjustments to PV output periods";

Harmonic mitigation: Monitor current harmonics. For substations with THD >

5%, analyse harmonic sources (e.g., inverters, charging points) and recommend "installing active filters", tracking mitigation effectiveness;

Customer Supply Reliability Management:

Reliability Statistics: Automatically calculate substation reliability metrics (SAIDI: System Average Interruption Duration; SAIFI: System Average Interruption Frequency; CAIDI: Customer Average Interruption Duration), e.g., "Substation XX: SAIDI = 1.2 hours/customer·year, outperforming target value of 1.5 hours";

Outage Traceability: Record outage causes (scheduled outage / fault outage / non-payment outage) and duration, generating a "Customer Outage Log" accessible for user queries (e.g., via app: "2 outages this month, total 2 hours");

Scheduled Outage Management: Prior to planned outages, send SMS/app notifications (24 hours in advance) specifying outage timing, scope, and restoration time; provide real-time progress updates during outages (e.g., "Line maintenance completed, power expected to resume in 1 hour");

Distributed Load Coordination:

Charging Pile Management: Monitor charging pile load connections. When the total power of charging piles in a transformer district exceeds 30% of the transformer's rated capacity, trigger an "Orderly Charging" command (e.g., "Limit power output of selected charging piles to 50%") to prevent transformer overload.

Residential PV Integration: Monitor grid-connection point voltage. When voltage exceeds 242V, prompt with "Excess PV output detected; recommend temporarily disconnecting grid-connection switch" or "Guide PV users to charge storage systems";

Load Forecasting: Combines historical consumption data and distributed load patterns to predict the substation's 24-hour load (e.g., "Tomorrow 18:00-20:00, XX substation load will reach 120kW; pre-emptive adjustment of distribution transformer load required");

User Service Support:

Abnormal Consumption Alerts: Automatically notifies users when meters detect "abnormal voltage" or "low power factor" (e.g., "Your household voltage is 190V, which may affect appliance operation. Maintenance has been scheduled");

Overdue Payment Alerts: Notifies users when electricity account balances are insufficient ("Overdue payment alert issued to prevent disconnection due to unpaid bills");

Fault Reporting: Supports one-click fault reporting via the app (e.g., "Power outage at home"). The system automatically locates the user's transformer district, correlates it with the district's meter box status, and rapidly determines the cause (e.g., "District switch tripped, indicating a widespread outage").

7.1.3.6 Power Supply Status Statistics Reporting Function

This function implements a closed-loop process of "power supply data statistics - report generation - automatic submission - decision analysis", meeting both internal operational management and external regulatory reporting requirements.

7.1.3.6.1 Statistical Dimensions and Core Metrics

Establishes a "multi-dimensional, comprehensive" statistical framework covering power supply quality, reliability, and economic efficiency.

Statistical Dimensions	Core Statistical Metrics	Calculation Logic
Time Dimensions	Daily / Weekly / Monthly / Annual electricity	Daily electricity supply = sum of electricity

	supply volume, maximum load, average load , load factor, voltage compliance rate, outage duration	supply across all time periods on that day; Load factor = average load / maximum load × 100%
Regional Dimension	Province / City / District / Substation Power Supply Volume, Line Loss Rate, SAIDI/SAIFI, Number of Faults, Number of Users	Transformer district line loss rate = (Transformer district electricity supply - Sum of user electricity consumption) / Transformer district electricity supply × 100%
Voltage Level Dimension	High/Medium/Low Voltage Line Power Supply Volume, Line Loss Rate, Equipment Failure Rate, Load Growth Rate	High-voltage equipment failure rate = Number of high-voltage equipment failures / Total number of high-voltage equipment × 100%
User Type Dimension	Industrial / Residential / Commercial / Agricultural electricity consumption, voltage compliance rate, number of power outages	Industrial electricity consumption = Total electricity consumption of all industrial users; Residential voltage compliance rate = Duration of normal voltage for residential users / Total duration × 100%
Power Source Type Dimension	Grid power supply volume, backup power supply engagement	Energy storage charge/discharge volume = Total charge volume - Total

	duration, energy storage charge/discharge volume, distributed power generation volume	discharge volume (Positive values indicate net charging; negative values indicate net discharging)

7.1.3.6.2 Report Generation and Custom Configuration

Standard Report Templates: Pre-installed industry-compliant templates meeting regulatory requirements:

State Grid / China Southern Power Grid Standard Reports: e.g., Monthly Power Supply Reliability Report, Voltage Quality Statistics Report, Line Loss Rate Statistics Report, formatted to National Energy Administration and grid company specifications;

Operations Management Reports: e.g., Monthly Equipment Failure Analysis Report (categorising failure causes by equipment type), Emergency Repair Efficiency Report (average resolution time per repair order, first-time fix rate);

Customisable Reports: Enables users to configure reports independently:

Dimension Selection: Freely combine statistical dimensions (e.g., "October 2025 - Suzhou City - Industrial Park - 10kV Lines - Industrial Users");

Metric Selection: Select required metrics from the metric library (e.g., "Power Supply Volume, Line Loss Rate, Number of Power Cutoffs");

Format settings: Select report format (Excel, PDF, Word) and chart type (line chart, bar chart, pie chart), e.g. "Display line loss rate comparisons across transformer districts using bar charts";

Report Preview and Export: Preview reports before generation, adjusting fonts, colours, and chart styles during preview. Supports batch export (e.g., exporting monthly reports for all 13 provincial cities simultaneously), with automatically named output files (e.g., "202510_Suzhou_City_Power_Reliability_Report.xlsx").

7.1.3.6.3 Automatic Reporting and Data Validation

Scheduled Reporting: Supports configuring reporting cycles (daily/weekly/monthly), reporting times (e.g., 6:00 daily, 8:00 on the 1st of each month), and recipients (superior dispatch centres, energy regulatory authorities, internal enterprise management systems);

Reporting Methods: Interfaces with higher-level systems (e.g., National Energy Administration's "Electric Power Safety Production Information Reporting System"), supporting FTP uploads, API pushes, and email transmission; Generates a "Reporting Log" post-submission, recording "Reporting Time, Recipient, Report Name, Success Status"; automatically retries failed submissions (up to 3 times) with alerts;

Data validation: Automatically verifies data validity prior to submission:

Logical validation: For instance, "The power supply volume of a transformer district should exceed the aggregate electricity consumption of its users" or "The line loss rate must fall within 0-100%"; failure to meet these criteria triggers an alert stating "Data anomaly detected, verification required".

Threshold Validation: For instance, "A distribution area's line loss rate of 15% exceeds the acceptable range (low voltage ≤12%)", prompting "Line loss rate anomaly detected; recommend investigating potential electricity theft or data collection errors";

Consistency validation: Comparing data from different sources (e.g., customer consumption from marketing systems versus transformer district consumption from monitoring systems), with deviations exceeding 5% triggering the alert: "Data inconsistency detected; verification required."

7.1.3.6.4 Statistical Analysis and Decision Support

Trend Analysis: Generates indicator trend charts, e.g., "SAIDI trend for a specific urban district over the past 12 months", analysing causes of improvement or deterioration (e.g., "August SAIDI increase due to typhoon-induced fault surge");

Comparative Analysis: Supports cross-regional and cross-temporal comparisons, such as "Line loss rate comparison between Suzhou and Nanjing from January to October 2025" or "Supply volume comparison for a specific transformer district between the same periods in 2025 and 2024";

Early warning analysis: Issues alerts for indicators approaching thresholds, e.g., "Line loss rate in a transformer district has risen for three consecutive months, currently at 11.8%, approaching the fault threshold of 12%. Prompt: 'Prioritise investigation into line loss causes'";

Decision Recommendations: Automatically generate suggestions based on statistical data, such as "Medium-voltage line load factor in XX area has exceeded 85% for six consecutive months. Recommendation: 'Add one 10kV line to divert load'"; "Industrial user voltage compliance rate is low. Recommendation: 'Optimise tap position of distribution transformer'".

7.1.3.7 Power Outage Management Functionality

This function covers the entire process from "power outage detection – localisation – resolution – restoration – analysis", establishing a "rapid response, closed-loop management" power outage resolution system to minimise disruption.

7.1.3.7.1 Power Outage Detection and Identification

Automatic Identification: Triggered by real-time data collection to determine outages:

Grid power outage: Line voltage and current both at zero, persisting for >30 seconds (excluding transient fluctuations), classified as "grid power outage";

Equipment Failure Power Outage: Circuit breaker tripping, distribution transformer shutdown, or switch disengagement, coupled with zero current on associated lines, is classified as an "equipment failure power outage";

User power disconnection: When the user's electricity meter displays zero voltage and zero current, and the transformer substation's main switch is closed, this is determined as a "user-side power disconnection" (e.g., meter failure, disconnection of the incoming service cable).

Manual reporting: Receives reports from users/maintenance personnel via multiple channels:

User reporting: Users report "power outage at home" via the app, WeChat mini-program, or the 95598 hotline. The system automatically obtains the user's location (based on mobile number/address) and associates it with the relevant transformer district;

Operations reporting: Field personnel discover outages (e.g., broken lines) and report via the emergency repair app: "XX line outage caused by tree obstruction resulting in conductor short circuit";

Power outage classification: Categorised into 3 types based on cause, corresponding to different handling priorities:

Power Outage Type	Common Causes	Priority Level
Fault-induced power outage	Equipment failure (circuit breaker tripping, damaged distribution transformer), natural disasters (typhoons, lightning strikes), tree	Extremely high

	obstructions, construction damage	
Planned power outage	Line maintenance, equipment replacement, load transfer	Medium
Customer-side power outage	Meter malfunction, disconnection of service line, suspension of supply due to unpaid bills	High

7.1.3.7.2 Power outage localisation and scope delineation

Topology-based localisation: Utilising grid topology diagrams to determine outage scope via "fault isolation points":

High-voltage outage: Utilising substation protection devices and line fault recorders to pinpoint the faulty line segment (e.g., "110kV XX Line, Poles #100–#120");

Medium-voltage outage: Identify affected transformer districts via ring main unit switch status and fault indicator activation (e.g., "10kVXX line, transformers #3 and #4");

Low-voltage outage: Pinpoint affected users via distribution panel status and consumer meter data (e.g., "Buildings 2 and 3 in Distribution Panel #3");

GIS-based visualisation: Highlight the outage area on the integrated map:

Mark boundaries of affected zones (e.g., "XX Residential Estate, XX Industrial Park"), number of impacted users (calculated by transformer district), and user types (e.g., including hospitals, schools, critical enterprises);

Associated peripheral information: e.g., "Critical Priority Users" within the outage zone (hospitals and care homes marked in red), "Backup Power

Configuration" (e.g., diesel generators at certain enterprises);

Impact assessment: Automatically evaluate the severity of the outage:

Number of affected users: Total users within the outage area, including critical users (industrial/medical/transport);

Estimated duration: Based on fault type (e.g., "tree-related outage" estimated at 1 hour, "main transformer failure" estimated at 4 hours);

Estimated economic loss: Calculated using average industrial user outage losses (e.g., "One-hour outage at an industrial park estimated to cause £500,000 loss"), providing a basis for resource allocation.

7.1.3.7.3 Power Outage Response and Emergency Repair Dispatch

Automatic Work Order Generation: The system automatically generates emergency repair work orders based on the type of power outage, location, and affected area:

Work Order Details: Location of outage, cause (preliminary assessment), number of affected users, priority users requiring support, recommended response plan (e.g., "Require deployment of 2 repair personnel and 1 utility vehicle, equipped with conductors and insulators");

Work Order Allocation: Dispatch repair teams according to the "proximity principle + skill matching":

Proximity principle: Select the nearest available repair team to the outage location (e.g., "XX Operations Station repair team, 3 kilometres away, estimated arrival time 15 minutes");

Skill matching: High-voltage outages assigned to "High-voltage maintenance teams"; low-voltage user outages assigned to "Low-voltage repair teams";

Emergency Resource Dispatch:

Personnel dispatch: Verify repair personnel's real-time location (GPS tracking) and certification (e.g., "High-voltage electrician licence", "Elevated work permit") to ensure compliance with qualification requirements;

Material Dispatch: Query nearby spare parts warehouse inventory (e.g., "XX Warehouse has 2 units of 10kV circuit breakers available for deployment to outage site"), generate "Material Allocation Orders", and arrange vehicle transport;

Cross-regional support: When power outages affect extensive areas (e.g., multiple substations disrupted by a typhoon), automatically request assistance from neighbouring repair teams and display support routes on the map;

Repair Progress Tracking:

Work Order Status Updates: Repair teams update status via the app (Assigned → En Route → On-Site Resolution → Power Restored → Closed);

Real-time Communication: Dispatchers and repair teams engage in live chat via the app, sharing on-site photographs (e.g., "Send photo of broken conductor; confirm 200 metres of conductor replacement required");

Overtime alerts: Triggered when repairs exceed estimated duration (e.g., 1 hour estimated vs. 1.5 hours elapsed), prompting dispatchers to intervene (e.g., deploy additional personnel).

7.1.3.7.4 Power Restoration and Verification

Restoration Procedure Guidance: The system provides step-by-step restoration instructions to prevent operational errors:

Fault Power Restoration: "Confirm fault rectified → Close isolating switch → Close line switch → Monitor current/voltage → Confirm customer power restored";

Planned power restoration: "Confirm maintenance completed → Close the interconnection switch → Gradually restore load → Monitor line load";

Restoration Confirmation:

Automatic Confirmation: Following power restoration, real-time data acquisition indicates normal line voltage/current and user meter readings. The system automatically confirms "Power restored".

Manual Confirmation: Repair personnel confirm on-site that "the customer's power supply has been restored" and click "Restoration Confirmed" via the app; upon receiving the "Power Restoration Notification", customers may respond with either "Restored" or "Still Without Power".

Restoration Notification: Following power restoration, send SMS and app notifications stating "Power has been restored in your area. Thank you for your understanding." For planned outages, concurrently inform: "This outage lasted 2 hours, primarily for maintenance on the line."

7.1.3.8 Grid Corridor Safety Management Function

Grid Corridor (Protected Zone Along Transmission/Distribution Lines) This function focuses on "hazard identification, risk warning, and inspection management" to prevent grid failures caused by internal/external corridor risks (tree obstructions, construction activities, foreign objects).

7.1.3.8.1 Corridor Data Collection and Modelling

Basic Data Collection: Establishing a "digital archive" for corridors:

Corridor boundaries: Delineated according to standards (20-50 metres for high-voltage corridors, 10-20 metres for medium-voltage corridors), with boundaries marked on GIS maps;

Line Parameters: Voltage level, conductor type, tower type/height, insulator model, construction year;

Surrounding Environment: Trees within the corridor (species, height, distance from conductors), structures (distance from lines, purpose), roads, rivers, meteorological stations;

Dynamic data acquisition: Employ multiple methods to capture real-time corridor status:

Video surveillance: Installation of high-definition PTZ cameras (supporting 360° rotation and night vision) on pylons to monitor personnel/equipment activity within the corridor (e.g., intrusion by construction machinery);

Infrared temperature measurement: Drones equipped with thermal imaging cameras detect conductor temperatures and insulator overheating, identifying hazards such as "poor contact" and "icing";

LiDAR: Drones equipped with LiDAR measure tree height and distance from conductors, achieving accuracy ≤0.5 metres ( ), identifying "excessive tree clearance violations";

Meteorological Data: Integrates with corridor-adjacent weather stations to acquire wind speed, wind direction, icing, lightning, and temperature data for risk forecasting;

3D Modelling: Constructing corridor 3D models integrating line, tower, and environmental data to support "immersive viewing" (e.g., assessing tree proximity from conductor perspective) for hazard visualisation analysis (e.g., simulating potential conductor contact after tree growth).

7.1.3.8.2 Hazard Identification and Grading

Hazard Types and Identification Methods:

Hazard Type	Identification Method	Severity
Tree Obstruction Hazard	Laser radar measures tree height and distance from power lines;	High

	distance < safety distance (e.g., ≥5 metres for high-voltage lines) is deemed non-compliant	
Construction intrusion	Video surveillance identifies construction machinery (excavators, cranes) entering the corridor; infrared temperature measurement detects construction sparks	Extremely high
Foreign object hazards	Video surveillance identifies kites, plastic bags, advertising signs, etc. entangled in conductors; drone inspections detect foreign objects	Medium
Ice accumulation hazard	W eather station icing data and conductor temperature sensor readings. Icing thickness > 10mm is deemed excessive.	High
Pylon hazards	Drone inspections reveal tower inclination and foundation settlement; infrared temperature measurements detect overheating at tower joints	High

Lightning hazards	Lightning location systems monitor strike frequency within corridors. Combined with historical circuit breaker trip data, this identifies "high lightning strike risk"	Medium

Hazard Classification: Categorised into four levels based on "severity of risk + response timeframe":

Hazard Level	Criteria	Time Limit for Resolution
Urgent Hazard	Construction machinery contacting conductors, foreign objects causing conductor short circuits, tower inclination exceeding 15°	Within 1 hour
Major hazards	Tree clearance distance to conductors <2 metres, ice thickness >15mm, frequent lightning strikes causing circuit breakers to trip	Within 24 hours
Minor hazard	Tree clearance distance from conductors 2–5 metres, minor subsidence of tower foundations, foreign objects caught on	Within 7 days

	towers (not touching conductors)	
Minor hazard	Tree clearance distance from conductors 5-10 metres (requires monitoring for growth), missing tower identification markings	Within 30 days

7.1.3.8.3 Hazard Management and Inspection Procedures

Hazard resolution process:

Hazard Dispatch: System automatically generates "Hazard Resolution Work Orders" and assigns them to responsible departments (e.g., tree hazard orders to Operations & Maintenance, construction intrusion orders to Safety Supervision).

Tracking: Responsible personnel upload resolution progress via the app (e.g., "Three non-compliant trees felled; site photos uploaded"), with the system updating work order status in real time (Not Resolved → In Progress → Completed);

Closure Verification: Upon completion, drone inspections/on-site verification confirm hazard elimination (e.g., "Tree obstruction cleared, now 6 metres from power lines, meeting safety requirements"), closing the work order. Unresolved hazards (e.g., "Construction cannot cease immediately") are escalated to "Urgent Hazards" for multi-departmental coordination.

Inspection Planning and Execution:

Automatic inspection plan generation: Plans are formulated based on hazard distribution, line criticality, and meteorological conditions:

Critical lines (e.g., power supply lines): Monthly UAV inspections, quarterly

LiDAR tree obstacle measurements;

Standard lines: Quarterly UAV inspections, biannual tree obstacle measurements;

High-risk areas (e.g., mountainous regions, frequent thunderstorm zones): Additional inspection following rainfall/thunderstorms;

Inspection Task Management:

Task allocation: Assign inspection tasks to personnel, specifying scope, content, and completion deadlines (e.g., "Complete UAV inspection of 110kV XX line by 26 October 2025");

Data Upload: Upon completion, personnel upload video, photographs, and infrared data; the system automatically compares against historical records (e.g., "Overhead insulator heating detected at pole #50 during this inspection; no abnormalities noted in previous inspection");

Inspection Assessment: Calculate inspection completion rate (e.g., "This month's inspection plan comprised 100 items, with 98 completed, achieving a 98% completion rate") and defect detection rate (e.g., "Inspections identified 20 defects, representing an increase of 5 compared to last month"), incorporating these metrics into performance evaluations.

Emergency Response:

Emerging hazards (e.g., tree obstructions on lines caused by typhoons): Automatically trigger "Emergency Response", deploying emergency repair teams, cranes, chainsaws and other resources to prioritise obstacle clearance;

Icing Management: When ice accumulation exceeds 15mm, initiate de-icing protocols (e.g., DC de-icing, mechanical removal), with real-time monitoring of effectiveness (conductors' temperature rise, ice thickness reduction);

Lightning Protection: In high-strike zones, recommend "installing surge arresters and optimising earthing systems". Issue "lightning warnings" before thunderstorms to alert maintenance personnel to monitor line conditions.

7.1.4 Electrical Schematic Management Subsystem

Objectives of this subsystem:

- Achieve "layer-switch-power outage status" linkage: Dynamically simulate power outage zones based on switch states across different layers, enabling O&M personnel to anticipate operational impacts;
- Achieve visualisation of "geographical area - grid switching": Correlate geographical information with schematics to simulate grid switching processes between regions, displaying pre- and post-switching power supply statuses;
- Real-time linkage between schematics and equipment parameters: Directly view real-time/ al operational parameters on schematics without cross-system queries;
- Achieve precise representation of "switch status": employ intuitive visual indicators to display real-time switch states (closed, open, faulted, etc.) on schematics, ensuring synchronised information.

System functional development primarily encompasses: Module

7.1.4.1 Basic Power Schematic Management Module

The Basic Electrical Schematic Management Module includes the following functions:

1. Schematic Drawing and Import:

Supports two drawing methods: - Built-in drawing tools (similar to Visio) with a library of common power grid components (switches, transformers, lines, instrument transformers, etc.), featuring drag-and-drop layout; - Importing external drawings (supporting DWG, DXF, SVG formats), with automatic recognition of drawing elements and association with equipment IDs upon import;

2. Layer Classification Functionality: Supports categorising layers by "voltage level (e.g., 500kV, 220kV, 10kV)", "equipment type (e.g., transmission equipment, substation equipment, distribution equipment)", or "geographical area (e.g., Substation A, Area B)". Each layer can be independently displayed or hidden, with overlapping display supported between layers (e.g. simultaneously displaying 220kV and 10kV layers);

3. Schematic version management:

Automatically logs drawing modification records (including modifier, modification time, and modification details), with support for version rollback (e.g., restoring to a drawing version from three days prior);

Version review mechanism: Drawing modifications require submission for approval (by the operations and maintenance manager). Changes only take effect after approval, preventing unintended modifications;

4. Schematic retrieval and location:

Supports multi-criteria searches: retrieve schematics by drawing name, voltage level, geographical area, or equipment ID;

Quick location function: Entering a device name (e.g., "Main Transformer #1") on the schematic automatically locates and highlights that device's position on the drawing; Supports GIS-linked location (clicking an area on the GIS map automatically opens the corresponding schematic).

7.1.4.2 Multi-layer Power Outage Simulation Module

This module primarily includes the following functions:

1. Switch Status and Layer Association Configuration:

Establish a mapping relationship between "Switch - Power Supply Area - Layer": Configure the control scope of each switch within the system (e.g., a circuit breaker controls the 10kV lines in Area A), and specify the layer to which this control scope belongs (e.g., the 10kV distribution layer);

Switch State Definition: Supports three states (Closed = 1, Open = 0, Fault = 2). State data synchronises in real-time from the sensing layer (update frequency ≤ 1 second) and supports manual state setting (for simulated operations);

2. Power Outage Simulation Logic:

Simulation Triggering Methods: Categorised as "Automatic Triggering" and "Manual Triggering":

Automatic Triggering: When the sensing layer detects a switch tripping/fault signal, the system automatically identifies the switch's control area and marks the power outage zone on the corresponding layer (using a red semi-transparent overlay matching the switch's control range). If multiple switches trip simultaneously, the system automatically calculates and displays the combined power outage zone after overlaying overlapping areas ( ). For example, if Switch 1 and Switch 2 both trip, the power outage zone is the union of their control areas.

Manual Triggering: Operations personnel may manually set switch states on the schematic (click switch icon and select "Open" or "Close"). After setting, the system updates the simulated power outage area in real time, supporting multi-switch linked simulation (e.g., simultaneously setting three switches to open to view the overall power outage range);

3. Stratified display of power outage status:

Supports viewing outage status by layer: e.g., displaying only outage areas on the 10kV distribution layer, or simultaneously viewing the superimposed outage effects of both 220kV and 10kV layers;

Outage Severity Classification: Outage status is categorised by scope as "Localised Outage (≤1 transformer district)", "Regional Outage (1-5 transformer districts)", or "Widespread Outage (≥5 transformer districts)". Different severity levels employ distinct shades of red (pale red for localised, deep red for widespread), with severity indicators displayed in the top-right corner of the diagram;

4. Exporting and sharing outage simulation results:

Supports exporting simulation results as images (PNG/JPG) or PDF files. Exported documents include simulation timestamps, switch status lists, and power outage area descriptions;

Sharing functionality: Simulation results may be sent to other users via system messages or email (e.g., for dispatch personnel to confirm operational plans).

7.1.4.3 Geographical Grid Switching Status Simulation Module

The geographical area grid switching status simulation module includes the following functions:

1. Geographic Area Division and Grid Topology Configuration:

Geographical Area Definition: Partition grid zones on GIS maps (supporting division by administrative regions (e.g., District XX, County XX), supply areas (e.g., Substation A supply zone, Substation B supply zone), or transformer districts (e.g., Village XX transformer district)), with each zone linked to its corresponding schematic layer;

Grid Topology Construction: Establish inter-regional grid connection relationships within the system (e.g., Substation A connects to Substation B via a 110kV interconnection line; Substation B connects to Distribution Area C via a 10kV line). Visualise topology relationships (display connection lines on the GIS map using distinct coloured lines, e.g., red for interconnection lines, blue for distribution lines).

2. Grid Switching Triggering and Simulation:

Switching Trigger Conditions: Supports two trigger methods:

Automatic Triggering: When the system detects a grid fault in a specific area (e.g., failure of Main Transformer #1 at Substation A) or load overload (e.g., load factor ≥95% in Distribution Area B), it automatically recommends a switching plan (e.g., transferring load from Area A to Substation B) and prompts the user to execute a simulation;

Manual Triggering: Users select the area to be switched (e.g., C feeder) and the target area (e.g., D substation) on the GIS map. The system automatically identifies the connecting lines and switches between them, generating a switching path (e.g., "C feeder → 10kV C line → #2 interconnection switch → 10kV D line → D substation");

3. Switching Process Simulation:

Dynamic display of switching steps: Simultaneously presents the switching process on both schematic diagrams and GIS maps, with textual annotations for each step (e.g., "Step 1: Disconnect C Substation's #1 Main Switch (Open State)" "Step 2: Close #2 Interconnection Switch (Closed State)"). Manual control of progress between steps is supported (e.g., pause, , rewind);

4. Switching Status Display: During the process, switches awaiting operation are marked with "flashing yellow", while operated switches are indicated by "green (closed)/red (open)". Switching paths are highlighted with "flashing lines"; Upon completion, areas with restored power are marked in "green" on the GIS map, while previously de-energised zones appear in "grey" (turning green if switching succeeds);

5. Switching Impact Analysis:

Upon simulated switchover completion, the system automatically analyses impacts on relevant areas: e.g., load rate in target areas post-transfer (e.g., D substation load rate rising from 60% to 75%), voltage changes (e.g., C transformer area voltage recovering from 0kV to 10.5kV), switchover duration (e.g., total switchover time 8 minutes);

6. Risk Alert Function: Should the target area's load factor exceed thresholds (e.g., ≥90%) or voltage overlimit risks arise post-switching, the system issues warning alerts (e.g., "Substation D load factor excessively high; recommend adding backup power supply").

7.1.4.4 Equipment Operational Parameters Visualisation Module

This module enables real-time linkage between "schematic diagrams and equipment parameters". Users can view operational parameters by clicking on equipment within the schematic diagram, eliminating cross-system queries. It includes the following functions:

1. Parameter Association Configuration:

Establish the association between "Schematic Device Icons - Equipment Register - Parameter Acquisition Terminals": Bind schematic device icons to the Equipment Register (model, commissioning date) and Parameter Acquisition Terminals (acquired parameter types, acquisition frequency) via unique device IDs, ensuring clicking an icon directly retrieves corresponding parameters;

2. Parameter Type Configuration: Supports configuring parameter types for different equipment (e.g., transformer parameters include oil temperature, winding temperature, load factor, insulation resistance; line parameters include current, voltage, power factor, line loss rate). Each parameter may be assigned a normal range (e.g., transformer oil temperature normal range 0-85°C);

3. Real-time parameter viewing:

Pop-up View: Clicking a device icon (e.g., #1 Main Transformer) on the schematic displays a parameter pop-up showing real-time values (updated at ≤1-second intervals matching the acquisition frequency). Values are colour-coded by status: green for within normal range, red for out of range, yellow for approaching threshold.

4. Parameter detail display: The pop-up supports viewing the parameter's "current value, unit, normal range, and acquisition time", e.g., "Oil temperature: 65°C (Unit: °C, Normal range: 0-85°C, Acquisition time: 2025-10-25 14:30:01)";

5. Multi-parameter comparison: Simultaneously view multiple parameters for the same device (e.g., oil temperature, load factor, voltage for Main Transformer #1) or compare identical parameters across different devices (e.g., load factor between Main Transformer #1 and #2);

6. Historical Parameter Query and Trend Analysis:

7. Historical Data Query: Select the "Historical Data" option in the parameter pop-up window to query past parameters by time range (e.g., last hour, last 24 hours, last 7 days). Data is displayed in tabular format and can be exported to Excel;

8. Trend Curve Display: Automatically generates parameter trend curves (e.g., oil temperature variation over the past 24 hours). Curves support zooming (to examine specific time periods) and annotation (marking anomalies such as instances where oil temperature exceeded 85°C). Multiple parameter curves can be overlaid (e.g., simultaneously displaying oil temperature and load factor variations to analyse their correlation);

9. Parameter Alarm Interlocking:

When equipment parameters exceed normal ranges (e.g., transformer oil temperature reaching 90°C), the system highlights the affected equipment with a "flashing red" indicator on the schematic diagram. The abnormal parameter is simultaneously emphasised in red text within the parameter pop-up window, triggering an alarm.

7.1.4.5 Switch Status Real-Time Display Module

This module ensures real-time, precise representation of switch status on the schematic diagram, providing maintenance personnel with an intuitive status reference. It includes the following functions:

1. Visual Switch Status Indication:

Utilises a "colour + icon + text" combination: - Closed state (green circular icon with "Closed" text) - Open state (red square icon with "Open" text) - Fault state (yellow triangular icon with "Fault" text, featuring an "!" symbol within the triangle)

Status animation effect: When switching states (e.g., closing to opening), a transition animation is displayed (e.g., green icon gradually changes to red icon, animation duration 0.5 seconds), preventing misjudgements caused by abrupt state changes;

2. Real-time switch status updates:

Data source: Priority is given to real-time status collected from the sensing layer (update frequency $\leq$ 1 second). Should sensing layer data transmission be interrupted (e.g. due to communication failure), the system automatically switches to "manual update" mode (where operational staff manually input status), displaying a "Data Interruption" alert (grey exclamation mark) beside the icon.

Batch Status Viewing: Supports filtering switches on schematics by "status type" (e.g., displaying only faulty switches). Filtered results are highlighted in colour for rapid fault switch identification;

3. Switch Status Details and Operation Logs:

Status Details Pop-up: Clicking a switch icon displays a status details pop-up showing "Current Status, Status Update Time, Status Change Reason (e.g., Manual Operation, Remote Control Operation, Fault Trip), Associated Equipment (e.g., line name controlled by this switch)";

Operation Log Query: The pop-up supports querying the switch's historical operation records (within the past year), including operator, operation time, operation type (close/open), operation result (successful/failed), and operation remarks (e.g., "Opened for maintenance");

4. Switch Status Interlock Control:

Interlocked with power outage simulation: When switch status changes, the multi-layer power outage simulation module automatically updates affected areas (e.g., switch tripped → corresponding area de-energised);

Interlocking with Area Switching: During geographical area switching simulations, operating a switch (e.g., closing an interconnection switch) updates its status in real time, synchronising changes across schematic diagrams and GIS maps.

7.1.5 Planning and Investment Project Information Management Subsystem

7.1.5.1 System Development Objectives

The specific objectives of the Planning and Investment Project Information Management Subsystem are as follows:

Enhancing Comprehensive Planning Information Display Capabilities

Achieve dynamic, integrated display of grid planning information. Present time-varying comprehensive planning data— , such as regional electricity consumption and load development trends—in intuitive graphical formats accessible to users with varying permissions. This enables rapid, accurate grasp of the overall grid planning landscape, providing robust decision-making support.

Strengthen planning information management efficiency

Provide convenient planning information management functions, allowing users to flexibly manage plan lists, display planning diagrams, and effectively control planning diagram versions. Simultaneously, fully leverage grid planning data to extract its value, enhancing the scientific and rational nature of planning.

Optimising Investment Information Management Processes

Enables efficient management of new investment plans, encompassing creation, modification, and querying operations. By displaying investment plan diagrams and managing design versions, users gain clear visibility into plan progress and details, providing reliable foundations for investment decisions.

7.1.5.2 Planning Function Development Module

7.1.5.2.1 Comprehensive Planning Information Functionality

This functionality enables integrated display across "Time - Area - Data - Charts", supporting tiered permission access. Specific features include:

1. Data Filtering and Permission Control:

Time Filtering: Supports data filtering by "Year (2020-2025), Quarter (Q1-Q4), Month (January-December)", with current year data displayed by default; Supports switching between "Year-on-Year" (e.g., Q1 2025 vs. Q1 2024) and "Quarter-on-Quarter" (Q1 2025 vs. Q4 2024) data comparisons;

Regional Filtering: The left pane displays a hierarchical regional structure (Country → Province → City → County → Subdistrict). Users can only view regions within their authorised scope (e.g., a Nanjing operations staff member can only see districts and counties under Nanjing City). Clicking a specific region automatically updates the central chart area and right-hand details pane with data for that region.

Data Type Filter: Supports switching between "Electricity Consumption Information" and "Load Development" data categories. Electricity consumption information includes "Total Electricity Consumption, Residential Electricity Consumption, Industrial Electricity Consumption"; load development includes "Peak Load, Average Load, Load Factor".

2. Multi-format chart display:

Time Trend Chart: Utilises line charts to illustrate data changes over time (e.g., Nanjing's total electricity consumption trend from January to June 2025). Supports mouse hover for specific values (e.g., March 2025 consumption: 520 million kWh) and chart downloads (PNG/PDF formats).

Regional comparison chart: Utilises bar charts to compare data across regions of the same administrative level (e.g., maximum load comparison for 13 cities in Jiangsu Province during Q1 2025). Supports sorting by numerical value (high to low / low to high) and clicking bars to view regional details;

Load Heatmap: Displays regional load distribution as a heatmap on a GIS map (darker colours indicate higher loads). Supports map zooming to view different administrative levels (e.g., from provincial to county/district level). Heatmap data updates every 30 minutes.

Structural Analysis Chart: Presents electricity consumption structure via pie charts (e.g., Nanjing's Q1 2025 breakdown: residential 35%, industrial 55%, other 10%). Supports drag-and-drop adjustment of pie sectors to visually highlight proportion differences.

3. Data Details and Export:

Detail Display: The right-hand detail pane presents raw data under current filters in tabular format (e.g., time, region, data type, numerical values, collection source), with paginated viewing (20 entries per page).

Data Export: Supports exporting tabular data to Excel format. Exported files include filtering criteria and data descriptions (e.g., "Data Source: Marketing System synchronised 30/06/2025"). Batch export of data across multiple regions is supported (up to 50 regions).

4. Data Drill-Down Functionality:

Supports drilling down from higher-level regions to lower-level regions (e.g., from Jiangsu Province to Nanjing City, then to Jiangning District). Charts and detailed data automatically update after drilling;

Supports drilling down from aggregate data to granular breakdowns (e.g., from "Total Electricity Consumption" to "Residential Consumption - Commercial Consumption - Industrial Consumption" subcategories), meeting requirements for detailed analysis.

7.1.5.2.2 Planning Information Management Function

This functionality enables full lifecycle management of planning schedules and planning diagrams, supporting version control and data reuse. Specific features include:

Planning Programme List Management:

Plan Entry: Users may create new planning initiatives. Required fields include: "Plan Title (e.g., 'Nanjing Distribution Network Plan 2025-2030')", "Planning Area (dropdown selection: Province/City/County)", "Planning Period (Start Year - End Year)", "Planning Objective (e.g., 'Meet 15% load growth')", Responsible Person, Contact Details, Plan Attachments (e.g., Word version of planning specifications). Supports attachment uploads (formats: Word/PDF, single file ≤200MB);

Plan Editing and Deletion: Only plans with a status of "Draft" or "Rejected" may be edited. During editing, the "Planning Area" cannot be modified (to prevent cross-area data inconsistencies). Only system administrators and the plan creator may delete plans, requiring double confirmation prior to deletion. Archived plans cannot be deleted.

Plan Status Control: Supports six status transitions: "Draft → Submitted → Regional Review → Network-wide Review → Archived → Execution". Status changes must follow the workflow:

Draft → Submit: Upon the creator clicking "Submit", the status changes to "Pending Regional Review";

Pending Regional Review → Approved / Rejected: Regional reviewers (e.g., Jiangsu Province planning lead) review; approval advances to "Pending Network-wide Review", rejection reverts to "Draft" with reason provided;

Pending Network Review → Approved / Rejected: Network reviewers (e.g., State Grid planning department) review. Approval changes status to "Archived"; rejection returns to "Pending Regional Review";

Archived → Execution: Upon plan initiation, the network reviewer changes status to "In Execution". Upon completion, status changes to "Completed";

Plan Filtering and Search: Supports filtering plans by "Status (Draft / Pending Review / Archived), Planning Area, Planning Period, Responsible Person"; supports fuzzy search for plan names (e.g., entering "Nanjing 2025" locates relevant plans);

Planning Diagram Management:

Planning Diagram Upload and Preview: Supports uploading planning diagrams (formats: DWG/SVG/PNG, single file ≤500MB). Uploads must be linked to an archived planning scheme. Supports online preview (SVG/PNG formats preview directly; DWG formats require conversion to SVG for preview). Preview supports zooming (1:1–1:10), pan, and rotate;

Layout Annotation: Supports adding annotations within the preview interface (e.g., labelling a planned substation location as "New 220kV Substation, 2026"). Annotations comprise three types: text, arrows, and rectangles. Annotated content is automatically saved to the layout's properties.

Planning Diagram Export: Supports exporting planning diagrams in their original format (e.g., uploaded DWG files can be exported as DWG) or converting to PDF format. Exported files include planning scheme information (e.g., scheme name, associated areas);

Planning Map Version Management:

Version Creation: When planning diagram content changes (e.g., line path modifications due to load forecast adjustments), a new version can be created. The new version inherits the original version's basic information (e.g., associated plans, annotations). The reason for the version change must be entered (e.g., "Load growth exceeded expectations in Q2 2025, line capacity adjusted"). Version numbers increment automatically (e.g., V1 → V2).

Version History: Supports viewing a list of historical versions (sorted in descending order by version number). The list displays "Version Number, Creator, Creation Date, Reason for Change". Clicking a specific version allows previewing its planning diagram. Supports reverting the current version to a historical version (requires approval before reversion to prevent accidental changes).

Version Comparison: Enables selection of two versions for comparison (e.g., V1 versus V2). The system automatically highlights areas of discrepancy (e.g., newly added lines marked in green, deleted lines in red). Comparison results may be exported as a PDF report.

Version Archiving: Upon completion of the planning schedule, the final version is marked as an "Archived Version". Archived versions cannot be modified and are accessible only for viewing and exporting.

Planning Data Reuse:

Historical Data Query: Supports retrieval of historical planning data (e.g., 2024 load forecast data for a specific region, planning project lists). Query results are displayed in tabular format and support export.

Data Reuse for New Plans: Supports generating new plans based on historical planning data. Upon selecting a historical plan, the system automatically replicates its "Planning Area, Planning Period (auto-incremented, e.g., 2024-2028 → 2025-2029), and Planning Targets". Users need only modify differing elements (e.g., changing load growth target from 12% to 15%), reducing repetitive data entry.

7.1.5.3 Investment Information Function Development Module

This functionality enables closed-loop management of investment plans by linking planning and investment data, with version control support. Specific features include:

1. New Investment Plan Management:

Investment Plan Entry: Supports adding new investment plans. Entry fields are categorised into three types: Basic Information, Project Information, and Financial Information:

Basic Information: Investment plan name (e.g., "Nanjing City 2025 Distribution Network Upgrade Investment Plan"), linked planning plan (select from archived plans via dropdown to ensure investment-planning alignment), investment region (matches linked plan region and is non-editable), plan period (start month - end month);

Project Information: Supports multiple investment projects (e.g., "10kV Line Upgrade Project", "Distribution Transformer Capacity Expansion Project"). Each project requires entry of: "Project Name, Project Type (New Construction /

Upgrade / Maintenance), Project Location (linked to GIS map coordinates), Design Scale (e.g., line length 5km, transformer capacity 1000kVA)";

Financial Information: Each project requires entry of "Budget Amount (RMB), Funding Source (e.g. State Grid Special Investment, Local Matching Funds), Estimated Payment Timeline". The system automatically calculates the total investment plan amount (sum of all project budgets);

Investment Plan Review Process: A three-step process is adopted: "Technical Review → Financial Review → Final Approval". Reviewers and their respective authorisations for each stage are as follows:

Technical Review: Conducted by the regional technical lead, assessing "project necessity (alignment with planning objectives) and design scale rationality". Approval advances to financial review; rejection returns the proposal to "Draft" status with reasons noted (e.g., "Project scale exceeds planning requirements, reduction needed").

Financial Review: Conducted by the finance department, assessing "reasonableness of budgeted amounts (compliance with cost standards) and legitimacy of funding sources". Approval advances to final approval; rejection returns the project to "Pending Technical Review".

Final Approval: Reviewed by the Network Investment Lead. Approval changes status to "Approved" and enables execution. Rejection returns the project to "Pending Financial Review".

2. Investment Plan Status Tracking: Supports viewing the execution status of investment plans, with statuses including "Draft, Pending Technical Review, Pending Financial Review, Pending Final Approval, Approved, In Progress, Completed, Terminated". Status changes are automatically logged (e.g., "10 June 2025, Financial Reviewer Zhang San, Approved").

3. Investment Plan Filtering and Search: Supports filtering plans by "Status, Investment Region, Associated Planning Programme, Plan Cycle". Enables fuzzy search by plan name or project name (e.g., entering "220kV Substation" locates relevant investment projects);

Investment Plan Modification and Deletion: Only plans in "Draft" or "Rejected" status may be modified. Modifications to approved plans ( ) require initiating a "Change Request" (subject to re-review). Only the creator may delete draft-status plans. Approved plans cannot be deleted but may be marked as "Terminated";

4. Display of new investment plan diagram:

Investment Plan Map Generation: Upon plan approval, the system automatically generates an investment plan map. This map is derived from the associated planning map, overlaying investment projects onto the planning map:

Project Marking: Each investment project is marked with a distinct coloured icon (new projects: blue circle; renovation projects: yellow square; maintenance projects: green triangle). The icon displays "Project Name, Budget Amount, Implementation Status".

Regional Summary Marking: At the core location of the investment area, mark "Regional Total Investment: XX million yuan, Number of Projects: XX". Summary data updates in real time (e.g., total investment automatically refreshes upon adding new projects);

5. Investment Plan Map Interactivity:

Click project icon: Pop-up window displays project details including "Project Name, Type, Scale, Budget, Funding Source, Progress (e.g. 30% complete), Responsible Person";

Multiple project selection: Supports selecting multiple projects via mouse selection. The system automatically calculates the total budget and average progress of selected projects, displaying aggregated information;

GIS Map Integration: The investment plan map integrates with GIS mapping. Clicking the "Map Switch" button displays the actual geographic locations of investment projects on the GIS map (e.g., latitude/longitude coordinates for new substations). Supports zooming to view surrounding power grid facilities (e.g., associated transmission lines, distribution substations);

Exporting and printing investment plans: Supports exporting investment plans as PDF/SVG files, with exported documents containing investment plan details (e.g., plan name, total amount). Direct printing is supported, offering two print modes: "Project annotations only" or "Include summary information" ( ).

6. Investment Plan Design Version Management:

Version Creation: When investment plan content changes (e.g., project budget adjustments, project additions/deletions), new versions may be created subject to the following rules:

Change Triggers: A new version must be created when: - Project budget changes exceed 10% - Projects are added or removed - Funding sources change

Version Information: New versions inherit the base information of the original version. The following must be completed: "Version Number (auto-incrementing, e.g. V1→V2), Reason for Change, Person Responsible for Change, Time of Change";

Associated Updates: Upon version creation, the investment plan diagram automatically updates to the new version, whilst historical versions' diagrams are retained;

Version Viewing and Comparison:

Version List: Displays all versions of the investment plan. The list includes

"Version Number, Reason for Change, Date of Change, Status (Current Version / Historical Version)". Clicking a version number allows viewing the investment plan details and plan diagram for that version.

Version Comparison: Supports selecting two versions for comparison. The system generates a comparison table across four dimensions: "Number of Projects, Total Budget, Individual Project Budget, and Execution Status". Differences are highlighted in red (e.g., V1 Total Budget: £10 million, V2 Total Budget: £12 million, Difference: +£2 million). The comparison table can be exported to Excel;

Version Approval and Archiving:

Version Approval: New versions require initiation of an approval process (following the same workflow as investment plan review: Technical Review → Financial Review → Final Approval). Upon approval, the version becomes the "Current Version".

Version Archiving: Upon completion of the investment plan execution, the final version is marked as the "Archived Version". Archived versions cannot be modified and are accessible only for viewing, exporting, and comparison purposes;

8. Investment Data Statistics and Analysis:

Statistical Report Generation: Three types of statistical reports are automatically generated:

Regional Investment Report: Aggregates investment amounts by region (e.g., 2025 investment totals for cities and counties within Jiangsu Province). Presented as a bar chart with sortability by amount;

Project Type Report: Calculates investment proportions by project type (new construction / renovation / maintenance). Presented as pie charts with support for viewing detailed project lists by type;

Progress Reports: Track execution progress by investment planning cycle (e.g., monthly investment completion as a percentage of total budget for January-June 2025). Presented as line charts with capability to compare actual versus planned progress (e.g., planned 50% completion in June vs. actual 45% completion, with variance highlighted);

Report Export and Sharing: Supports exporting reports to Excel/PDF formats and sharing reports with other users via system messages or email (e.g., sharing with the finance department for fund accounting purposes);

Investment Benefit Analysis: Enables benefit analysis based on planning and investment data, e.g., "Investing £12 million in line upgrades for a specific area increases load-bearing capacity by 20%, meeting future load growth demands for the next three years." Analysis results generate PDF reports to inform subsequent investment decisions.

7.1.6 Power Communication Telecommunications Management Subsystem

7.1.6.1 System Development Objectives

Achieve comprehensive management of telecommunications equipment information: consolidate equipment ledgers, real-time status, and maintenance records. Display aggregated equipment information summaries and status overviews (e.g., lists of abnormal equipment, health rankings) according to permission levels. Support multi-condition queries and associated navigation.

Enable visualisation of telecommunications network maps: Provide online viewing of provincial and inter-provincial telecommunications network diagrams, supporting zoom, pan, node expansion, dynamic fault point annotation with linked details, and import/preview/management of connection point diagrams (e.g., sockets, ODFs);

Automated multi-dimensional statistical reporting: Generates reports (e.g., equipment integrity rate reports, fault statistics) by dimensions including "organisation (e.g., city/county companies), provincial regions, cross-provincial areas, routes, equipment types". Supports report export, sharing, and customisable templates.

7.1.6.2 Telecom Equipment Information Integration Module

This module aggregates and manages "equipment ledgers + real-time status + maintenance records", with specific functions as follows:

1. Equipment Information Consolidation:

Equipment Filtering and Classification:

The left pane displays a hierarchical device type tree ("Core Equipment (routers, switches) → Transmission Equipment (optical terminals, ODF racks) → Access Equipment (communication sockets, ONUs)"), supporting multi-filtering by "Device Type, Installation Location (Province/City/County/Substation), Commissioning Date, Operational Status".

Supports fuzzy search: Enter device ID, model, or location keywords (e.g., "Nanjing 220kV substation ODF") to swiftly locate target equipment;

2. Equipment Information Table Display:

The central area presents aggregated device information in tabular format, with fields including: "Device ID, Device Name, Type, Model, Installation Location, Commissioning Date, Responsible Person, Contact Number, Current Status (Normal / Faulty / Offline), Last Updated Date";

The table supports sorting (e.g. ascending/descending by commissioning date), pagination (20/50/100 entries per page), and selecting multiple devices for batch operations (e.g. bulk export, batch task assignment);

3. Device Details View:

Clicking a device in the table displays a right-hand detail panel showing: "Basic Information (matching table entries), Technical Parameters (e.g., ODF rack port count, router bandwidth), Real-time Status (e.g., ODF port optical power, socket connection status), Maintenance Records (past year's maintenance dates, details, and personnel)";

Real-time status fields are colour-coded (green for normal, red for abnormal, grey for offline), with alert icons displayed beside abnormal statuses (e.g., "!" for optical power below -30dBm);

4. Status Information Summary:

Anomalous Device Statistics:

The top of the right-hand panel displays an anomaly device summary ("Total Anomalous Devices: 12 units, comprising 3 ODF racks, 8 communication sockets, and 1 router"), with clickable values linking to the anomaly device list at ;

Anomaly distribution by device type (pie chart), e.g. "ODF racks: 25%, Communication sockets: 67%, Routers: 8%", visually highlighting high-risk device categories;

Device Health Assessment:

Calculate device health (maximum 100 points) based on "years in operation, maintenance frequency, and status stability". Health ≥80 points is rated "Excellent", 60–79 points is "Good", and <60 points is "Requires Maintenance";

Display health rankings (Top 10 excellent devices, Bottom 10 requiring maintenance), with clickable device details showing calculation breakdowns (e.g., "Operating for 5 years, maintained twice annually, stable status → Health score 85");

5. Status alert linkage:

When device status anomalies occur (e.g., optical power exceeding limits, socket disconnection), the system automatically triggers alerts: the affected device entry flashes on the dashboard, accompanied by a pop-up alert window (displaying device name, anomaly type, and recommended corrective actions). Supports alert dispatch: Clicking the "Dispatch" button automatically generates an operations work order (including equipment location and anomaly details), assigning it to the relevant regional maintenance personnel. Work order status (Pending / In Progress / Completed) synchronises in real-time to the dashboard;

6. Equipment maintenance record management:

Maintenance Record Entry: Supports maintenance personnel in recording equipment maintenance details, including fields such as "Maintenance Time, Maintenance Type (Routine Inspection / Fault Repair / Upgrade/Modification), Maintenance Content, Person in Charge, Result (Successful / Unsuccessful), Remarks". Supports uploading maintenance reports (PDF format, individual files ≤50MB);

Maintenance Record Query: Supports searching records by "Equipment ID, Maintenance Time Range, Maintenance Type". Results are displayed in tabular format and can be exported to Excel;

Maintenance Reminders: Based on equipment maintenance cycles (e.g., quarterly maintenance for ODF racks), the system automatically generates reminders three days prior to due dates, pushed to responsible personnel (system notifications + SMS).

7.1.6.3 Telecommunications Equipment Management Functional Module

Refer to 5.2.5 Equipment Full Lifecycle Information Management

Subsystem

7.1.6.4 Telecom Network Mapping Module

This module enables viewing of provincial/inter-provincial network diagrams, fault point annotation, and connection point management. Specific functions include:

1. Provincial/Inter-provincial Telecommunications Network Map Viewing:

Map Type Switching:

Top-level "Intra-provincial Network Map" and "Inter-provincial Network Map" toggle buttons display maps within the user's authorised scope by default (e.g., Suzhou maintenance personnel default to Jiangsu provincial network maps);

Supports map layer switching: "Provincial Overview → Municipal Districts → Substations/Equipment Rooms", displaying network topology at corresponding granularity levels (e.g., provincial overview shows backbone routing, municipal districts display distribution network routing);

Network topology display:

Network topology is displayed on the GIS map using a "node + line" format: Nodes (e.g., substation communication rooms, provincial dispatch centres) are identified by distinct icons (core nodes with red circles, standard nodes with blue circles). Lines (e.g., optical cables, Ethernet) are colour-coded (backbone optical cables orange, distribution network optical cables blue, inter-provincial optical cables purple);

Supports node expansion/collapse: Clicking a core node (e.g., provincial dispatch centre) expands its connected sub-nodes (e.g., municipal sub-centres); clicking the "Collapse" button restores the original view.

Node / Line Details:

Clicking a node icon displays a details panel on the right, showing "Node

Name, Location, Equipment List (e.g., containing 2 routers, 1 ODF rack), Connected Lines (e.g., connected to Nanjing-Suzhou backbone fibre optic cable)";

Clicking a line displays a line details panel showing: "Line name, origin/destination, length, bandwidth, laying method (aerial/buried), commissioning date, maintenance responsible party";

2. Telecommunications Network Fault Map:

Fault Point Marking:

Upon uploading fault data (such as fibre optic cable breaks), the fault location device automatically marks the fault point on the GIS map (red triangular icon with flashing effect), displaying the fault type (e.g., "fibre optic cable break") beside the marker.

Supports manual fault annotation: Upon identifying a fault (e.g., ODF port failure), operations personnel may click the corresponding node on the map, select the fault type (e.g., "Port optical power anomaly"), and manually add a fault annotation;

Fault Details and Impact Scope:

Clicking the fault point icon displays a fault details panel on the right, showing: "Fault ID, Fault Type, Occurrence Time, Location Result (e.g., 'Breakpoint at 15km on Nanjing-Suzhou Optical Cable'), Handling Status (Awaiting Location / Awaiting Dispatch / Under Emergency Repair / Restored), Responsible Handler";

The system automatically analyses the fault's impact scope, marking affected areas on the map with semi-transparent red zones (e.g., fibre optic cable interruption affecting 3 substations and 5 distribution transformer districts along the route). Node icons within the impact zone turn orange;

Fault Response Coordination:

The dashboard features a "Dispatch Emergency Repair" button. Clicking generates a repair work order (including fault location, impact area, and required materials), automatically assigned to the nearest maintenance team;

Supports fault tracking: When work order status updates (e.g., "Under repair → Restored"), the fault point icon colour synchronously changes (yellow during repair, green when restored), and affected area markings automatically disappear;

3. Connection Point (Socket, ODF) Connection Diagram Management:

Connection Point List:

The left pane displays the connection point list categorised by "ODF Rack" and "Communication Socket". Fields include "Connection Point ID, Name, Location, Connection Diagram Version, Last Updated".

Supports filtering connection points by "Location, Type, Version" and enables fuzzy search (e.g., entering "220kV substation ODF");

Connection Diagram Preview and Operations:

Clicking a connection point displays the connection diagram in the central area (supporting DWG, SVG, PNG formats). Preview functions include scaling (1:1 to 1:5), panning, and rotation;

Supports connection diagram annotation: Add annotations in the preview interface (e.g., annotate "Connecting Nanjing - Wuxi optical cable" on ODF port 1). Annotations support text and arrow types, with content saved automatically;

4. Connection Diagram Import and Version Management:

Supports importing new connection diagrams: Click the "Import" button, select a local file (format: DWG/SVG/PNG, single file ≤200MB). Upon import, enter a version number (e.g., V1.0) and update description (e.g., "ODF port expansion June 2025").

Version Management: Displays all historical versions of this connection point (sorted in descending order by version number), supporting viewing historical connection diagrams, reverting to past versions (subject to approval prior to reversion), and deleting expired versions (only the most recent three versions are retained);

5. Connection Diagram Export and Sharing:

Supports exporting connection diagrams in native format or PDF format. Exported files include connection point information (e.g., name, location);

Supports sharing connection diagrams with other users via system messages or email (e.g., sharing with emergency repair personnel for on-site verification of port connection relationships).

7.1.6.5 Power Communication Telecommunications Management Subsystem Statistical Reporting Module

This module enables the automated generation and management of multi-dimensional statistical reports, catering to the analytical requirements of users at various levels. Specific functionalities include:

1. Report Dimension Filtering:

Basic filtering dimensions:

Time dimension: Supports filtering by "Year (2023-2025), Quarter (Q1-Q4), Month (January-December), Custom time range". Current year's data is displayed by default.

Regional Dimension: Supports filtering by "Organisation (e.g. Jiangsu Electric Power Company, Nanjing Municipal Company), Provincial Sub-regions (e.g. Southern Jiangsu / Central Jiangsu / Northern Jiangsu), Inter-provincial Areas (e.g. East China Region, North China Region)". Users may only select regions within their authorised scope;

Equipment / Route Dimension: Supports filtering by "Equipment Type (ODF

Rack, Communication Socket, Router)", "Route Type (Backbone Route, Distribution Network Route, Inter-provincial Route)";

Advanced Filtering: Supports multi-dimensional combined filtering (e.g., "Q1 2025 + Jiangsu Province + ODF rack"). Filter criteria can be saved as "My Templates" (e.g., "Monthly Equipment Integrity Rate Template") for direct reuse in subsequent sessions;

2. Core report generation:

Equipment Reports:

Equipment Inventory Statistics Report: Statistics by region/type on equipment quantity (e.g., "50 sets of ODF racks in 220kV substations, Jiangsu Province") and integrity rate (Integrity Rate = Number of Operational Devices / Total Devices × 100%). Presented via bar chart + table format, with support for sorting by integrity rate.

Equipment Status Anomaly Report: Statistics on the number of anomalous equipment by time/type and distribution of anomaly causes (e.g., "Optical power anomalies account for 60%, connection disconnections account for 30%, offline accounts for 10%"). The report uses line charts + pie charts for display, with annotation of anomaly peaks (e.g., "15 anomalous equipment units in March 2025, representing the quarterly high").

Network Reports:

Provincial/Inter-provincial Routing Statistics Report: Statistics on routing quantity, length, and bandwidth utilisation rate (Utilisation Rate = Actual Traffic / Bandwidth × 100%) by region/type. Presented using tables + heat s (darker colours indicate higher bandwidth utilisation), with clickable routes to view traffic trends.

Fault Statistics Report: Provides statistics on fault occurrence frequency, average repair duration (repair duration = fault resolution time - fault occurrence time) by time period / region / fault type. The report employs bar charts + tables to compare repair efficiency across different regions (e.g., "Suzhou City's average repair duration of 45 minutes outperforms the provincial average of 60 minutes");

Customisable Reports:

Supports user-defined report templates: Select report fields (e.g., "Equipment ID, Location, Commissioning Date, Number of Faults"), statistical logic (e.g., "Group by commissioning date and count faults per group"), and display style (table / bar chart / line chart);

Saved custom templates can be shared with users of equivalent permissions (e.g., municipal company users sharing templates with county company users), with support for template modification and deletion;

3. Report Export and Sharing:

Export formats: Supports exporting reports as Excel (editable data), PDF (fixed format), or PNG (chart screenshots). Exported files include report name, filter criteria, and generation time;

Sharing Methods: Reports can be shared via "System Messages" or "Email". Viewing permissions can be set during sharing (e.g., "View Only", "Export Permitted");

Scheduled Pushes: Supports configuring automated report delivery (e.g., "Push last month's equipment integrity rate report to city company administrator email at 8:00 on the 1st of each month"), with content automatically updated upon delivery;

4. Report Data Analysis:

Trend analysis: Forecast trends based on historical data (e.g., predicting fault trends for over the next three months using the past six months' fault counts), with predicted ranges marked by dashed lines on line charts;

Comparative Analysis: Supports cross-period comparisons (e.g., fault frequency between Q1 2025 and Q1 2024) and cross-regional comparisons (e.g., equipment integrity rate between Suzhou and Nanjing), with variance values highlighted in red/green (e.g., "+5%" in green indicates improvement, "-3%" in red indicates decline);

Anomaly Analysis: Automatically identifies abnormal data in reports (e.g., a 20% sudden drop in equipment integrity rate in a specific region), generates analysis reports, suggests potential causes (e.g., "Recent lack of maintenance in this region has led to an increase in abnormal equipment"), and provides improvement recommendations (e.g., "Recommendation: Immediately schedule specialised maintenance").

7.1.7 Comprehensive Report Generation Subsystem

7.1.7.1 System Architecture Design

Adopting a "layered architecture + microservices" model to ensure system flexibility and scalability, comprising four layers:

Architectural Layers	**Core Functionality**	**Key Technologies / Components**
1. Data Source Layer	Interfaces with various business systems within the power industry to acquire raw data	- Internal Systems: SCADA (Supervisory Control and Data Acquisition), ERP (Enterprise Resource Planning), Equipment Management System - External Data: Meteorological data, grid dispatch data - Access Methods: API interfaces, ETL tools,

		direct database connections
2. Data Layer	Responsible for data storage, cleansing, and standardisation	- Storage: Time-series database (stores real-time operational data), relational database (stores business reporting data) - Processing: Data cleansing, format conversion, outlier removal
3. Application Layer	Implements core business functionality and provides services to users	- Report Generation Module, Report Management Module, Data Visualisation Module, Permissions Management Module
4. Presentation Layer	User interaction entry point, supporting multi-terminal access	- Web interface (PC), mobile applications (smartphones/tablets), large-screen displays (monitoring centres)

7.1.7.2 Core Functionality Design

1） Report Generation Module

Template-based design: Pre-loaded with industry-standard templates (e.g., Monthly Production Operations Report, Equipment Maintenance Report, Energy Consumption Statistics Report), with support for user-defined templates (drag-and-drop components, formula configuration).

Automated Generation: Schedule recurring tasks (e.g., daily/monthly automatic triggers). The system retrieves the latest data from sources, automatically populates templates, calculates metrics (e.g., power generation, line loss rate), and generates reports in Word/Excel/PDF formats.

Intelligent Validation: Automatically verifies data completeness (e.g., missing entries) and logical consistency (e.g., energy consumption values exceeding normal ranges). Abnormal data is highlighted in red with cause notifications.

2） Report Management Module

Full Lifecycle Management: Supports report creation, editing, review, publication, archiving, and retrieval. Review workflows are customisable (e.g., three-tier review: team → department → company).

Version Control: Retains historical report versions, enabling users to view version differences and revert to previous versions to prevent data loss from accidental operations.

Convenient Retrieval: Supports searching by report type, date, keywords, or creator. Results can be exported or previewed directly online.

3） Data Visualisation Module

Multi-dimensional Presentation: Data is intuitively displayed through line charts (power generation trends), bar charts (energy consumption comparisons across power plants), maps (grid coverage and load distribution), dashboards (real-time power), and other visualisations.

Interactive Analysis: Supports drill-down (e.g., clicking "Monthly Energy Consumption" to drill down to "Daily Energy Consumption") and filtering (e.g., filtering data by region/equipment type) to assist users in quickly identifying issues.

4） Data Governance Module

Data Lineage Management: Tracks data origins (e.g., which SCADA system device a metric derives from) and processing steps. Users can view lineage links by clicking data points in reports, ensuring traceability.

Quality Monitoring: Establishes data quality metrics (e.g., accuracy rate, completeness rate), conducts real-time monitoring, and generates Data Quality Reports. Low-quality data triggers alerts (SMS/system notifications).

5） Equipment Statistics Module

Core Functionality: Retrieves equipment ledger data based on filter criteria, automatically categorises and aggregates statistics, and generates reports.

Specific Report Implementation:

➢ Statistical Report — Equipment by Unit

Filter Criteria: Select "Statistical Unit" (e.g., XX Power Supply Bureau, XX Operations & Maintenance Station), "Asset Category" (optional, e.g., only transformers).

Report Content: Unit name, total number of devices, quantity of devices per asset category (e.g., 50 transformers, 80 switchgear units), proportion of devices in active/idle status, distribution of device commissioning years.

➢ Statistical Report — Customer-Owned Assets by Equipment

Filter criteria: Select "Customer Name" (e.g., XX Factory, XX Residential Estate), "Equipment Status" (in service / decommissioned).

Report Content: Client name, total number of owned equipment, list of equipment by type (including equipment ID, installation location, commissioning date), maintenance expiry reminders.

6） Maintenance and Servicing Statistics Submodule

Core Functionality: Links "Equipment Information" with "Maintenance Records" to statistically analyse metrics such as maintenance frequency, duration, and costs by dimension.

Specific Report Implementation:

➢ Statistical Report — Unit Maintenance Operations

Filter Criteria: Select "Executing Unit" (e.g., XX Maintenance Team), "Statistical Period" (e.g., Q3 2024), "Maintenance Type" (Routine Maintenance / Fault Repair).

Report Content: Unit name, total maintenance occurrences, maintenance frequency per equipment type (e.g., 12 transformer maintenance instances), average maintenance duration, maintenance completion rate (planned maintenance instances / actual completed instances).

- Statistical Report — Maintenance Work on Customer-Owned Assets

Filter criteria: Select "Client Name", "Statistical Period", "Equipment Type" (optional).

Report Content: Client name, number of maintenance operations on owned assets, detailed maintenance records per equipment type (equipment ID, fault type, maintenance cost, maintenance personnel), list of equipment requiring overdue maintenance.

7） Major Overhaul Equipment Statistics Submodule (Supporting Category 1 Major Overhaul Equipment Reports)

Core Functionality: Identify equipment requiring major overhaul (determined based on operational lifespan and condition monitoring data), categorised by unit and asset type for statistical analysis.

Specific Report Implementation:

- Statistical Report — Equipment requiring major overhaul and asset categories by unit

Filter Criteria: Select "Affiliated Unit", "Statistical Period" (e.g. equipment requiring overhaul in 2024), and "Asset Category" (optional).

Report Content: Unit name, total number of equipment requiring overhaul, quantity per asset category (e.g., 10 units of 110kV transformers, 5 units of 35kV switchgear), along with each unit's "Recommended Overhaul Date", "Current Operational Status", and "Historical Overhaul Records".

8） Loss Statistics Submodule (Supports 6 Types of Loss Reports)

Core Functionality: Automatically calculates loss rates based on metering data (Formula: Loss Rate = (Total Active Power Loss / Total Power Supply) × 100%), supporting breakdowns by "Voltage Level / Commercial Scenario" and "Monthly / Quarterly / Annual" dimensions.

Specific report implementations:

- Loss rate reports by voltage level (monthly / quarterly / annual)

Filter criteria: Select "voltage level" (e.g. 110kV/10kV/0.4kV), "statistical period" (monthly/quarterly/annual), and "statistical area" (optional).

Report content: Period, voltage level, total electricity supplied, total active power loss, loss rate, year-on-year/month-on-month change rate (e.g., this month's 10kV loss rate is 3.2%, a decrease of 0.3% compared to last month).

- Commercial Energy Loss Rate Report (Monthly / Quarterly / Annual)

Filter criteria: Select "Commercial Scenario" (e.g. Commercial Complex / Office Building / Convenience Store), "Statistical Period", "Region" (optional).

Report Content: Period, commercial scenario, total electricity consumption, energy loss volume, energy loss rate, loss ranking ( ) (e.g., XX Commercial Complex recorded an energy loss rate of 4.5% this month, ranking 3rd in the region).

7.1.8 On-site Data Acquisition Subsystem

7.1.8.1 System Architecture Design

Adopts a four-layer architecture: "Field Perception Layer → Edge Transmission Layer → Edge Processing Layer → Application Support Layer". This achieves a closed-loop data transmission chain from field to platform, with emphasis on enhancing field adaptability and transmission stability.

Architectural Layers	**Core Functions**	**Key Components / Equipment**
1. Field Perception Layer	Directly collects various raw data from the field, serving as the data entry point	- **Automatic collection devices:** Smart sensors (current/voltage/temperature sensors), smart meters (electricity meters, pressure gauges), video cameras, infrared thermometers - **Manual collection devices:** Handheld terminals (PDAs), mobile tablets (supporting offline storage)
2. Edge Transmission Layer	Enables stable transmission of field data to edge nodes, adapting to complex field environments	- **Wired transmission:** Industrial Ethernet (fibre optic/Ethernet cables, suitable for fixed equipment), RS485/RS232 (short-range device interconnection) - **Wireless transmission:** 4G/5G (high bandwidth, low latency), LoRa (low power consumption, long range, suitable for remote areas), Wi-Fi (short-range within workshops/substations)
3. Edge Processing Layer	Performs localised pre-processing of field data to reduce redundant data transmission and alleviate pressure on central platforms	- Edge computing nodes (industrial-grade servers / edge gateways): Support data cleansing, format conversion, anomaly detection, local storage - Edge Software: Data pre-processing algorithms, local alert logic (e.g., real-time alerts for equipment overheating)
4. Application Support Layer	Provides data interfaces for upper-layer systems while enabling local visualisation and management of field data	- Data interface module (API/SDK, integration with SCADA and reporting systems) - Local monitoring interface (supporting real-time data viewing and equipment status monitoring) - Configuration Management Module (remote configuration of data acquisition frequency and alarm thresholds)

7.1.8.2 Core Functional Design

1. Multi-source data acquisition capability (core of the perception layer)

Tailored acquisition strategies for diverse data types in power plant environments ensure data is comprehensive, accurate, and timely.

1） Automatic Collection (Core Scenarios):

- Equipment operational data: Collects transformer temperature, line current/voltage, switch status, etc., at configured intervals (e.g., 1 second/cycle, customisable). Supports three data formats: analogue (e.g., temperature 25°C), digital (e.g., switch "closed"/"open"), and numerical (e.g., electricity meter reading 1000kWh).
- Environmental Data: Collects temperature, humidity, wind speed, rainfall, and ice thickness (via ice sensors) around substations/lines every 5 minutes. Automatically increases collection frequency during extreme weather (e.g., every minute during heavy rain).
- Security Data: Real-time video recording via cameras (supporting motion detection, recording only during periods of activity), with access control systems logging personnel entry/exit times and identity information.

2） Manual Data Collection (Supplementary Scenarios):

Staff use handheld terminals (PDAs) to enter equipment inspection records (e.g., "insulators undamaged") and defect information (e.g., "switching noise") on-site. Supports photo/video upload; data is temporarily stored locally in offline mode ( ) and automatically synchronised upon network connection.

2. Stable Transmission and Resumable Transfer Functionality (Core Transmission Layer)

Resolves issues of weak transmission signals and frequent interruptions in power field environments, ensuring data integrity.

- Transmission Adaptation: Automatically identifies on-site network conditions, prioritising wired transmission (stable) where available. Switches to wireless (e.g., LoRa for remote lines) when wired is unavailable. Activates signal enhancement modules in areas with weak 4G/5G coverage.
- Resume-from-breakpoint: During transmission interruptions (e.g., wireless signal loss), the edge gateway temporarily stores un-transmitted data. Upon network restoration, synchronisation proceeds in the order "transmit older data first, then newer data" to prevent data omission or duplication.
- Data Encryption: SSL/TLS encryption protocols are employed during transmission to prevent data theft or tampering, complying with power industry data security standards.

3. Data Pre-processing and Anomaly Detection Functionality (Core Processing Layer)

Performs initial data processing at the edge to reduce uploads of invalid data while rapidly identifying anomalies to assist field operations and maintenance.

1） Data Pre-processing:

- Data cleansing: Automatically removes outliers (e.g., "voltage 9999V" caused by sensor faults), duplicates, and completes missing data (e.g., filling one missing value with the average of the preceding three readings).
- Format Conversion: Unifies heterogeneous data from different devices (e.g., Sensor A outputs JSON format, Sensor B outputs XML format) into standard power industry formats (e.g., IEC 61850) for seamless integration with upper-layer systems.

- Data compression: Compresses large-volume data such as video and historical records (e.g., employing H.265 encoding for video) to reduce transmission bandwidth consumption.

2） Anomaly Detection:

Edge nodes pre-set anomaly thresholds (e.g., transformer temperature ≥85°C constitutes an anomaly), continuously comparing collected data against these thresholds. Upon anomaly detection, immediate local alerts are generated (e.g., audible/visual alarms via edge gateways) while simultaneously pushing alert notifications to staff mobile applications, thereby shortening response times.

4. Equipment Management and Remote Control Functionality (Core Support Layer)

Enables full lifecycle management of field data acquisition devices, reducing manual maintenance costs.

- Device Status Monitoring: Remotely view operational status (e.g., "Online/Offline"), battery level (for wireless devices), and signal strength of collection devices (sensors, gateways). Offline devices are automatically geotagged for field troubleshooting.
- Remote Configuration: Supports remote adjustment of data collection frequency (e.g., from 5 minutes to 1 minute) and alarm thresholds (e.g., changing temperature anomaly threshold from 85°C to 80°C) without on-site intervention.
- Firmware upgrades: Enables remote batch firmware updates for data collection devices, eliminating the need for individual on-site upgrades and enhancing maintenance efficiency.

5. Field Data Aggregation and Plan Comparison Module (covering

"Comprehensive Information + Multi-Period Comparison")

Core implementation of full-cycle comparison for "data collection - task allocation - plan registration", supporting multi-dimensional filtering and visualised presentation.

1） Comprehensive Field Data Collection Information

Functionality: Consolidates comprehensive details from individual collection records, including "Collection Device Name (e.g., 10kV Switch), Collector, Collection Time, Collected Data (e.g., Voltage 10.5kV), Assigned Task, Planned Completion Time, Task Status (Completed / Overdue)".

Display: Supports filtering by "Equipment Type / Collection Area / Task ID". Clicking a record reveals the complete digital form data.

2） Field Data Collection Status Aggregated by Task

Functionality: Aggregates data by task number, displaying "Task Name, Planned Number of Devices to Collect, Actual Number of Devices Collected, Completion Rate (Actual/Planned), List of Uncollected Devices, Collector".

3） Multi-period data versus plan comparison (daily / weekly / monthly / quarterly)

Functionality: Automatically aggregates "Planned collection volume (registration plan), Task allocation volume, Actual collection volume" by cycle, calculates deviation rate (Deviation rate = (Actual - Planned) / Planned × 100%), supports chart display (bar chart comparison, line chart trends).

Period	**Core Display Content**
Daily	Date, planned collection devices, assigned tasks, actual collection count, daily deviation rate, list of uncompleted tasks
Weekly	Week number (e.g., Week 30 of 2024), weekly planned total, weekly allocated total, weekly actual total, weekly deviation rate, week-on-week

	change
By Month	Month, Monthly planned total, Monthly allocated total, Monthly actual total, Monthly deviation rate, Year-on-year change, Proportion of overdue tasks
By quarter	Quarter (e.g. Q3 2024), quarterly planned total, quarterly allocated total, quarterly actual total, quarterly deviation rate, regional ranking

6. Grid Map Data Integration Module (covering "Map Data Integration + Offline Download")

Core implementation links collected data with maps, supports permission-based offline downloads to meet field operations without network connectivity.

1） Integrates grid map data collected from field records

Functionality: Associates each device's collection record (including GPS positioning data) with vector grid maps, marking device locations on the map. Clicking a marker displays "Device Type, Collected Data, Collection Time, Collector".

Map Layers: Supports switching between "Base Map (Satellite/Vector), Grid Layers (Transmission Lines/Substations/Poles), and Collection Status Layer (Collected/Pending)".

2） Offline map downloads configured by permission

Permission Control: Based on the RBAC model, administrators can configure "Role - Map Scope" permissions (e.g., "Maintenance Officer A" may only download "XX Area 10kV Grid Map").

Downloadable content:

- Offline base maps: Supports downloading satellite imagery/vector maps for designated areas, optimised for offline viewing.

- Offline grid map data: Contains the locations and basic information (equipment name, type) of collected devices within the area. After downloading, it enables offline viewing and device location tracking within the app.

7. Comprehensive digital data collection form module for all equipment (covering 15 equipment categories)

Standardised digital forms designed for each category of electrical equipment, with fields tailored to on-site collection requirements. Supports mandatory field validation and data format restrictions (e.g., numerical ranges) to prevent manual input errors.

Equipment Type	Core Data Fields
Switchgear	Equipment ID, Model, Rated Voltage, Rated Current, Switching Status, Maintenance Date, Collector, Remarks
Metering Equipment	Meter ID, Model, Installation Location, Measurement Accuracy, Current Reading (Active / Reactive), Communication Status, Collection Time
Capacitor Bank	Bank number, capacity (kVar), operational status, insulation resistance, operating temperature, defect description
Substation	Substation name, address, voltage level, main transformer capacity, commissioning year, current operational status, data collector
Boundary Meter	Meter serial number, associated circuit, ownership (customer / utility), metering range, current reading, collection time
Connected Equipment	Equipment number, type (connector / terminal block), material, specifications, installation location, fastening status
Electricity Pole	Pole number, material (concrete / steel), height (m), burial depth (m), line affiliation, inclination angle, defect location
Transmission line	Line name, voltage level, length (km), conductor type, number of towers,

	years in operation, icing conditions
Cable trench	Trench number, length (m), burial depth (m), water accumulation status, number of cables, fire prevention measures, inspection records
Substation Compound	Site area, integrity of perimeter fencing, number of firefighting facilities, earth resistance value, landscaping status, security equipment condition
Telecommunications lines	Line number, type (fibre optic cable / cable), number of cores, transmission rate, connected sites, signal strength
Terminal Equipment	Terminal number, model, installation location, communication protocol, online status, data collection cycle, battery charge level
Connection points	Point number, associated equipment, connection method (bolt / weld), contact resistance, oxidation condition, tightening torque
Accessories	Accessory number, name (e.g. insulator / arrester), model, installed equipment, manufacturer, replacement date
Transmission Equipment	Equipment number, type (switch / router), number of ports, transmission bandwidth, operating temperature, fault history

8 Task Management Module (covering "Listing - Assignment - Execution - Approval")

Enables end-to-end closed-loop management of field data collection tasks, eliminating task omissions and unclear accountability.

1） Pending Equipment Collection List Management

Functionality: Automatically synchronises with the equipment ledger system to generate a "Pending Collection Equipment List", detailing "Equipment Name, Type, Location, Scheduled Collection Time, Priority (High/Medium/Low)", with support for manually adding temporary pending collection equipment.

2） Task Allocation and Acceptance

Assignment: Administrators select "Devices Awaiting Collection", designate "Collector, Completion Deadline, Collection Requirements (e.g. photography required)", generate tasks and push them to the collector's app.

Acceptance: Upon receiving task notifications, collectors may "Accept" or "Return" (requiring reason, e.g., "No access to device area"). Accepted tasks transition to "Pending Execution" status.

3） Task Execution and Registration

Execution: Collectors input data on-site via digital forms, supporting photo/video uploads (e.g., defect documentation). Upon submission, task status changes to "Pending Registration".

Registration: The system automatically links collected data to the task, generating a "Task Execution Record" containing "Collected Data, Attachments, Execution Duration". Manual supplementation is supported for special circumstances (e.g., "Equipment temporarily unavailable for collection").

4） Task Approval / Rejection

Approval: Administrators review the completeness and accuracy of collected data in "Pending Registration Tasks". If compliant, they "Approve" the task, changing its status to "Completed"; if non-compliant, they "Reject" it (requiring a reason, e.g., "current data missing"), returning the task to "Pending Execution" status.

9 Field Data Collection and Surveying Module (covering "Collection - Surveying - Map Display")

Supports practical field operations to ensure precise correlation between collected data and location information.

1） Field Data Collection Functionality

Functionality: Field personnel open digital forms for corresponding equipment via the mobile application, supporting both manual entry and QR code scanning (for equipment identification). Mandatory fields must be completed before submission. Data is temporarily stored locally in real-time (offline mode) and automatically synchronised to the platform upon reconnection.

2） Field Data Collection Surveying Function

Functionality: Integrates GPS positioning (accuracy ≤5 metres) and laser ranging (suitable for utility pole height/line distance measurement). Automatically records equipment latitude/longitude coordinates during collection, with manual position adjustment supported (e.g., during weak GPS signal). Generates surveying coordinates linked to collected data.

3） Display collected equipment locations on map

Functionality: Displays collected equipment with "green markers" and pending equipment with "red markers" on the grid map. Supports filtering markers by "collection time / equipment type". Clicking a marker allows viewing the full collection record and attachments (photos / videos) at .

10+-dimensional statistical reporting module (covering "session - task - cycle" reports)

Automatically generates standardised reports, supporting online viewing and export (Excel/PDF), to assist management decision-making.

1） Report aggregating collection data by work session

Definition: "Work session" denotes a single field operation by a collector (from app login to logout). Reports display: "Session ID, Collector, Session Duration (Start - End), Number of Devices Collected, Data Volume Collected, Number of Anomalies (e.g., out-of-range values)".

2） Statistical report on data collection by assigned task

Content: Statistics by task ID for "planned collection volume, actual collection volume, completion rate, collection duration, number of attachments (photos/videos), approval outcome (number of approvals/rejections)", with support for grouping by "collector/time period".

3） Periodic comparison statistical report (daily / weekly / monthly / quarterly)

Content: Derived from the same data source as Module 1.3, generating standardised reports including: "Planned total volume within the period, allocated total volume, actual total volume, deviation rate, list of uncompleted tasks, regional completion rate rankings". Can be automatically sent to administrator email addresses.

11 Data Synchronisation Module (covering "offline-online" data synchronisation)

Ensures offline field data collection is not lost, automatically synchronising upon online status to guarantee data integrity.

1） Offline Data Temporary Storage and Synchronisation

Offline caching: Forms completed and attachments photographed by fieldworkers in areas without network coverage are automatically cached locally on the mobile device at , marked with a "Pending Synchronisation" status.

Automatic Synchronisation: Upon device reconnection, the system automatically synchronises data in the order of "older data first, then newer data". Upon completion, the status updates to "Synchronised". Manual synchronisation can be triggered for urgent data.

2） Data Consistency Verification

Functionality: During synchronisation, the system compares local data with the platform's data version. Should conflicts arise (e.g., data collected by two individuals using the same device), it applies the "timestamp priority (new data overrides old data) + manual confirmation" approach to prevent data inconsistencies.

7.1.9 Data Integration and Management Subsystem

7.1.9.1 System Architecture Design (Layered Architecture + Microservices)

Adopts a "five-layer architecture + microservices" model to ensure system flexibility and scalability, with clear responsibilities and decoupling between layers. The specific architecture is as follows:

Architectural Layers	**Core Functionality**	**Key Components / Technical Support**
1. Data Source Layer	Interfaces with data sources across the entire electricity business chain, providing raw data for integration	- Real-time data sources: SCADA systems (equipment operational data), field data acquisition subsystems (form data collection), metering systems (energy consumption data) - Batch Data Sources: ERP systems (financial/HR data), equipment ledger systems (basic equipment information), operations and maintenance systems (maintenance records) - Access Methods: Direct database connection, API, Kafka message queue, FTP/SFTP files, OPC UA (industrial protocol)
2. Data Integration Layer	Enables collection, transmission, and temporary storage of multi-source data, supporting both real-time and batch integration modes	- Real-time integration: Kafka (data transmission), Flink (stream processing collection), OPC UA Client (industrial equipment interfacing) - Batch Integration: Spark (batch ETL), DataX

		(cross-database synchronisation), FTP Client (file retrieval) - Temporary Storage Components: Kafka Topic (real-time data staging), HDFS (batch data staging)
3. Data Governance Layer	Performs data cleansing, standardisation, integration, and lineage management to establish a unified data model	- Data cleansing: Rule engine (removal of outliers, imputation of missing values) - Data Standardisation: Code Table Management (unified coding for equipment types, voltage levels, etc.) - Data Integration: Entity Matching (correlating data from multiple systems for the same equipment) - Data lineage: Atlas (records data sources and processing chains) - Storage Components: Hive (data warehouse for historical data), InfluxDB (time-series data for operational data), MySQL (structured business data)
4. Data Service Layer	Encapsulates governed data into standardised services for upper-layer system invocation	- Service Types: API Services (RESTful API), Data Marts (thematic repositories e.g., "Equipment Operations Mart", "Energy Consumption Statistics Mart"), File Services (Excel/PDF export) - Supporting Components: Spring Cloud Gateway (API Gateway), Swagger (API Documentation), Redis (Service Caching)
5. Application and Monitoring Layer	Provides data integration configuration, monitoring, and management interfaces to support	- Configuration Interface: Integration task configuration, data model management, API permission configuration - Monitoring Interface: Data ingestion volume

	upper-layer business applications	monitoring, governance quality monitoring, service call monitoring - Supporting Components: Grafana (monitoring visualisation), Prometheus (metric collection), ELK (log analysis)

7.1.9.2 Core Functional Design

1. Multi-source data ingestion capability (core of the integration layer)

Design differentiated ingestion strategies for diverse power sector data sources to ensure rapid, lossless data acquisition.

1） Real-time Data Ingestion

Functionality: Interfaces with real-time data sources such as SCADA and field data acquisition subsystems. Utilises the OPC UA protocol to collect high-frequency data (e.g., equipment voltage, current, switch status) at configurable intervals ranging from 1 second to 5 minutes. Transmits data via Kafka message queues to the integration layer, temporarily storing it in Kafka Topics to prevent data backlogs.

2） Batch Data Ingestion

Functionality: Integrates with bulk data sources such as ERP systems and equipment ledgers, supporting scheduled (daily at 2:00 AM) or manual triggering of ETL tasks. Utilises DataX cross-database synchronisation and FTP retrieval of Excel files to batch-import data into HDFS staging areas, with support for resume-from-breakpoint functionality (tasks may be restarted and continue from the point of interruption).

Supported data source types: Relational databases (MySQL, Oracle, SQL Server, PostgreSQL), CSV/Excel/TXT files, FTP/SFTP servers.

3） Task Management Integration

Functionality: Supports visual configuration of integration tasks (select data source, set collection frequency, define field mapping), view task status (Running / Successful / Failed), automatic retry for failed tasks (configurable up to 3 retries), and generation of failure logs (e.g., "Database connection timed out").

2. End-to-End Data Governance Capabilities (Core Governance Layer)

Resolves issues of "dirty, disordered, and substandard" power data by establishing unified data standards to ensure data usability.

1） Data cleansing

Rule configuration: Supports configuring standardised cleansing rules, such as "Outlier removal (voltage > 380V deemed abnormal), Missing value imputation (fill with average of previous 3 readings), Duplicate value deduplication (by equipment ID + collection time)".

Automatic Execution: Cleaning rules are linked to ingestion tasks, triggering automatic processing upon data arrival. Results are documented in a Data Cleaning Report (including cleaned data volume and causes of anomalies).

2） Data Standardisation

Code Table Management: Establishes unified code tables for the power industry, e.g., "Equipment Type Code Table (01 = Transformer, 02 = Switchgear), Voltage Level Code Table (01 = 110kV, 02 = 35kV)", supporting manual addition/modification of code values.

Format Standardisation: Convert heterogeneous data from different systems into standard formats, such as "Uniform date format: YYYY-MM-DD HH:MM:SS, numerical values retained to two decimal places".

3） Data Integration and Modelling

Entity Fusion: Link data from different systems for the same equipment (e.g., SCADA operational data + foundational information from equipment ledgers) using unique identifiers such as "Equipment Number" or "Asset ID", generating a "360° Equipment View".

Data Model Construction: Establish three core thematic models to support upper-layer applications:

Equipment Model: Includes fundamental equipment details (ID, model, affiliated unit), operational data (voltage, current), and maintenance records (repair logs, servicing intervals).

Energy Consumption Model: Includes regional energy consumption (by voltage level/customer type), loss data (line loss rate, energy loss rate), and metering data (electricity consumption, power supply volume).

Task Model: Includes collection tasks (planned/actual collection volumes), O&M tasks (task allocation/execution status), and approval tasks (approval/rejection records).

4） Data lineage management

Functionality: Automatically records the "source (e.g., a specific device within the SCADA system), processing steps (cleaning rules, fusion procedures), and destination (e.g., writing to device models/API service calls)" for each data point. Supports visualisation of lineage links (e.g., "clicking on a device's current data reveals the acquisition time and cleaning rules from SCADA"), ensuring data traceability.

3. Standardised Data Service Functionality (Service Layer Core)

Encapsulates governed data into user-friendly services to meet diverse requirements of upper-layer systems while ensuring service security.

1） API Services

Service Generation: Support rapid generation of RESTful APIs based on data models, such as "Retrieve a device's operational data for the past 7 days API" or "Retrieve monthly energy consumption statistics API", with automatic generation of Swagger documentation (including parameter descriptions and response examples).

Permission Control: Configure API access permissions based on the RBAC model, such as "Reporting systems may only call energy consumption statistics APIs, while operations systems may only call device maintenance APIs", preventing unauthorised access.

Cache Optimisation: High-frequency API calls (e.g., real-time device status queries) are automatically cached in Redis with configurable expiry times (e.g., 5 minutes), reducing database load and improving response times.

2） Data Mart Services

T hematic Marketplace: Construct data marketplaces by business theme, such as the "Equipment Maintenance Marketplace" (containing equipment maintenance, servicing, and fault data) and the "Energy Consumption Statistics Marketplace" (containing energy consumption data by voltage level and customer type). Supports filtering data by "time range, region, and equipment type".

Marketplace Export: Supports exporting marketplace data to Excel/PDF formats, with scheduled export capabilities (e.g., automatic daily export of previous day's energy consumption data to a designated FTP server at 8:00).

3） Data Subscription Service

Functionality: Enables upper-tier systems to subscribe to specific data (e.g., "Subscribe to 110kV transformer fault data"). Updated data is automatically pushed to subscribing systems (via Kafka/HTTP callbacks), eliminating redundant queries and reducing resource consumption.

4. End-to-End Monitoring and Management Functionality (Core Monitoring Layer)

Real-time monitoring of the entire data integration process enables prompt issue detection and resolution, ensuring stable system operation.

1） Data Ingestion Monitoring

Monitoring Metrics: Ingestion task status, data ingestion volume (per second/daily), ingestion latency, failure rate.

Anomaly Alerts: Trigger alerts (SMS/email/system notifications) when ingestion failure rate exceeds 1% or latency exceeds 10 seconds, displaying failure reasons (e.g., "Database connection timed out").

2） Data Governance Monitoring

Monitoring Metrics: Data cleansing volume, standardisation completion rate, data accuracy rate, integration matching success rate.

Quality Reports: Daily generation of the Data Quality Report, displaying accuracy rates for each data source (e.g., "SCADA data accuracy 99.8%, equipment ledger data accuracy 99.5%). Low-quality data (accuracy <95%) is annotated with reasons and forwarded to responsible departments.

3） Data Service Monitoring

Monitoring Metrics: API call volume, call success rate, response latency, cache hit rate.

Service Alerts: Trigger alerts when API call failure rate exceeds 0.5% or response latency exceeds 500ms. Supports viewing call logs (e.g., "Parameter error during API call by a certain system").

4） System Management Functions

Configuration Management: Supports configuration of data source connection details (database IP, credentials), ingestion task parameters (collection frequency, retry count), and alert rules (thresholds, notification methods).

Log Management: Stores comprehensive system logs (access logs, governance logs, service logs), supporting retrieval by "time, module, log level". Log retention periods are configurable (e.g., 6 months).

5 Data Integration Configuration and Scheduling (covering "Configuration - Scheduling - Recording - Reporting")

Enables full lifecycle management and scheduling of synchronisation sources, ensuring configurable, traceable, and monitorable integration processes.

1） Synchronisation Source List Management

Functionality: Supports manual addition/removal of synchronisation sources, categorised by "type" (e.g., "device-class synchronisation sources", "external system synchronisation sources"). Each synchronisation source category is annotated with "name, data source type (database/API), affiliated system (e.g., device ledger/CMIS), connection status (online/offline)".

2） Synchronisation Source Detailed Configuration

Functionality: Configure core parameters for each synchronisation source:

Connection Configuration: Configure JDBC connection details for database synchronisation sources; configure interface URL, request headers (Token), and timeout settings for API synchronisation sources.

Data Configuration: Select tables/fields for synchronisation (e.g., for switchgear sources: "Equipment ID, Model, Rated Voltage") and filtering conditions (e.g., "Synchronise only switchgear rated 110kV and above").

Scheduling Configuration: Set synchronisation frequency (e.g., "Synchronise hourly" or "Full synchronisation daily at 02:00") and synchronisation mode (full/incremental; incremental synchronisation filters by "Update Time").

3） Synchronisation History Management

Functionality: Automatically logs each synchronisation task's "Task ID, Synchronisation Source Name, Synchronisation Time, Synchronisation Type

(Full/Incremental), Synchronised Data Volume (Successful/Failed Records), Failure Reason (e.g., "Database Connection Timeout")". Supports retrieval by "Time Range, Synchronisation Source". Log retention period is configurable (e.g., 6 months).

4） Synchronisation Status Reporting

Functionality: Automatically generates synchronisation status reports by day/week/month, containing:

Core Metrics: Total synchronisation tasks, successful tasks, failed tasks, success rate, average synchronisation duration.

Detailed Data: List of failed synchronisation sources, failure cause statistics (e.g., "Database timeouts account for 60%"), top 5 synchronisation sources by data volume.

Output Methods: Supports online viewing and Excel export, with configurable scheduled delivery to administrator email.

6 API Development for 10 Device Categories (Covering "Catalogues + Technical Specifications + Operational Data")

For each device category, develop standardised RESTful APIs with unified interface specifications (request methods, parameter formats, response formats) to ensure seamless data retrieval by upper-layer systems.

Device Type	**API Name**	**Core Request Parameters**	**Core Response Fields**	**Data Source**
Switchgear	1. Retrieve Switchgear Catalogue API	Equipment ID (optional), Voltage Level (optional)	Equipment ID, Name, Model, Responsible Unit, Installation Location,	Equipment Ledger System

			Commissioning Date	
	2. Switchgear Technical Specifications Retrieval API	Equipment ID (mandatory)	Rated voltage, rated current, closing/opening time, insulation rating, protection rating, manufacturer	Equipment Ledger System
	3. Switchgear Operational Data Retrieval API	Equipment ID (Required), Time Range (Optional)	Acquisition Time, Closing/Opening Status, Real-time Current, Real-time Voltage, Temperature, Fault Signals	SCADA System
Metering Equipment	1. Retrieve Metering Equipment Directory API	Meter number (optional), installation location (optional)	Meter number, model, type (active/reactive), associated circuit, ownership status	Metering Equipment Ledger System
	2. Retrieve Metering Equipment	Meter Serial Number (Required)	Metering accuracy, rated voltage, rated	Metering Equipment Ledger System

	Technical Specifications API		current, communication protocol, maximum measurement range	
	3. Retrieve Metric Equipment Operational Data API	Meter ID (Required), Time Range (Optional)	Collection Time, Active Reading, Reactive Reading, Power Factor, Voltage/Current RMS	Electricity Information Collection System
Capacitor Bank	1. Retrieve Capacitor Bank Directory API	Group number (optional), substation (optional)	Group number, name, affiliated substation, installation location, commissioning date	Equipment Ledger System
	2. Retrieve Capacitor Bank Technical Specifications API	Group Number (Required)	Rated Capacity (kVar), Rated Voltage, Number of Phases,	Equipment Ledger System

			Insulation Resistance, Manufacturer	
	3. Retrieve Capacitor Bank Operational Data API	Group Number (Required), Time Range (Optional)	Collection Time, Operational Status, Operating Temperature, Voltage, Current, Reactive Power	SCADA System
Substation	1. Retrieve Substation Directory API	Substation Name (Optional), Voltage Level (Optional)	Substation name, address, voltage level, number of main transformers, commissioning year, affiliated organisation	Substation Ledger System
	2. Substation Technical Specifications Retrieval API	Substation Name (Required)	Total Main Transformer Capacity (MVA), Site Area, Building Area, Fire	Substation Ledger System

			Protection Rating, Earth Resistance Value	
	3. Substation Operational Data Retrieval API	Substation Name (Required), Time Range (Optional)	Collection Time, Main Transformer Load Factor, Busbar Voltage, Total Power Supply, Total Power Consumption, Power Factor	SCADA System
Boundary Metering Point	1. Retrieve Boundary Meter Directory API	Meter ID (optional), Circuit (optional)	Meter ID, Associated Circuit, Ownership (Grid / Consumer), Installation Location, Commissioning Date	Metering Ledger System
	2. Retrieve Boundary Meter Technical Specifications	Meter Number (Required)	Metering accuracy, rated voltage, rated current,	Metering Ledger System

	API		communication method, data upload frequency	
	3. Retrieve Boundary Meter Operational Data API	Meter ID (Required), Time Range (Optional)	Collection time, active reading, reactive reading, line loss rate, voltage deviation value	Electricity consumption information collection system
Connected Devices	1. Retrieve Connected Device Directory API	Device ID (optional), Type (optional)	Equipment ID, Name, Type (Connector / Terminal Block), Associated Equipment, Installation Location	Equipment Ledger System
	2. Retrieve Connected Device Technical Specifications API	Device ID (Required)	Material, Specification (Model), Rated Current, Contact Resistance, Protection Rating	Equipment Register System
Poles	1. Retrieve Pole	Pole Number	Pole Number,	Line Ledger

(Electricity Poles)	Catalogue API	(Optional), Circuit (Optional)	Associated Circuit, Material (Concrete / Steel), Height (m), Burial Depth (m), Commissioning Date	System
	2. Retrieve Pole Technical Specifications API	Pole Number (Required)	Wind resistance rating, compressive strength, top diameter, bottom diameter, service life	Line Ledger System
Transmission Line	1. Transmission Line Directory Retrieval API	Line Name (Optional), Voltage Level (Optional)	Line Name, Voltage Level, Starting Station, Ending Station, Length (km), Commissioning Date	Line Ledger System
	2. Transmission Line Technical Specifications Retrieval API	Line Name (Required)	Conductor Type, Number of Conductor Splits, Lightning	Line Ledger System

			Conductor Type, Number of Towers, Insulation Level	
	3. Transmission Line Operational Data Retrieval API	Line Name (Required), Time Range (Optional)	Collection Time, Line Current, Line Voltage, Power Factor, Ice Thickness (Extreme Weather), Vibration Amplitude	SCADA / Line Monitoring System
Substation Site / Platform	1. Site Directory Retrieval API	Site Name (optional), Substation (optional)	Site Name, Associated Substation, Area (m²), Functional Zones (Main Transformer Zone / Switching Zone), Commissioning Date	Substation Ledger System
	2. Site Technical	Site Name (Required)	Floor load capacity,	Substation Ledger System

	Specifications Retrieval API		firefighting facility configuration, perimeter wall height, security equipment count, drainage capacity	
Cable Trench	1. Retrieve Cable Trench Directory API	Trench ID (optional), Area (optional)	Trench ID, assigned area, length (m), burial depth (m), number of cables laid, commissioning date	Cable Ledger System
	2. Retrieve Cable Trench Technical Specifications API	Trench Number (Required)	Cross-sectional dimensions (width × height), material (concrete / brickwork), waterproofing grade, ventilation method, fire	Cable Inventory System

			protection measures	

API Standard Specification:

- Request Methods: GET (Retrieval), POST (New Entry, not applicable at present).
- Parameter Transmission: URL path parameters (e.g., /api/switch/tech-spec/{equipment ID}) or query parameters (e.g., /api/switch/catalog?voltage_level=110kV).
- Response Format: JSON, containing code (status code, 200 = success), message (description), data (core data).
- Authorisation Control: Token-based authentication. Accessible API scope for different roles (e.g., Operations Personnel / Administrators) is configured via RBAC.

7.1.10 Public Data Processing and Sharing Service Subsystem

7.1.10.1 Public Data Scope Definition

Firstly, clearly define the boundaries of public data within the power industry, excluding user privacy (e.g., individual electricity consumption details) and core operational maintenance data (e.g., SCADA real-time control data). The core scope is as follows:

Data Categories	**Specific Content**
Basic Public Grid Data	Substation/transmission line geographical locations (de-identified to regional level), voltage level distribution, public charging facility locations and operational status
Public Electricity Consumption	Regional electricity consumption totals (by city/district, excluding individual users), sectoral electricity consumption shares (industrial/commercial/residential),

Statistics	monthly/quarterly electricity consumption trends
Service-Related Public Data	Power Outage Notices (area, time, cause), Electricity Service Application Guides, Bill Payment Channels, Energy Conservation Service Policies
Regulatory Public Data	Power Industry Energy Efficiency Metrics (Regional Line Loss Rate, Renewable Energy Absorption Rate), Public Supply Reliability Data (SAIDI/SAIFI)

7.1.10.2 System architecture design ("Five-layer, Three-horizontal" architecture)

Adopting a five-layer architecture—"Data Source Layer → Data Processing Layer → Scenario Utilisation Layer → Shared Service Layer → Security Control Layer"—overlaid with three horizontal support layers—"Standards & Specifications, Operations Monitoring, User Management"—ensures the flexible and scalable " " framework:

Architectural Layers	Core Functions	Key Components / Technical Support
1. Data Source Layer	Aggregates internal public data (e.g., marketing system statistics, O&M system outage data) and external public data (e.g., government energy statistics)	Marketing System, Operations and Maintenance System, Government Open Platform, Public Charging Infrastructure Management System
2. Data Processing Layer	Performs public data cleansing, standardisation, de-identification, and modelling to produce usable public datasets	Big data processing platform (Hadoop/Spark), data anonymisation tool (Yisaitong), data model management module
3. Scenario Utilisation Layer	Implement public data utilisation scenarios for government, enterprise, and public users, developing scenario-specific application	Government regulatory reporting engine, enterprise energy efficiency analysis tools, public

	functionalities	service applications/mini-programmes
4. Shared Services Layer	Provides diverse sharing methods, managing sharing authorisations and access requests	API Gateway (Spring Cloud Gateway), Open Data Platform (in-house development), Data Mart (ClickHouse)
5. Security Control Layer	Implements data classification, permission controls, transmission encryption, and operational auditing to ensure shared data security	Data classification module, RBAC permission system, SSL/TLS encryption, audit logging system (ELK)
Horizontal 1: Standards and Specifications Layer	Establishes public data classification standards, processing specifications, and sharing workflow protocols	Guidelines for Classification and Grading of Public Power Data; Public Data Sharing Operations Manual
Horizontal 2: Operations and Monitoring Layer	Monitor data processing pipelines, shared service statuses, and security incidents to generate operational reports	Prometheus (metrics collection), Grafana (monitoring dashboard), security alerting module
Horizontal 3: User Management Layer	Manage government/enterprise/public user accounts and maintain user role-to-permission mappings	Single Sign-On System (OAuth 2.0), User Role Management Module

7.1.10.3 Core Functionality Design

Module 1: Public Data Processing Functionality (Core of Data "Usability")

Addressing the characteristics of public power sector data – diverse sources, inconsistent formats, and requiring anonymisation – a comprehensive processing mechanism has been designed:

1） Data Aggregation

Automatic Aggregation: Utilises API interfaces and direct database connections to periodically (e.g., hourly) retrieve regional electricity consumption statistics from marketing systems and power outage announcements from operations systems, supporting incremental synchronisation (only updating changed data).

Manual Supplementation: For offline public data (e.g., energy conservation policy documents), administrators can upload Excel/Word files. The system automatically extracts textual data and structures it.

2） Data Cleansing and Standardisation

Cleansing Rules: Automatically removes outliers (e.g., negative regional electricity consumption), fills missing values (using the average of the preceding three entries), and deduplicates records (by "data type + time + region"). Rules are configurable via visualisation.

Standardisation: Unifies data formats (e.g., dates as "YYYY-MM-DD", numerical values rounded to two decimal places) and labels data levels according to the "Guidelines for Classification and Grading of Public Power Data" (e.g., "Public Access Level", "Authorised Access Level").

3） Data De-identification and Anonymisation

De-sensitisation rules:

Geolocation de-identification: Substation locations displayed only as "XX District", without specific latitude/longitude coordinates;

Statistical Data Anonymisation: Regional electricity consumption aggregated only by "City/District", not broken down to street or neighbourhood level;

Text Desensitisation: Internal reference numbers in policy documents replaced with "*" (e.g., "Hubei Electric XX〔2024〕*").

De-identification Validation: Data must pass compliance checks (e.g., absence of individual user identifiers) prior to subsequent utilisation.

4） Public Data Modelling

Establish three core public data models to support scenario applications:

Basic Information Model: Includes grid infrastructure data (region, voltage level, facility type) and public facility data (charging station locations, operational status);

Statistical Analysis Model: Includes regional electricity consumption statistics (total volume, sectoral distribution, trends) and power supply reliability metrics (SAIDI/SAIFI, outage duration);

Service Interaction Model: Includes power outage announcements (area, time, cause, restoration progress) and service guides (application procedures, required documentation).

Module 2: Three-category user scenario utilisation functions (core of data 'value creation')

Implementing scenario-based applications tailored to diverse user needs, ensuring public data is "usable and effective":

1） Government-Side Utilisation Scenarios

Energy Regulation and Planning: Provides "Regional Electricity Consumption Trend Analysis Reports" and "Renewable Energy Absorption Rate Statistical Charts", supporting filtering by "Time (Monthly/Quarterly/Annual), Region, Sector". Governments may export data to Excel/PDF for energy regulation or planning formulation.

Emergency Coordination: Open access to "power outage event synchronisation interfaces" enables government emergency services to obtain real-time information on large-scale power failures (e.g., line outages caused by typhoons) for emergency resource deployment.

2） Enterprise-side application scenarios

Energy-saving services: Provide "industry electricity consumption benchmarks" (e.g., average electricity consumption per unit of output for industrial enterprises) and a "regional energy-saving policy repository". Enterprises can compare their own energy consumption against these benchmarks to obtain energy-saving retrofit recommendations.

Industrial Chain Collaboration: Open access to "Public Charging Infrastructure Status Data" (e.g., charging point availability/occupancy status) enables charging operators to optimise charging point deployment; Open access to "Regional Electricity Demand Trends" allows photovoltaic enterprises to forecast distributed PV grid connection requirements.

3） Public-facing Application Scenarios

Power Outage Query and Notification: Members of the public can input "area/estate" via the app/mini-programme to check planned power cuts for the next 7 days and the progress of current fault-related outages (e.g., "Power cut in XX Estate, expected restoration at 18:00"). Supports subscription to power cut notifications (SMS/push).

Electricity Usage Guidance Services: Provides "electricity bill payment channel enquiries," "electricity service application procedures (e.g., account transfers, capacity upgrades)," and "common electricity usage Q&As (e.g., 'How to reduce high air conditioner power consumption')." Supports voice search (e.g., "How do I check my electricity bill?").

Energy Conservation Education: Pushes "Household Energy Saving Tips" (e.g., "Setting refrigerator temperature to 5°C saves most electricity") and "Public Energy Saving Policies" (e.g., peak/off-peak tariff periods), assisting the public in reducing electricity costs.

Module 3: Diversified Shared Service Functions (Core of Data Circulation)

Offering four sharing methods to accommodate diverse user preferences while implementing tiered authorisation:

1） API interface sharing (for enterprises/government bodies)

API Types:

Statistical Data API: e.g., "Monthly electricity consumption total API for City X", "Power outage event API for District X";

Service Data API: e.g., "Retrieve Public Charging Facility Status API", "Subscribe to Power Outage Notifications API".

Sharing Process:

Users (enterprises/government bodies) submit API applications via the open platform (specifying purpose and required data types);

Administrator review (completed within 1 working day), followed by issuance of API key (Token) upon approval;

Users invoke APIs using the key; call volume and frequency are configurable (e.g., enterprise API calls ≤1000 per day).

2） Open Data Platform (for the public / micro-enterprises)

Functionality: Establishes web/app-based open platforms displaying "public-access level" data (e.g., power outage notices, electricity usage guides, regional consumption trend charts), supporting:

Online viewing: Present statistical data visually via line charts and bar graphs;

On-demand download: Public data exportable to Excel (e.g., "2024 Electricity Consumption Breakdown by Industry in XX City");

Interactive Enquiry: Members of the public may input "estate name" to check power outage information without registration or login.

3） Data Marketplace Sharing (for Key Partner Organisations)

Functionality: Establishes dedicated data marketplaces for key government departments (e.g., Development and Reform Commission, Emergency Management Bureau) and core partner enterprises (e.g., major renewable energy companies), providing "authorised-level" data (e.g., granular regional electricity consumption data, power outage contingency plans). Supports:

Customised Queries: Configure data filtering dimensions according to user requirements;

Scheduled Pushes: Automatically deliver previous day's electricity statistics to designated government email accounts daily at 9:00.

4） Offline Application for Data Sharing (for users without online capabilities)

Process: Users (e.g., community committees, small businesses) submit a paper Public Data Usage Application Form (specifying purpose and data type). Upon administrator approval, data is provided via email or offline delivery (e.g., USB drive copy, subject to confidentiality agreement signing).

Module 4: End-to-End Security Control Functionality (Core of Data "Securitisation")

Controls implemented across four dimensions—"classification, permissions, transmission, and auditing"—to ensure data sharing without compromise:

1） Data Classification Management

Classification Criteria: Public data is categorised as "Public Access" (e.g., electricity usage guidelines, power outage notices) or "Authorised Access" (e.g., regional electricity consumption statistics, charging station status). "Public Access" data is freely accessible, while "Authorised Access" data requires approval before release.

Classification Marking: Each public data category is labelled with its classification during processing, automatically triggering corresponding sharing workflows (e.g., "Authorised Level" initiates review).

2） Fine-grained Permission Control

Based on the RBAC model, configure the "User - Role - Permission" mapping:

Public Users: Access only "Public Level" data, utilising query and download functions;

Enterprise Users: Access "Authorised Level" data within approved scopes, limited to invoking pre-authorised APIs;

Government Users: Access "Authorised Level" data; certain key departments may apply for "Customised Data Marketplace" permissions.

3） Transmission and Storage Security

Transmission Encryption: API calls and data downloads employ SSL/TLS encryption to prevent data interception during transmission;

Storage Encryption: "Authorised-level" data is stored using AES-256 encryption with keys rotated periodically (every 3 months).

4） Operational Auditing and Alerts

Audit Logs: All sharing operations are recorded (e.g., "User A downloaded electricity consumption data for District XX", "Enterprise B invoked the power outage API"), including details of "user, time, operation, data type". Logs are retained for ≥6 months and are traceable.

Anomaly Alerts: Trigger alerts (via SMS/email to administrators) for abnormal activities such as "high-frequency API calls", "unauthorised IP access", or "bulk data downloads", and suspend the user's sharing permissions.

Module 5: Map Data Sharing Functionality (Covering 14 Layer Categories for Management and Sharing)

Core implementation of "configuration - sharing - permission control" for map layers, supporting role-based access to corresponding layers to meet both power grid operational and public sharing requirements.

1） Shared Management of Administrative and Geographical Base Map Layers

Layer Management Content:

Vector-based administrative base map layers: Manage vector boundaries for provinces/cities/districts/subdistricts, supporting zoom levels to view administrative divisions with annotatable administrative names;

Raster-based administrative base map layers: Manage satellite imagery-format administrative maps, supporting overlaying administrative boundary lines ( ).

Vector geographic base map layers: Manage vector features such as roads, rivers, and buildings; supports selectively displaying/hiding specific feature categories;

Raster-based geographic base map layer: manages high-definition raster terrain imagery (e.g., Google Earth imagery), supporting offline image downloads by region.

Sharing Configuration: Supports setting "Public Access Levels" (e.g., municipal administrative boundaries accessible to the public) and "Authorised Access Levels" (e.g., street-level boundaries accessible only to internal operations personnel), with configurable sharing validity periods (e.g., permanent sharing / temporary sharing for 1 month).

2） Specialised Base Map Layer Sharing Configuration

Topographic base map layer: Manage terrain data including contour lines, elevation, and slope. Supports sharing configuration by "region + accuracy" (e.g., 10-metre accuracy terrain data for mountainous transmission line areas, 50-metre accuracy for plains), intended for line designers;

Population Data Layer: Manages regional statistics including permanent residents and electricity account numbers, displayed as heatmaps. Supports sharing configuration at "Street/Community" granularity for power demand analysis.

Transportation Data Layer: Manages motorways, national highways, railways and other transport routes. Supports overlay display and is shared with grid construction planners (to avoid construction impacting traffic).

National/Administrative Boundary Layer: Manages national borders, provincial boundaries, and municipal boundaries, ensuring alignment with official data. Editing permissions are restricted to authorised personnel (e.g., grid planning departments), with public users granted view-only access.

3） Grid-Related Layer Sharing Configuration

Voltage Level Grid Layers:

High-Voltage Grid Layer (110kV and above): Manages high-voltage line routes and substation locations, annotates line names and voltage levels, shared with dispatchers and planners;

Medium-voltage grid layer (10kV): Manages medium-voltage lines and ring main unit locations, annotates line load factors, shared with operations and maintenance personnel and power supply scheme designers;

Low-voltage grid layer (0.4kV): Manages low-voltage lines and distribution transformer locations, annotates transformer station boundaries, and is shared exclusively with transformer station managers and on-site construction personnel.

Dynamic Grid Layer:

Grid Operational Status Layer: Displays real-time line current, voltage, and power factor with colour-coded status indicators (green = normal, yellow = overloaded, red = fault). Shared with dispatch personnel and operations/maintenance staff.

Grid Event Layer: Marks power outage events (red flashing), maintenance events (blue markers), and fault events (orange markers), displaying event timestamps and affected areas. Shared with O&M personnel and customer service staff (for resolving user enquiries).

Grid Personnel Activity Layer: Real-time display of personnel locations (requires personnel to carry positioning devices) and operational tasks (e.g., "Line Maintenance"), accessible only to task supervisors and safety inspectors to ensure operational safety management.

4） Map layer sharing permission controls

Role-based permission configuration:

Public users: Permitted to view only "public-level" layers (e.g., municipal administrative boundaries, major high-voltage grid routes , grid outage event zones);

Corporate users (e.g., renewable energy enterprises): Access to medium-voltage grid layers and population data layers for electricity consumption zones;

Internal Operations Personnel: Access to all voltage level grid layers, topographic layers, and operational personnel activity layers;

Permission activation method: Upon system login, layers within the user's authorised scope are automatically loaded. Unauthorised layers are hidden by default and cannot be manually enabled.

Module 6: Equipment Data Sharing Functionality (covering 12 equipment categories and on-site power supply information)

Core implementation of "configuration sharing - attribute querying - on-site power information aggregation" for device data, ensuring on-demand data sharing and traceability of on-site power information.

1） 12 Categories of Device Data Sharing Configuration Configure shared content by device type, supporting either "Full Attribute Sharing" or "Partial Attribute Sharing" (masking sensitive parameters):

Device Type	Shared Configuration Content	Sharing Permission Control
Switchgear	Shared equipment inventory (ID, location), attribute data (model, rated voltage, operational status); sensitive data such as "maintenance costs" masked	Internal operations personnel may view all attributes; external partners may only view device location and operational status
Metering Equipment	Shared inventory (meter serial numbers, installation locations), attributes (model, measurement accuracy, ownership); "user electricity consumption details" masked	Public may view ownership status of their own electricity meters; power supply personnel may view full attributes
Capacitor banks	Shared inventory (bank number, affiliated substation), attributes (rated capacity, commissioning date, operating temperature)	Access restricted to internal operations and dispatch personnel
Substation	Shared inventory (name, address, voltage level), attributes (main transformer capacity , number of outgoing circuits, fire protection rating)	Public access to substation name and address; internal personnel may access full attributes
Boundary Metering Point	Shared list (ID, affiliated circuit), attributes (metering accuracy, ownership, current reading)	Property owners (e.g., enterprises) may access full attributes; public access is restricted
Connected	Shared inventory (ID, associated equipment),	Accessible only to internal

equipment	attributes (material, specifications, fastening status)	maintenance personnel
Poles (Electricity Poles)	Shared inventory (pole number, associated circuit), attributes (material, height, burial depth, inclination)	Internal operations personnel may access all attributes; contractors may access location and height
Transmission lines	Shared inventory (line name, start/end points), attributes (voltage level, conductor type, number of towers)	Public access to line names and routes; internal personnel access to full attributes
Substation Compounds	Shared inventory (site name, affiliated substation), attributes (area, functional zones, security equipment)	Accessible only to internal management personnel
Cable Trench	Shared inventory (trench ID, affiliated area), attributes (length, burial depth, number of cables laid)	Accessible only to internal cable operations and maintenance personnel

2） On-site Power Information Design and Sharing

On-site power information aggregation: The system automatically aggregates four categories of on-site power information into a unified view:

- On-site Power Design Information Aggregation: Links design drawings, equipment lists, and load calculation documents, annotating design capacity and power supply methods;
- On-site Power Request Information Summary: Consolidates user-submitted power supply requests (e.g., "XX Residential Area 1000kW Load Increase Request"), including request time, area, and requirement description;
- On-site Power Supply Plan Construction Information Summary:

Consolidates plan approval status, construction progress (e.g., "Survey completed", "Equipment procurement in progress"), and estimated commissioning date;

- O n-site Power Supply Plan Implementation Personnel Allocation Information Aggregation: Consolidate responsible personnel for each phase (surveyors, designers, construction team leaders), contact details, and task deadlines;

Information sharing: Configured by "business phase" for access permissions. For instance, survey personnel may only view request details and allocation information; designers may access design details and survey data; construction personnel may review implementation details and scheme documentation.

Module 7: On-site Power Supply Scheme Design Functionality (Comprehensive Process Support)

Core support spans the entire workflow from "power supply request reception" to "scheme documentation preparation", enabling automated task allocation, data linkage, and process control.

1） Power Supply Request and Task Allocation

Receiving on-site power supply requests: Supports online submission (entering area, load requirements, contact details) or offline paper submissions processed by administrators into the system, with requests automatically assigned unique reference numbers;

Registering Site Power Requests: The system automatically registers request details, links to the grid map for the requested area (automatically locating the request address), and marks the status as "Pending";

Retrieve grid map for requested supply area: Clicking the request number automatically loads the medium/low-voltage grid layers and equipment distribution (e.g., nearby transformers, line loads) for design reference;

Assign preliminary design task: Administrators select designers within the system to assign preliminary design tasks (including request number and completion deadline), with the system automatically pushing task notifications to designers' accounts;

Receive preliminary design task assignment: Upon logging into the system, designers may view task details, request information, and grid maps, confirming acceptance or rejection (requiring justification, e.g., "incomplete load data").

2） Survey, Design and Scheme Adjustment

Allocation of site survey and data collection tasks: Upon completion of the preliminary design, administrators assign survey tasks to surveyors, specifying survey requirements (e.g., site topography, existing equipment capacity, verification of user loads).

Receiving field survey and data collection tasks: Surveyors receive assignments, conduct on-site surveys using mobile terminals, input survey data into the system (e.g., "Site permits installation of one additional 500kVA transformer"), and upload photographs/videos;

Designing on-site power supply solutions: Designers utilise survey data and grid diagrams to formulate solutions within the system (selecting equipment, planning cable routes, calculating loads), with support for plotting proposed routes on maps;

Collecting site information and data: The system automatically links survey data and request details to the plan. Designers may supplement additional data (e.g., equipment quotations, construction timelines);

Adjust the power supply plan based on survey findings: Should survey data conflict with the preliminary design (e.g., "Site topography precludes cable laying"), designers may modify the plan (e.g., switching to overhead lines), with the system recording modification history;

Compile site power supply proposal documentation: Upon finalising the proposal, the system automatically generates standardised proposal files (including design drawings, equipment lists, construction budgets, and approval forms), supporting export to Word/PDF formats.

Module 8: Map-Based On-Site Power Supply Solution Functionality (Map-Business Integration)

Core implementation integrates "map visualisation + power supply plan" to enhance design and review efficiency.

1） Permission-Based Map Access

Access grid maps according to user permissions: Upon login, the system loads corresponding grid layers based on user rights (e.g., designers load medium/low-voltage layers, surveyors load topographic layers), ensuring visible map data ( ) aligns with operational requirements;

Map Operations: Supports zoom in/out, panning, distance measurement (line length), and area measurement (substation site area) for scheme design purposes.

2） Viewing Grid Design Archives

Viewing Grid Design Archives on the Map: Clicking equipment/lines on the map automatically displays their design archives (e.g., "Transformer T1: 2023 design, capacity 500kVA, design unit XX");

Scheme comparison viewing: Supports overlaying "Existing Grid" and "Design Scheme Grid" on the map, distinguished by colour (Existing = black, Design = red), enabling intuitive comparison of scheme differences.

Module 9: On-site Power Supply Information Reporting Function (Automated Report Generation)

Core functionality for compiling and reporting power supply requirements and progress, supporting online viewing and export to assist management decision-making.

1） On-site Power Supply Demand Statistics Report

Report Content: Statistics by "Area (City/District/Street), Time (Month/Quarter/Year), User Type (Residential/Commercial/Industrial)" for: number of power supply requests, total load demand, processed/pending quantities, average processing duration.

Generation Method: System automatically aggregates data, supports manual selection of statistical dimensions to generate reports, presents data via charts (bar charts = regional demand comparison, line charts = monthly demand trends), supports export to Excel/PDF.

2） On-site Power Supply Progress and Implementation Status Report

Report Content: Statistics by "Scheme Number, Region, Implementation Stage (Survey / Design / Construction / Inspection -off)" for completed quantities per stage, overdue quantities, reasons for delay (e.g., "Equipment not delivered"), and number of schemes commissioned;

Generation Method: Real-time synchronisation of progress data across all stages, automatically generating daily/weekly/monthly reports. Supports viewing detailed progress for individual schemes (e.g., "Scheme A: Survey completed (1 September) → Design in progress (expected completion 10 September)"), with push notifications to administrator email.

7.2 Mobile Application System

7.2.1 Integrated System Management Subsystem

Module 1: Organisational Structure Management (Adapted for Power Sector Hierarchical Management)

Core implementation of mobile visual management for the power industry's five-tier organisational structure: "Headquarters - Provincial Company - Municipal Company - County Company - Work Team", supporting editing, querying, and filtering operations.

1） Manage organisational structure tree

Visual Presentation: Displays the entire organisational hierarchy in a tree structure, with default expansion of organisations within the administrator's current permission scope (e.g., a city company administrator defaults to expanding their city and subordinate county companies). Supports "one-tap expand/collapse" and "search navigation" (quickly locate corresponding nodes by entering organisation names).

Core Operations:

- Add Organisation: Select parent organisation (e.g., "XX City Company"), enter organisation name, type (e.g., "County Company", "Operations Team"), responsible person, and contact details. Submit to synchronise with the backend organisational management system.
- Edit Organisation: Click the organisation node to modify responsible person, contact details, etc. Supports "node relocation" (e.g., moving "XX Operations Team" from County Company A to County Company B). Hierarchical relationships update automatically post-adjustment.
- Disable Organisation: Perform the "Disable" operation on organisations

to be dissolved/merged (e.g., "XX Temporary Project Department"). After disabling, users under this organisation cannot log into the system, and the organisation node is marked grey (inactive) in the tree.

Power Adaptation: Supports filtering organisations by "voltage level" and "business line" (e.g., transmission, distribution, marketing). For instance, "Filter all 110kV operations-related organisations in XX Province" aligns with power sector classification management requirements.

Module 2: Application, Module and Function Management (Fine-grained Permission Control)

Manages core web/mobile applications, functional modules, and operational permissions for power systems, ensuring roles access only relevant functions in accordance with the power sector's "principle of least privilege".

1） Application and Module Management

Application List: Displays existing power applications (e.g., "Power Data Integration and Management Subsystem," "Field Data Collection APP"), annotated with application type (web/mobile), current status (enabled/disabled), and business domain affiliation (e.g., "Operations Management," "Data Sharing").

Module and Function Configuration:

- Clicking an application (e.g., "Field Data Collection APP") displays all subordinate modules (e.g., "Equipment Acquisition Module," "Data Synchronisation Module") and functional points (e.g., "Add Acquisition Form," "Export Acquisition Report").
- Supports enabling/disabling modules (e.g., disabling the "Export Collection Report" function prevents all users from accessing it); supports configuring "access periods" for modules (e.g., restricting access to the "Operations Module" to weekdays between 08:00-18:00).

2） Permission allocation (aligned with power industry roles)

Assign application/module permissions based on power roles (e.g., "Provincial Company Administrator", "County Company Operations & Maintenance Officer", "Team Data Collector"), supporting "batch selection" functionality (e.g., granting "Team Data Collector" permission to "Equipment Data Collection Module - Add/Edit Forms" while excluding "Data Deletion" permission).

Permission Effectiveness: Assignments synchronise in real-time to the backend permission system, with permissions automatically updating upon the user's next login. Supports "Permission Preview" (simulating a role's login to view accessible applications/modules), preventing permission assignment errors.

Module 3: Creating Shared Pages (Secure Information Sharing)

Core functionality supports creation of shared pages related to power system management (e.g., "Organisational Restructuring Notices", "Application Permissions Guidelines"), controlling sharing scope and validity periods to prevent information leakage.

1） Shared Page Creation

Page Editing: Provides a rich text editor supporting insertion of text, images (e.g., organisational restructuring diagrams), and links (e.g., redirecting to application download pages). Includes a default unified watermark for the power system (e.g., "XX Power System Management Platform").

Sharing Configuration:

- Select Sharing Scope: Configure by "Organisational Structure" (e.g., "Visible only to all administrators of XX City Company ") or "Role" (e.g., "Visible only to Operations & Maintenance roles"), with multiple selections supported.

- Set validity period: Choose "Permanent" or customise the duration (e.g., "1 October 2024 to 31 October 2024"). Pages automatically expire and become inaccessible upon expiry.
- Preview and publish: Preview the page before publishing. Upon confirmation, submit for publication. The system will automatically push notifications to users within the shared scope (mobile notifications).

2） Shared Page Management

Displays all created shared pages, showing title, sharing scope, validity period, and access count. Supports "Edit" (modify content/sharing scope), "Terminate Sharing" (expire early), and "View Access Log" (who accessed and when).

Module 4: Session Management (End-to-End Security Control)

Covers core scenarios including login, logout, passwords, user sessions, and account authentication, meeting the power industry's stringent security requirements to eliminate risks of account theft and session hijacking.

1） System Login Management (Multi-factor Authentication)

Login Methods: Supports "Username/Password + Two-Factor Authentication". Two-factor options include "SMS Verification Code" (linked to power employee mobile numbers) or "Biometric Authentication" (facial/fingerprint recognition, only enabled on the user's own device), eliminating risks arising from compromised credentials.

Login Controls:

- Geolocation Login Alert: When a login IP address differs from the user's usual IP (e.g., provincial power network IP), an SMS alert is triggered to the user. Login requires identity verification (e.g., answering a pre-set question like "Your assigned work team").

- Failed Login Restriction: After five consecutive incorrect password attempts, the account is temporarily locked for one hour. During this period, login is prohibited, but the account can be unlocked via "identity verification" (e.g., SMS verification code).

Power Sector Adaptation: Supports Single Sign-On (SSO). After logging in, users may directly access other power sector mobile applications (e.g., Field Data Collection APP) without repeated authentication.

2） System Logout Management

Active logout: Provides a "One-click logout" button. Upon clicking, it clears session information cached on the mobile device (such as Tokens) and returns to the login page. During logout, prompts "Retain login credentials?" (for expedited entry next time).

Automatic Logout: Supports configurable session timeout (default 30 minutes, adjustable by administrators). Upon timeout, automatically logs out and displays a prompt. For in-progress operations (e.g., editing organisational structure), a "Extend Session?" alert appears 5 minutes before timeout to prevent interruption.

3） Password Management (Enhanced Security Verification)

Password Change: Requires verification of "Current Password + SMS Verification Code". New passwords must comply with power security standards (8-20 characters, including uppercase/lowercase letters, numbers, and special symbols; excludes account ID/mobile number). The system provides real-time password strength assessment (Weak/Medium/Strong).

Forgotten Password: Retrieval via "mobile verification code + identity authentication" (e.g., entering affiliated organisation and employee ID). Password reset forces modification upon next login. Supports "password expiry reminders" (default 90-day expiry with 7-day advance notification).

4） User Session Management (Administrator Control)

Session Monitoring: Administrators may view the "Online User List" within their authorised scope upon login. This displays: username, login device (e.g., "Android - XX model industrial handset"), login time, IP address, and current operational module.

Abnormal Session Handling: Supports "Force Logout" (e.g., if an account logs in from an unusual location, clicking "Force Logout" immediately invalidates the session and expels the user from the system); supports viewing "Historical Session Logs" (login/logout records from the past 3 months, including abnormal login flags).

5） Account Authentication Management (Full Lifecycle Control)

Account Activation: Newly created power company employee accounts (e.g., newly hired operations personnel) require receiving an "activation SMS" via mobile device. Upon clicking the link to set an initial password and completing identity verification (uploading ID badge photo), the account becomes operational.

Account Status Management: Supports "freezing/unfreezing" accounts (e.g., freezing accounts upon employee departure to prevent data leakage). Reasons must be provided during freezing (e.g., "departure," "non-compliant operations"), and unfrozen accounts require administrator approval. Account status synchronises in real-time with the Power IAM system.

Authentication Method Management: Users may independently enable/disable "biometric authentication" (e.g., facial recognition login restricted to their personal mobile device). Administrators may mandate that high-privilege accounts (e.g., provincial company administrators) "must enable two-factor authentication", which cannot be disabled.

7.2.2 Device Lifecycle Information Management Subsystem

Module 1: System Information Aggregation (Device Status at a Glance)

Core functionality enables mobile visualisation of equipment statistics, supporting hierarchical drill-down to fulfil "overview-to-detail" management requirements.

1） Total Equipment Count Statistics (by Asset Management Status)

Statistical Dimensions: Categorised by core power asset management status, default display shows total equipment counts for five categories: "In Operation", "Standby", "Under Maintenance", "Awaiting Scrapping", and "Retired". Presented intuitively via pie charts/bar charts (e.g., "1,200 units in operation, accounting for 75%; 80 units under maintenance, accounting for 5%").

Hierarchical Drilldown: Supports clicking a specific status (e.g., "In Operation") to further drill down by "Equipment Type" (transformers, switches, metering devices, etc.) or "Voltage Level" (110kV, 35kV, 10kV) to refine the count. For example: "In-Service Equipment → In-Service Transformers → 110kV In-Service Transformers (35 units)".

2） 1.2 Equipment Lifecycle / Management Status Summary and Breakdown

Lifecycle Status: Covers the full cycle from "Planning → Procurement → Installation → Commissioning → Operational → Maintenance → Decommissioning". Statistics are provided for equipment quantities at each stage, with anomalies such as "Overdue for commissioning" or "Exceeded service life" flagged (e.g., "12 units exceeding service life, primarily 10kV switches").

Management Status Breakdown: Classifies states according to power operation and maintenance requirements, including "Normal, Abnormal, Faulty, Out of Service". Supports filtering by "Area" (e.g., XX Substation, XX Line).

Example: "5 abnormal units in XX area, comprising 3 metering faults and 2 capacitor bank anomalies".

Module 2: Equipment Notifications and Alarms (Instant Response to Anomalies)

Core implementation enables real-time mobile alerts for all equipment anomalies, supporting a closed-loop "Receive - View - Resolve" process to prevent operational delays.

1） Multi-type alert coverage

Alert Types	**Trigger Scenarios**	**Alarm Presentation Method**	**Alert Type**	**Trigger Scenario**
Equipment Operational Status Alarms	Switchgear "Abnormal Disconnection", Transformer "Oil Temperature Exceeds 85°C", Line "Current Overload"	Red pop-up window + vibration alert, with title marked "[Urgent] XX Equipment Operational Failure". Content includes equipment name, location, and abnormal metric (e.g., "Transformer #1 oil temperature 88°C, threshold ≤85°C")	Equipment Operational Status Alarms	Switchgear "Abnormal Trip", Transformer "Oil Temperature Exceeds 85°C", Line "Current Overload"
Equipment data input status alerts	Metering equipment "Data collection interrupted for over 2 hours", new equipment "Attributes	Yellow notifications with titles marked "[Reminder] XX equipment data anomaly", clicking redirects to the "Data Completion / Fault Troubleshooting" page	Equipment Data Input Status Alarms	Metering equipment "Data collection interrupted for over 2 hours", new equipment

	incomplete (missing rated voltage)"			"Attributes incomplete (missing rated voltage)"
Anomalous Device Metric Alerts	Capacitor bank "Power factor < 0.9"; Cable trench "Water accumulation exceeds warning threshold"	Orange notification, accompanied by "metric trend graph" (e.g., power factor variation over the past hour), with "Mark as Viewed" functionality	Anomalous Equipment Metric Alerts	Capacitor bank "Power factor < 0.9", Cable trench "Water accumulation exceeds warning threshold"
Equipment Health Rating Alerts	Equipment health rating downgraded from "Good" to "Fair"/"Poor" (calculated based on CHI index)	Red pop-up alert + SMS notification synchronisation, containing "Reason for health rating decline (e.g., 'reduced insulation resistance')" and "Recommended corrective action (e.g., 'schedule insulation testing')"	Equipment Health Rating Alert	Equipment health rating downgraded from "Good" to "Fair"/"Poor" (calculated based on CHI index)

2） Closed-loop alert resolution

Supports "alert tagging": After receiving an alert, it can be marked as "Pending Action", "In Progress", or "Resolved", with action notes added (e.g., "Inspection personnel dispatched for on-site investigation");

Status Synchronisation: Upon completion of resolution, the system automatically synchronises the equipment status to the backend, updating the alert status to 'Closed' while retaining resolution records (resolver, time, measures).

Module 3: Equipment Management (All Types + Full Lifecycle Control)

Covers 11 categories of equipment management and critical lifecycle operations (transfer/decommissioning/status updates), with role-based access permissions (e.g., "Substation maintenance personnel manage only on-site equipment").

1） Basic Equipment List Management

Role-Based Default Lists: Utilising an RBAC permission model, different roles load default equipment lists (e.g., "Line Maintenance Operators" default view includes poles, lines, and connection equipment for their assigned lines; "Substation Administrators" default view includes transformers, switches, and capacitor banks within the substation).

Filtering and Search: Supports searching by "Equipment Status (Operational/Under Maintenance)", "Voltage Level", and "Equipment ID". For example, entering "#3 Switch" enables rapid location of target equipment.

2） Project/Task-Based Device Management (PMIS Tree View)

Hierarchical Association: Synchronises PMIS project data, presenting a hierarchical structure of "Project → Work Task → Associated Equipment" (e.g., "XX Substation Expansion Project → #2 Main Transformer Installation → Associated Equipment: #2 Main Transformer, Associated Switchgear, Metering Equipment");

Task linkage: Clicking a device under a project displays associated task progress (e.g., "#2 Main Transformer installed, awaiting commissioning"). Supports updating device "task association status" (e.g., "Commissioning complete → Update to 'In operation, awaiting acceptance'").

3） Manage equipment on maps (location-based + scale)

Scale adaptation rules:

Small scale (e.g. 1:100,000): Displays regional-level equipment (substations, high-voltage lines) with "Operational / Faulty" status colour coding;

Medium scale (e.g., 1:10,000): Displays line segments, utility poles, and cable trench locations. Supports clicking lines to view "associated substation and voltage level";

Large scale (e.g. 1:500): Displays equipment details (e.g. switch positions within substations, meters/sensors on poles), annotated with equipment IDs;

Location interaction: Supports "map positioning" (GPS/BeiDou, accuracy ≤5 metres) for rapid identification of nearby equipment. Clicking equipment icons displays a pop-up showing "core status + quick actions" (e.g., "Pole #5: Operational → Quick actions: Update status / Flag anomaly").

4） Specialised Management for 11 Equipment Categories For core power equipment types, provides "attribute viewing - editing - attachment uploading" functionality, with core fields aligned to industry standards:

Device Type	**Core Management Content (Attributes + Operations)**
Switchgear	Attributes: Equipment ID, Model, Rated Voltage/Current, Switching Status, Maintenance Date; Operations: Update Switching Status, Upload Maintenance Report
Metering Equipment	Attributes: Meter ID, Measurement Accuracy, Current Reading, Communication Status; Operations: Complete Data Collection, Flag as "Metering Anomaly"
Capacitor Bank	Attributes: Bank number, rated capacity, power factor, operating temperature; Operations: Update health rating, link maintenance records
Substation	Attributes: Name, voltage rating, main transformer capacity, commissioning date; Operations: View station equipment inventory, update station operational status
Boundary Meter	Attributes: Serial number, ownership status, metering range, current reading; Operations: Record meter readings, mark "Ownership transfer"

Connected Equipment	Attributes: Serial number, type (connector/terminal), material, tightening status; Operations: Mark "Loose, requires tightening", upload inspection photographs
Electricity Pole	Attributes: Pole number, Material, Height, Burial depth, Tilt angle; Operations: Update tilt angle data, Record "Pole body defect"
Line / Circuit	Attributes: Line name, voltage level, length, conductor type; Operations: Mark "Line icing", link to fault repair records
Substation Site	Attributes: Area, functional zones, number of security devices; Operations: Update site inspection status, upload fire safety inspection reports
Cable Trench	Attributes: Trench ID, length, burial depth, water accumulation status; Operations: Flag "Excessive water accumulation", record dredging progress

5） Key Lifecycle Operations

Create Equipment Duplicates: For batches of identical equipment (e.g., 10 switches of the same model), supports "Copy Existing Equipment Attributes" (only modifies equipment ID and location), reducing duplicate data entry;

User-defined tags: Supports adding "temporary tags" (e.g., "Seal replacement pending", "Key monitoring during rainy season"), with customisable tag colours/icons (e.g., red triangle = urgent, blue dot = routine);

Retirement/Removal of Equipment: When initiating retirement requests, specify "retirement reason (e.g., 'exceeded service life')" and "disposal method (e.g., 'scrap/transfer)'. Upon submission, the equipment status updates to "Pending Retirement". Historical data (operational logs, maintenance records) is automatically archived in the "Historical Equipment Repository" (non-deletable, for report traceability);

Device Status Updates: Supports one-click updates for core device statuses (e.g., "Under Maintenance → Operational", "Abnormal → Normal"). Requires completion of "Reason for Status Change" (e.g., "Maintenance completed, tests passed") and retains change records (operator, time);

Equipment Transfer Management:

Initiate Transfer: Select "Transfer Equipment" and "Target Entity" (e.g., transfer from Substation A to Substation B), then submit the transfer request;

Notification Receipt: The responsible party at the destination entity receives a "Device Transfer Notification" (including equipment list and attributes). Supports "Accept / Return" (return requires reason).

Transfer Confirmation: Upon acceptance, the system automatically updates the equipment's "Owning Entity" and synchronises changes to the equipment ledger;

Extended Attribute Management: Configure "Custom Extended Attributes" for each equipment category (e.g., transformer extension "Insulation Resistance Value", utility pole extension "Lightning Protection Grade"). Supports "Add Field - Set Required Field - Upload Attachments (e.g., inspection reports)".

6） Substation Equipment Inventory Summary

Aggregate by substation: Select a substation to automatically compile all equipment within it (categorised as "Primary Equipment / Auxiliary Equipment", e.g. primary: main transformers, switches; auxiliary: meters, sensors);

Status Statistics: Displays the quantity of each equipment category in the list marked as "In Operation / Faulty / Under Maintenance". Supports exporting the "Substation Equipment List Excel" (including equipment attributes, status, and assigned area).

Module 4: Grid Map Functionality (Visualisation + Simulation Diagram Management)

Enables layered grid map display, equipment location correlation, and operational simulation diagram viewing, facilitating on-site positioning and status assessment.

1） Device Attributes and Map-Linked Management Supports viewing attributes and status of 11 equipment categories on the grid map. Clicking a device icon triggers an "attribute pop-up window". Example:

Click "#2 Main Transformer": Displays "Model: S11-5000kVA, Voltage Rating: 110kV, Health Rating: Good, Last Maintenance Date: 01/09/2024";

Click "10kV Line": displays "Line Name: XX Line, Length: 5km, Current Load: 80%, Anomaly Point: Conductor wear at pole #15";

I nteractive operations: Supports "Quick Marker" (e.g., marking line fault points) and "Navigate to Equipment" (launches mobile map app to plan route from current location to equipment) on the map.

2） Operational Simulation Diagram Management Supports mobile viewing of high-voltage (HVT), medium-voltage, low-voltage layered simulation diagrams, composite simulation diagrams, and global single-line schematic diagrams:

Layered Schematics:

High-voltage diagrams (110kV and above): Display main transformers, high-voltage switches, and busbar connections, annotated with "Operating Current/Voltage" (e.g., busbar voltage 115kV). Faulty equipment highlighted with red flashing markers;

Medium/Low Voltage Schematics: Similarly display equipment connections and operational status at corresponding voltage levels, with "zoom to view details" functionality (e.g., inspecting connections between substation transformers and user meters in low-voltage schematics);

Composite Schematic Diagram: Overlays "High-Voltage - Medium-Voltage - Low-Voltage" diagrams, distinguishing voltage levels by colour (e.g. red = high-voltage, yellow = medium-voltage, blue = low-voltage), providing an intuitive representation of grid hierarchical connections;

Global Single-Line Diagram: Presents the overall topology of the regional grid (e.g., "XX Regional Substation → Feeder Lines → Distribution Transformer Stations"), annotates critical equipment (e.g., boundary switches, interconnection switches), and supports clicking lines to view "Load Distribution".

Module 5: Statistical Reports (Multi-dimensional automated generation)

Supports generating mobile reports by "Equipment Type / Status / Operational Condition" to meet operational statistics and asset analysis requirements.

1） Group/Type Statistics (covering all equipment types) Generates "Quantity - Status" statistical reports for each equipment category. Example:

Switchgear Statistics: Grouped by "voltage level (110kV/35kV/10kV)", displaying quantities "in operation/under maintenance/faulty" for , accompanied by "fault cause proportion" (e.g., "mechanical faults account for 60% of 10kV switch failures").

Statistics for pole-mounted equipment: Grouped by "pole number", tallying the quantity of meters, sensors, and surge arresters per pole (e.g., "Pole #10: 1 meter, 1 lightning strike sensor");

Other equipment (capacitor banks, substations, cable trenches, etc.): Statistics are compiled by the dimensions "Type - Status - Area", with support for customisable "Statistical Time Range" (e.g., last month, current quarter).

2） Statistics by Status / Operational Condition

By status: Aggregate quantities and proportions of equipment in "Operational, Standby, Under Maintenance, Awaiting Decommissioning, Decommissioned" states, generating "Status Trend Charts" (e.g., "Equipment under maintenance decreased by 15% over the past 3 months");

Operational Status Statistics: Classify by "Normal Operation, Abnormal Operation, Fault-Induced Shutdown" to calculate each equipment category's "Operational Duration" and "Fault Count" (e.g., "Main Transformer #1: 8,760 hours of normal operation, 1 fault occurrence");

Report Output: Supports online viewing of reports (including charts), export to Excel/PDF, with automatic watermarking of "statistical period, generator, data source".

7.2.3 Power Supply Status Monitoring Subsystem

Module 1: Power Status Summary Information (Real-time "Overview - Drilldown" Monitoring)

Core implementation of multi-dimensional power status aggregation with map visualisation, enabling rapid identification of critical information for " ".

1） Multi-dimensional power supply status aggregation

Aggregation Dimensions	Core Content	Presentation Method
Aggregated Power Supply Status (Powered / Unpowered)	Aggregate "Number of Powered Devices / Number of Unpowered Devices" by region (city / county / substation), indicating the proportion of "Scheduled Power Cuts / Fault-Related	Ring chart + numeric cards, e.g. "Region XX: 1,200 units powered (95%), 60 units de-energised (5%, including 20 units due to fault outages)"

	Power Cuts"	
Aggregated by load curve (high voltage / medium voltage)	Display real-time load curves (last hour) for high-voltage (110kV+) and medium-voltage (10kV) lines, labelling "peak load / trough load"	Line chart with curves highlighted in red when exceeding thresholds (e.g., 90% rated load), accompanied by pop-up alerts
Aggregate switch operations by outage-affected area	Display "Number of switches operated / Number of switches pending operation" within outage areas, annotated with operation type (disconnect / connect)	Mark switch locations on map with "blue dots (operated)/orange dots (pending operation)"; click to view operation records
Aggregate switch operations by scheduled maintenance	Grouped by "Scheduled Maintenance Items", summarising associated switches' "Scheduled Operation Time / Actual Operation Time / Operation Status"	List + timeline format, e.g. "XX Substation Maintenance: 3 switches scheduled for 9:00 closing, 2 completed"

2） Map-based power supply aggregation

Permission-based map management: Configure map visibility by user role (e.g., "High-voltage Operations Personnel" view high/medium-voltage maps; "Substation Area Managers" view low-voltage maps only). Supports "one-click switching between voltage level layers".

Aggregation display rules:

High-voltage layer: Displays substations and high-voltage lines, with line status indicated by "green solid lines (energised)/red dashed lines (de-energised)".

Medium-voltage layer: Displays medium-voltage feeders and ring main units, annotated with "feeder load factor" (e.g., "Feeder XX: 85%");

Low-voltage layer: Displays transformer stations and low-voltage circuits, annotated with "Number of energised transformer stations / Number of de-energised transformer stations".

Module 2: High/Medium/Low Voltage Power Supply Management (Tiered Control, Precise Response)

Power supply management functions segmented by voltage level, covering "impact analysis, alerts, scenario simulation, map queries" to accommodate diverse operational scenarios.

1） High-Voltage Power Supply Management (110kV and above)

Impact Map Management: Automatically generates impact maps for medium/low-voltage grids based on high-voltage line energised/de-energised status (e.g., "#1 high-voltage line de-energised → impacts 3 medium-voltage feeders, 12 low-voltage transformer districts"). Affected areas are marked on maps with "semi-transparent red".

Operational Data Alarms: Real-time monitoring of high-voltage line current, voltage, and power factor. Exceeding thresholds (e.g., current exceeding 110% of rated value) triggers red alarms containing "equipment name, abnormal metrics, and recommended actions (e.g., 'reduce load')".

Hypothetical Scenario Management: Supports simulating scenarios such as "power outage at a high-voltage substation" or "line maintenance". The system automatically calculates affected medium-voltage feeders and low-voltage transformer districts, generating a "scenario impact report" (including recovery plan recommendations).

Map Search Query: Enables searches by "high-voltage line name / substation name". Upon location, a pop-up displays "real-time operational data (current / voltage), recent fault records, and associated medium-voltage feeders".

2） Medium-voltage power supply management (10kV)

Impact mapping management: Based on medium-voltage feeder status, reverse-annotate impacts on high-voltage (e.g., "Medium-voltage feeder overload → Prompt high-voltage line load adjustment required") and forward-annotate impacts on low-voltage (e.g., "Medium-voltage feeder outage → Affects 5 low-voltage transformer districts"), with distinct colour coding on the map.

Operational Data Alarms: Trigger alerts for medium-voltage line conditions such as "overcurrent, overvoltage, or low power factor", accompanied by a "30-minute data trend graph". Supports "one-click alert forwarding to feeder personnel".

Hypothetical Scenario Management: Simulates "Medium-voltage feeder sectional switch tripping", calculates affected low-voltage users and outage area, generating "Fault Isolation Recommendations" (e.g., "Close #2 sectional switch to restore power to 3 transformer districts").

Event Summary:

Aggregated by medium-voltage feeder name: Display each feeder's "Failure Count, Power Outage Duration, and Most Recent Failure Time" (e.g., "Feeder XX: 2 failures this month, total outage duration 4 hours");

Aggregated by medium-voltage substation (to be determined): Consolidates "Operation frequency and fault records" for medium-voltage switches within the station;

Trip Event Summary: Statistics on events causing power supply/section breaker trips (e.g., "Lightning strikes, short circuits"), presented as a percentage breakdown by "Event Type" (pie chart).

3）Low-voltage Power Supply Management (0.4kV)

Impact Diagram Management: When a low-voltage transformer district experiences a power outage, automatically correlate medium-voltage feeders and high-voltage lines, labelling the " ault Root Cause Path" (e.g., "XX low-voltage transformer district power outage → caused by #3 medium-voltage feeder tripping → caused by #1 high-voltage line fault").

Operational Data Alarms: Alarms triggered by "voltage deviation exceeding ±7%" or "current overload" on low-voltage lines, annotated with "number of affected users" (e.g., "XX substation: voltage 200V (low), affecting 50 households").

Hypothetical Scenario Management: Simulates "low-voltage transformer failure" to calculate affected users and restoration time, recommending "backup transformer deployment plans" (e.g., "Deploy one 500kVA transformer from XX warehouse, estimated arrival in 2 hours").

Map Search and Incident Summary: Supports searching by "Low-Voltage Distribution Area Name / Transformer ID". Aggregates "Power Outage Frequency and Customer Complaints" by low-voltage feeder name, enabling distribution area managers to swiftly pinpoint issues.

Module 3: Power Supply Status Statistics Report (Automatically generated, exportable on demand)

Supports multi-dimensional statistics for high/medium/low-voltage supply and outage faults. Reports are optimised for mobile viewing.

1） Power Supply Statistics by Voltage Level

High-voltage supply statistics: Aggregates "power-on duration, load factor (daily average/peak), fault frequency" by "substation/high-voltage line" (e.g., "Substation #1: 720 hours power-on duration this month, 75% daily average load factor, 1 fault").

Medium-voltage supply statistics: Organised by "feeder line" to track "supply reliability (SAIDI/SAIFI), number of outages, average restoration time";

Low-voltage supply statistics: By "transformer district", compile "power supply rate, number of customer complaints, voltage compliance rate".

2） Power Outage (Fault) Reporting

High-voltage feeder lines / substations: Track "number of fault-related outages, total outage duration, fault causes (e.g., 'equipment ageing, lightning strikes')", generating a "Top 3 fault-prone lines / substations" list;

Medium-voltage / Low-voltage Feeders / Substations: Similarly, statistical fault data is compiled, supporting filtering by "time range" (last week / month / quarter). Reports can be exported to Excel/PDF format, with automatic addition of "statistical time, generator" watermarks.

Module 4: Power Loss Management (Visualisation + Anomaly Alerts, Loss Reduction Support)

Core functionality includes aggregation of power loss data, visualisation maps, and periodic reporting to assist operations personnel in identifying high-loss areas.

1） Loss Information Aggregation and Visualisation

Multi-dimensional aggregation:

By company: Summarises each power company's "total loss volume and line loss rate" (e.g., "Company XX: Total loss 1.2 million kWh, line loss rate 6.5%");

By feeder: "Theoretical loss, actual loss, loss deviation" for each feeder (deviations exceeding 5% highlighted in red);

Abnormal Loss Display: Highlight areas where "loss rate exceeds thresholds (e.g., HV 8%, MV 10%, LV 12%)" with "proposed causes (e.g., 'electricity theft, line ageing')".

Loss Visualisation Map:

Generate loss simulation maps by feeder / substation / area / voltage level, using "colour intensity" to represent loss rate (darker = higher loss rate);

Clicking high-loss areas (e.g., deep red) displays a pop-up showing "loss volume, loss rate, 3-month trend, recommended investigation measures (e.g., 'prioritise inspection of XX line section')".

2） Periodic power loss reports cover eight dimensions: "feeder, substation, area, voltage level, time period, 110kV lines, medium-voltage lines, central substation (CC)". Example:

Time-period reports: Loss volume and loss rate trends over the past day/week/month/quarter (line charts);

By 110kV line: "Theoretical losses, actual losses, and effectiveness of loss reduction measures (e.g., 'loss rate decreased by 2% after conductor replacement')" for each 110kV line;

Report delivery: Automated periodic reports (e.g. monthly) pushed to O&M managers' mobile devices, with one-tap forwarding to work groups.

3） Abnormal Power Loss Alerts

Daily/Monthly Abnormal Loss Alerts: Triggered when daily/monthly loss rates exceed thresholds (local notifications + SMS), detailing "high-loss zones, loss rate, and month-on-month comparison";

Alert Resolution: Supports "Mark as Investigated" with resolution details (e.g., "Electricity theft detected at XX location, resolved"), enabling automatic loss data updates for closed-loop management.

Module 5: Corridor Safety Management (Mapped Control, Safety Inspection

Support)

Core implementation of mobile device management for key corridor safety points and hazard zones, tailored for on-site inspection scenarios.

1） Safety Information Management

Key Point Information Management:

Configure critical point list: Enter "Critical Point Name (e.g., 'XX Line #10 Tower Base'), Location ( ), Risk Level (High/Medium/Low), Inspection Cycle (Weekly/Monthly)";

Mobile display of key point list with "Inspected / Pending Inspection" status indicators; click to view "Recent Inspection Records, Hazard Photographs".

Cross-Section Information Management:

Manage grid intersection lists: Record "intersection name, involved lines (e.g., '110kV XX Line intersecting with 10kV YY Line'), safety clearance, protective measures (e.g., 'installing anti-bird spikes')";

Highlight red alerts for anomalies (e.g., "Insufficient safety clearance") and support "Uploading rectification photographs".

Unsafe Corridor Information Management:

Configure unsafe corridor points/area list: Note "cause of unsafety (e.g., 'tree obstruction, construction excavation'), affected lines, rectification deadline";

Mark unsafe areas on the map with a "red triangle"; clicking reveals "responsible party for rectification, progress (e.g., '50% of tree obstructions cleared')".

2） Corridor Safety Surveying (Mapped Visualisation)

Manage integrated safety information maps: Overlay layers for "key points, intersections, unsafe zones", with support for "one-click hide/show for specific layer types";

Specialised Map Management: Generate separate "Key Point Maps, Intersection Point Maps, Unsafe Corridor Maps" tailored to different inspection tasks (e.g., "Key Point Inspection" opens only the Key Point Map).

3） Corridor Safety Reporting

Statistics on "Number of Key Points (by risk level), Number of Intersections (by involved line type), Number of Unsafe Corridor Points/Areas (by rectification status)" ( );

Example: "Total critical points this month: 120 (High risk: 30, Medium risk: 50, Low risk: 40). Inspections completed: 100 (Completion rate: 83%)";

Reports support export functionality to serve as assessment evidence for safety inspections.

7.2.4 Planning and Investment Project Information Management Subsystem

Module 1: Consolidated Planning Information (Dual-dimensional aggregation by "Time - Area" for clear overview)

Core functionality enables multi-dimensional aggregation of planning information, supporting data visualisation and drill-down into details to fulfil "overview-to-detail" management requirements.

1） Aggregate planning information by time

Time dimension segmentation: Aggregates planning projects by "year, quarter, month". Displays "Current Year Planning" by default, with support for switching time periods (e.g., "2024 Annual Planning → 2025Q1 Planning").

Aggregated content:

Total number of planned projects: Categorised by "project type" (e.g., new substation construction, line expansion, transformer substation upgrades), with status distribution ("Initiated / In progress / Pending initiation") indicated (presented as pie charts);

Project progress summary: Calculate "planned completion rate" by time period (e.g., "20 planned projects for Q3 2024, 18 completed, 90% completion rate");

Investment Summary: Display "Total Investment Amount, Amount Disbursed , Amount Pending Disbursement" for planned projects within the current timeframe (presented via data cards + line chart illustrating funding trends).

Detail Drilldown: Clicking a project category (e.g., "New Substation Construction") reveals a project list (name, location, planned duration, responsible person), with project name search for rapid navigation.

2） Load Consumption and Growth by Region

Regional Dimension Segmentation: Aggregated by "Province / City / County / Substation Area", defaulting to regions within the current user's permission scope (e.g., "City Company Planner" defaults to counties subordinate to the city).

Aggregated content:

Load Consumption: Displays the region's current year/quarter "peak load, average load, peak-to-off-peak load difference", compared with the same period last year (e.g., "XX County 2024 peak load 120MW, 15% increase over last year");

Load Growth: Presents a line chart illustrating the region's load growth trend over the past three years, with a projected growth curve for the next two years (based on load forecasting system data). Highlights "Required Additional Supply Capacity" (e.g., "XX Region anticipates a 20MW load increase by 2025, necessitating one new 110kV substation").

Planning Alignment: Automatically link to planned projects within the region (e.g., "To accommodate load growth in XX County, three new 10kV lines are planned"). Project names appear as clickable links to view details.

Module 2: Planning Information Management (Mapped Presentation, Intuitive Control)

Core functionality: Visualises planning information via maps, supporting project queries and progress tracking, tailored for field survey scenarios.

1） Displaying the Planning Map

Map layer design:

Existing Grid Layer: Displays current substations, lines, and transformer districts within the area, marked with "grey solid lines / icons" (distinguishing high-voltage / medium-voltage / low-voltage).

Planning Project Layer: Overlays planned project locations, colour-coded by "project type" (e.g., "red dots = new substations, blue lines = line expansions, green squares = transformer station upgrades");

Load Growth Layer: Utilises a heatmap to illustrate regional load growth patterns (red = high growth, yellow = medium growth, green = low growth), enabling intuitive alignment of planning projects with load requirements.

Map Interaction Features:

Project Query: Supports filtering planning projects by "Project Type, Progress, Responsible Person". After filtering, the map displays only qualifying projects, with non-target projects automatically hidden.

Detail View: Clicking a planning project icon displays a pop-up window showing "Project Name, Investment Amount, Planned Duration, Current Progress, Responsible Person and Contact Details". Supports viewing project attachments (e.g., planning drawing thumbnails, site location photographs).

Progress Updates: Following site surveys, planners may directly update project statuses on the map (e.g., changing from 'Pending Initiation' to 'In Progress') and add progress notes (e.g., 'Site survey completed'). Updates synchronise in real-time to the backend.

Module 3: New Investment Design Management (Mobile Rapid Design, Efficient Implementation)

Core functionality supports mobile design, map annotation, and proposal association for new investment projects, reducing offline processes and enhancing efficiency.

1） Display New Investment Map

Project mapping annotations:

Site Marking: Planners use GPS positioning (accuracy ≤5 metres) on-site to mark new investment locations (e.g., "New 110kV substation site selection"), with manual position adjustment supported (e.g., during weak GPS signals);

Project Attribute Entry: After marking locations, input core project attributes (project name, type, estimated investment, planned duration, construction scale e.g., "Substation capacity 50MVA"). Supports uploading site photographs (e.g., current site condition photos, surrounding grid infrastructure).

Load correlation: Automatically retrieves load data (consumption + growth) for the project's surrounding area, generating a "Load Matching Analysis" (e.g., "This site can cover 150MW load across the XX area, meeting future three-year growth requirements"). Analysis results are saved with the project.

Investment Scheme Management:

Scheme Association: Supports linking preliminary design schemes for investment projects (e.g., "substation construction scheme, line route scheme"). Scheme documents can be retrieved from backend systems or uploaded locally (supporting PDF/Word formats).

Benefit Estimation: Automatically calculates projected benefits for investment projects (e.g., "Construction of XX new 10kV lines is expected to reduce line loss rate by 0.5%, yielding annual electricity savings of 100,000 kWh"). Benefit data is generated via backend algorithms (linked to load and line loss models).

Progress Reporting: Following project initiation, responsible personnel may update progress on the map (e.g., "Civil works 30% complete"), upload construction progress photographs (e.g., "Photograph of substation main framework"), and add construction issue feedback (e.g., "Underground pipelines encountered on-site, requiring adjustment to construction plan").

Module 4: Planning and Investment Map (Integrated Management, Holistic Perspective)

Core integration of regional grid status, planning projects, and investment schemes onto a single map, supporting multi-dimensional comparisons to aid decision-making.

1） Comprehensive map for managing regional grid status, planning, and investment schemes

Integrated map layers:

Grid Status Layer: Displays real-time regional grid operational status (e.g., "substation load factor, line current"), colour-coding anomalies (e.g., "substations exceeding 90% load factor highlighted in red");

Planning Project Layer: Retains planning project annotations from Module 2, overlaying project progress (e.g., "Progress bar indicating completion percentage for 'In Progress' projects");

Investment Plan Layer: Overlays new investment projects from Module 3, using "flashing icons" to mark unimplemented investment projects and "static icons" for implemented projects;

Correlation Analysis Layer: Connects grid anomaly zones with corresponding planning/investment projects via dashed lines (e.g., "XX substation load rate exceeds 90%, corresponding to plans for one new substation and investment in two line expansions"), visually demonstrating how planned investments improve grid performance.

Integrated Management Functions:

Multi-dimensional Comparison: Supports "Current vs Planned" comparison views (e.g., "Clicking the 'Compare' button splits the map display to show the current grid and the planned grid side-by-side, clearly illustrating changes");

Scheme Evaluation: Automatically assesses the improvement effects of planning and investment schemes on grid status (e.g., "Upon implementation of planned projects, the average substation load factor in the XX area is projected to decrease from 92% to 75%"). Evaluation results are displayed via pop-up windows at ;

Issue Alerts: Mark issues such as "planning project delays" or "investment plans failing to match load growth" on the map with "orange warning icons". Clicking displays the alert cause (e.g., "XX planned line is two months behind schedule and may fail to meet load growth demands in the XX area"). Supports pushing alert notifications to responsible personnel.

7.2.5 Power and Telecommunications Management Subsystem

Module 1: Telecommunications Asset Summary Information (Clear "Overview - Breakdown" View)

Core functionality enables multi-dimensional aggregation of telecommunications assets, supporting data visualisation for rapid grasp of overall asset status.

1） Total Equipment Count Statistics

Statistical Dimensions: Aggregates totals by "Equipment Type" (lines/routes, terminals/stations, joints/connection points, accessories, transmission equipment), presented with bar charts (e.g., "500 transmission devices, 300 lines/routes, 200 terminals/stations").

Detailed Drill-Down: Clicking a specific equipment category (e.g., "Transmission Equipment") enables further drilling down by "Manufacturer (Huawei/ZTE), Model (OSN 3500/6800), Voltage Level Association (110kV/220kV 配套)" to view quantities. Example: "Transmission Equipment → Huawei → OSN 3500 → 110kV 配套 (120 units)".

2） Equipment Status Summary

Status Classification: Quantities are aggregated by core status categories for power and telecommunications equipment (Operational, Standby, Under Maintenance, Faulty, Awaiting Reporting Scrapped). Proportions are displayed via pie charts (e.g., "Operational equipment accounts for 85%, faulty equipment accounts for 2%").

Abnormalities highlighted: Faulty/end-of-life equipment displayed in red. Click to view the "Faulty Equipment List" (including equipment name, location, fault cause, e.g., "XX transmission equipment: optical module damaged"), with support for "one-click dispatch" to maintenance personnel.

3） Maintenance Schedule Summary (via NOC data)

Plan aggregation: Synchronises NOC system maintenance data, summarising planned tasks by "Timeframe (This Week / This Month)" and "Maintenance Type (Routine Inspection / Fault Repair / Firmware Upgrade)". Status is marked as "Completed / Pending" (e.g., "100 maintenance tasks planned this month, 75 completed, 75% completion rate").

Reminder Functionality: Pending maintenance plans are prioritised by "Urgency Level (High/Medium/Low)". Mobile notifications trigger when deadlines approach (e.g., 1 day remaining), with click-through access to view "Maintenance Equipment, Scheduled Time, Responsible Personnel".

Module 2: Telecommunications Equipment Management (All Types + Multi-Dimensional Control)

Supports multi-view management of telecommunications equipment via "topology / list / asset tree" views, enabling status modifications and extended attribute configurations tailored to field operations.

1） Multi-view Equipment Management

View Types	**Core Functions**	**Operational Scenario Adaptation**
Network Topology View	Displays topology structure as "Core nodes (e.g., provincial central data centres) → Regional nodes (municipal data centres) → Terminal nodes (substation communication cabinets)", with line status indicated by "Solid lines (normal connection)/Dotted lines (disconnected)"; clicking nodes displays associated device lists	Planners review overall network architecture and pinpoint disconnected nodes (e.g., "Line disconnection between city data centre and substation; rapid fault section identification")

List View	Devices are paginated by "Device Type" (e.g., "Line/Router Page, Terminal/Station Page"), with each device labelled with "Name, Model, Status, Location"; supports filtering by "Status/Manufacturer".	Operations personnel can rapidly locate equipment on-site (e.g., "Filter terminal devices in 'Fault' status for sequential troubleshooting")
Asset Tree Model View	Tree-structured display by "Organisation (Provincial Company → Municipal Company → County Company) → Site (Substation / Equipment Room) → Equipment Type → Specific Equipment"; supports expanding/collapsing nodes	Managers trace asset ownership hierarchically (e.g., "View all jointing equipment at substations under XX County Company")

2） Comprehensive Equipment Detail Management

For 5 core telecommunications equipment categories, provides "View Properties - Edit - Attachment Upload" functionality. Core fields align with power/telecom standards:

Equipment Type	**Core detail content (attributes + operations)**
Line/Routing Equipment	Attributes: Line Name, Optical Cable Model (e.g. GYTA53-24B1), Length, Origin/Termination Sites, Laying Method (Direct Burial / Aerial); Operations: Update Disconnection Status, Upload Optical Cable Test Report (OTDR Curve)

Terminal/Platform Equipment	Attributes: Platform Name, Location (Substation / Equipment Room), Equipment Model (e.g. Huawei OptiX 155/622H), Number of Ports, Operating Temperature; Operations: Flag "Port Fault", Record Inspection Log
Joint/ - Connected Equipment	Attributes: Splice number, location (pole route / duct shaft), connection type (fusion / cold splice), attenuation value (≤0.1dB); Operations: Update attenuation test data, upload splice photographs
Accessory Equipment	Attributes: Accessory name (e.g., ODF rack, optical attenuator), model, installation location, associated equipment; Operations: Mark as "Missing/Damaged", link to supplementary procurement requirements
Transmission Equipment	Attributes: Device ID, Model (OSN 3500), Manufacturer, Service Interface (E1/GE), Operational Status (Normal / Alarm); Operations: View device alarm logs (e.g., "Optical Port LOS Alarm"), Restart Remote Control (requires authorisation)

3） Device Operation Functions

Tagging telecommunications equipment: Supports adding "custom tags" (e.g., "Priority Monitoring", "Rainy Season Protection"), with customisable tag colours/icons (red triangle = critical, blue dot = routine). Tag information synchronises to the backend asset system.

Query Device Operational Status: Enter device ID/name to retrieve "real-time status, recent fault records, maintenance schedule" within 1 second. Supports voice queries (e.g., "Query XX transmission device status").

Modify device status: Enables one-click switching between statuses (e.g., "Operational → Under maintenance", "Faulty → Operational"). Requires entry of status change rationale (e.g., "Maintenance completed, testing passed"). Operational records retained in audit logs.

Extended attribute management: Provides "customisable extended fields" for each equipment category (e.g., "lightning protection rating" for line equipment, "power redundancy method" for transmission equipment). Supports "field addition - mandatory field configuration - attachment upload (e.g., inspection reports)".

Module 3: Telecommunications Network Mapping (Visualisation + Tiered Management)

Core implementation enables mobile management of multi-type telecommunications network diagrams, supporting detailed viewing and logical analysis to accommodate network planning and fault troubleshooting.

1） Multi-dimensional network diagram management

Network Diagram Types	**Core Functions**	**Layer Design and Interaction**
Inter-provincial Telecommunications Network Diagram	Display inter-provincial core transmission lines (e.g., "Hubei - Henan 110kV supporting optical cable") and provincial central data centre nodes; annotate with "line bandwidth (10Gbps), operational status"	Layers: Core nodes (red dots), inter-provincial lines (blue solid lines); Interaction: Click lines to view "route details, maintenance unit", supports zooming to inspect provincial boundary connections
Intra-Provincial OT Telecommunications Network Diagram	Display provincial power OT (Operational Monitoring and Control) telecommunications equipment (e.g., transmission lines from substations to dispatch centres, terminal devices); labelled with	Layers: OT terminals (orange squares), OT lines (orange solid lines), fault locations (red flashing); Interaction: Filter "SCADA service" related equipment, locate transmission paths

	"Service Type (SCADA Data Transmission)"	
Provincial IT Telecommunications Network Diagram	Display provincial power IT (office/data) telecommunications equipment (e.g., server rooms, office switches); labelled with "IP Address..."	

7.2.6 Comprehensive Report Generation Subsystem

7.2.6.1 Equipment Statistics Module

1） Equipment statistics by unit

Display equipment quantity distribution by power unit hierarchy (Headquarters - Province - City - County - Team)

Supports breakdown statistics by equipment type (transformers, switches, lines, etc.)

Visual Presentation: Hierarchical Tree Diagram + Bar Comparison Chart

Interactive Functionality: Clicking organisational nodes enables drill-down to view subordinate unit details

2） Customer-Owned Asset Equipment Statistics

Compile statistics on the quantity, types, and distribution of customer-owned equipment

Supports filtering by customer type, equipment service life, and other dimensions

Visual Presentation: Pie Chart (Type Proportion) + Map Markers (Regional Distribution)

Distinctive Feature: Comparative Analysis of Customer Assets vs. Power Assets

7.2.6.2 Maintenance and Servicing Statistics Module

1） Repair/maintenance statistics by unit

Tracks maintenance frequency, duration, and costs per unit

Supports filtering by time period (monthly / quarterly / annually)

Visual Presentation: Line Trend Charts + Data Cards

Analytical features: Top 5 equipment types by maintenance frequency

2） Customer-Owned Asset Maintenance/Servicing Statistics

Compilation of maintenance and servicing records for customer-owned assets

Supports categorised statistics by service type (power supply / customer self-service)

Visual Presentation: Comparative Bar Chart

Derived Functionality: Maintenance Service Satisfaction Score Statistics

7.2.6.3 Major Overhaul Candidate Equipment Module

1） Statistics on major overhaul-required equipment/categories by unit

Display lists of overhaul-required equipment and category distribution by unit

Supports filtering by overhaul priority and estimated costs

Visual Presentation: Priority Distribution Chart + Cost Estimate Table

Supporting Functionality: Generation of Overhaul Planning Recommendations

7.2.6.4 Technical Loss Statistics Module

1） Unit Loss Rate by Voltage Level

Statistics compiled by monthly, quarterly, and annual cycles

Covering all voltage levels (500kV, 220kV, 110kV, 35kV, 10kV, etc.)

Visualisation: Multi-period comparison line charts

Analytical Capabilities: Marking of Abnormal Fluctuations in Loss Rates and Root Cause Analysis

7.2.6.5 Commercial Cycle Loss Rate Module

1） Commercial Cycle Loss Rate Statistics

Statistics organised by monthly, quarterly, and annual cycles

Supports breakdown by region and business type

Visual Presentation: Period Trend Charts + Target Achievement Rate Metrics

Early warning function: automatic flagging when loss rate exceeds threshold

7.2.6.6 Power Supply Statistics Module

1） Power supply status statistics by unit

Statistics on power supply reliability indicators (SAIDI, SAIFI, etc.) for each unit

Display distribution of outage frequency, duration and causes

Visual Presentation: Reliability Radar Chart + Interruption Cause Pie Chart

Comparison Functionality: Benchmarking against industry standards and historical data for the same period

7.2.6.7 Customer Statistics Module

1） Customer statistics by unit

Statistics on the number, type, and electricity consumption of customers served by each unit

Supports classification by customer importance and electricity usage nature

Visual Presentation: Customer Growth Trend Chart + Electricity

Consumption Distribution Map

Analytical Capabilities: Key Account Electricity Consumption Profile Analysis

7.2.7 Field Data Acquisition Subsystem

Module 1: Field Data Collection Progress Summary ("Progress visualised, tasks at a glance")

Real-time aggregation of collection progress, supporting multi-dimensional viewing to assist managers and collectors in tracking task advancement.

1） Field data collection summarised by task

Task List Display: Presents tasks by "Task ID, Task Name, Planned Assets, Collected Assets, Completion Rate, Deadline" with intuitive progress bars (e.g., "Task T2024001: Planned 50 units, Collected 38 units, 76% complete").

Status filtering: Supports filtering tasks by "Not started / In progress / Completed / Overdue" ( ). Overdue tasks are highlighted in red with clickable alerts displaying "Reason for delay (e.g., 'On-site equipment relocation')".

Detail Drilldown: Clicking a task displays the "Pending Asset List" (including asset name, model, location, priority) and "Collected Records" (including collector, time, key data screenshots), with support for "One-click navigation to pending assets".

2） Aggregate grid map data by collection results

Grid map visualisation: Aggregate collection results by "area (e.g., XX Street, XX Substation)" on the grid map, colour-coded by completion rate (green ≥80%, yellow 50%-80%, red <50%).

Area drill-down: Clicking a grid area displays a pop-up showing "Total assets in this area, collected count, uncollected count, list of uncollected assets", with support for "Batch assignment of uncollected assets to collectors".

Module 2: Data Synchronisation ("Permission-based offline access, no data loss")

Offline data download scope is controlled by user permissions to ensure secure offline operations, with automatic synchronisation upon reconnection.

1） Configure offline base map downloads according to user permissions

Permission Association: Administrators configure "Accessible Areas" for users (e.g., "Zhang San may only download 10kV line area base maps for XX County"). Base maps include fundamental geographic information such as roads, pylons, and substations.

Download Control: Upon user login, only base map download options within authorised permissions are visible, supporting either "Full Download" or "Regional Tile Download" (single-region base map ≤50MB, optimised for device storage).

2） Offline grid map data download configured according to user permissions

Grid Data Content: Includes "asset coordinates awaiting collection, basic equipment information (model, serial number), and historical collection records" within the authorised area. Supports filtering to "download only data for uncollected assets".

Offline validity period: Downloaded data is cached for 30 days by default. A pop-up prompting "Re-download updated data" appears before expiry to prevent offline data becoming obsolete.

Module 3: Field Data Collection ("Full Equipment Coverage, Standardised Forms")

Customised digital collection forms designed for 16 categories of electrical equipment, supporting rapid on-site data entry and multimedia attachment uploads to ensure data completeness and accuracy.

Equipment Type	**Core Collection Fields (Example)**	**Distinctive Features**
Digital Forms — Switchgear	Equipment ID, Model, Manufacturer, Rated Current, Number of Operations (Closing/Opening), Operational Status (Operational / Standby / Faulty), Visual Inspection Photographs	Supports "Scan QR Code to Enter ID" (automatically populates basic information by scanning the device's QR code)
Digital Form — Metering Equipment	Metering point number, meter model, accuracy class, installation date, last calibration date, current/voltage transformer ratio, reading photograph	Built-in "Validation Rules" (e.g., "Transformation ratio must not be 0"), with abnormal values highlighted in red for alerts
Digital format — Capacitor banks	Bank ID, Capacity (kvar), Commissioning Date, Number of Units, Operating Temperature, Oil Leakage Status, Wiring Configuration	Supports "photographing individual unit status within a bank", automatically linked to bank number
Digital format — Substation	Substation name, voltage level, commissioning year, main transformer capacity, number of outgoing bays,	Supports "Uploading Substation Layout Plans" with annotation of data collection points

	earth resistance value, station equipment inventory	
Digital format — Boundary metering point	Boundary ID, affiliated organisation, metering device model, gateway type (inter-provincial / inter-municipal), communication status, latest data upload time ( )	Automatically links to "historical data trends" (e.g., electricity consumption over the past 3 days) to assist in assessing metering accuracy
Digital table — Interconnection equipment	Interconnection ID, connection type (cable/overhead), interface specifications, operating pressure, insulation resistance value, counterpart equipment ID	Supports "Drawing Simplified Connection Diagrams" (mobile hand-sketching function)
Digital format — Electricity poles	Pole number, material (concrete/steel), height (m), burial depth (m), inclination angle, pole-mounted equipment (crossarms/insulators), photographs	Integrated "Inclinometer" function (utilises mobile phone sensors), automatically records inclination angle
Digital format — Line	Line name, voltage level, model (e.g. LGJ-240), length (km), installation method (overhead / direct burial),	Supports "marking defect points along the line" (annotating specific locations on the map)

	number of poles/towers, defect location	
Digital format — Cable ducts	Trench number, length, cross-sectional dimensions, number of cables laid, water accumulation status, cover plate integrity rate, inspection pathway photographs	Support for "capturing cable arrangement diagrams within trenches", with automatic thumbnail generation
Digital format — Substation insulating blocks	Pad number, material (rubber/ceramic), dimensions, load-bearing rating, ageing level, installation location (main transformer/switch)	Built-in "ageing assessment criteria" (e.g., "cracks exceeding 5cm in length indicate severe ageing")
Digital format — Communication lines	Line number, type (fibre optic cable / cable), core count, laying method, attenuation value (dB), joint location, test report photograph	Supports "OTDR test data entry", automatically generating attenuation trend graphs
Digital format — Telecommunications terminal equipment	Terminal ID, model (e.g. Huawei MA5620), IP address, port statu , operating temperature, number of connected users	Supports "ping testing" (invoking terminal interfaces), with real-time recording of communication status
Digital format — Telecommunications	Connection point number, type (fusion/cold splice),	Supports "QR code scanning to link both sides of the line"

connection/interconnection equipment	attenuation value, sealing grade, maintenance records, joint photographs	(automatically populates connection relationships by scanning QR codes at both ends)
Digital format — Telecommunications accessories	Accessory name (e.g., ODF rack / optical attenuator), model, installation location, quantity, damage status, associated equipment	Supports "Batch entry of identical accessories" (copy previous record and modify key details)
Digital format — Telecommunications transmission equipment	Equipment ID, model (e.g. OSN 3500), manufacturer, service interface (E1/GE), alarm status, power redundancy method	Automatically links to "last 3 alarm records" to assist in assessing equipment health status
Equipment Type	**Core Collection Fields (Example)**	**Distinctive Features**
Digital table — Switch devices	Equipment ID, Model, Manufacturer, Rated Current, Number of Operations, Operational Status (Operational / Standby / Fault), Visual Inspection Photo	Supports "Scan QR Code to Enter ID" (automatically populates basic information by scanning device QR code)
Digital Form — Metering Equipment	Metering point number, meter model, accuracy class, installation date, last	Built-in "Validation Rules" (e.g., "Transformation ratio must not be 0"), with

	calibration date, current/voltage transformer ratio, reading photograph	abnormal values highlighted in red
Digital format — Capacitor banks	Group number, capacity (kvar), commissioning date, number of units, operating temperature, oil leakage status, wiring configuration	Supports "photographing individual unit status within a group", automatically associating with group number
Digital format — Substation	Substation name, voltage level, commissioning year, main transformer capacity, number of outgoing bays, earth resistance value, station equipment inventory list ( )	Supports "Uploading substation layout plans" with annotation of data collection points
Digital format — Boundary metering points	Boundary ID, affiliated organisation, metering device model, gateway type (inter-provincial / inter-municipal), communication status, last data upload time	Automatically links to "historical data trends" (e.g., electricity consumption over the past 3 days) to assist in assessing metering accuracy
Digital table — Interconnection equipment	Interconnection ID, connection type (cable/overhead), interface specifications, operating pressure, insulation resistance value, counterpart equipment	Supports "Drawing Simplified Connection Diagrams" (mobile hand-sketching functionality)

	ID	
Digital format — Electricity poles	Pole number, material (concrete/steel), height (m), burial depth (m), inclination angle, pole-mounted equipment (crossarms/insulators), photographs	Integrated "Inclinometer" function (utilises mobile phone sensors), automatically records inclination angle
Digital format — Line	Line name, voltage level, model (e.g. LGJ-240), length (km), installation method (overhead / direct burial), number of poles/towers, defect location	Supports "marking defect points along the line" (annotating specific locations on the map)
Digital format — Cable ducts	Trench number, length, cross-sectional dimensions, number of cables laid, water accumulation status, cover plate integrity rate, inspection pathway photographs	Support for "capturing cable arrangement diagrams within trenches", with automatic thumbnail generation
Digital format — Substation insulating blocks	Pad number, material (rubber/ceramic), dimensions, load-bearing rating, ageing level, installation location (main transformer/switch)	Built-in "ageing assessment criteria" (e.g., "cracks exceeding 5cm in length indicate severe ageing")
Digital format —	Line number, type (fibre	Supports "OTDR test data

Communication lines	optic cable / cable), core count, laying method, attenuation value (dB), joint location, test report photograph	entry", automatically generating attenuation trend graphs
Digital format — Telecommunications terminal equipment	Terminal ID, model (e.g. Huawei MA5620), IP address, port status, operating temperature, number of connected users	Supports "ping testing" (invoking terminal interfaces), with real-time recording of communication status
Digital format — Telecommunications connection/interconnection equipment	Splice point number, type (fusion/cold splice), attenuation value, sealing grade, maintenance records, joint photographs	Supports "QR code scanning to link both sides of the line" (automatically populates connection relationships by scanning QR codes at both ends)

Module 4: Task Management ("Closed-loop workflow from assignment to execution")

Enables end-to-end online management of data collection tasks—from assignment and acceptance to execution—ensuring accountability and traceable progress.

1） Manage pending asset collection lists

List generation: System automatically synchronises "uncollected/requiring update" assets from equipment ledgers, sorted by "equipment type, area, priority", annotated with "last collection date" (e.g., "high priority for assets uncollected over 1 year").

Batch operations: Supports "Batch mark as collected" (for historical data already entered into the system) and "Batch priority adjustment", reducing repetitive tasks.

2） Assigning and Accepting On-site Data Collection Tasks

Task Assignment: Administrators select assets for collection, designate collectors, set target completion dates, and add "collection requirements" (e.g., "photograph equipment nameplates and terminal blocks"). Tasks are pushed to collectors' mobile devices (via notifications + SMS alerts).

Task Acceptance: Upon receiving a task, collectors may either "Accept" or "Return" it (returning requires submitting a reason via , e.g., "No access to this area"). Upon acceptance, the task status updates to "In Progress" and automatically synchronises to the to-do list.

3） Execute on-site data collection

Navigate to asset: Clicking an asset in the task automatically opens the map and plans a navigation route (walking/driving). Upon arrival, click "Start collection" to access the corresponding digital form for the equipment.

Data entry: Form fields are categorised as "Required" or "Optional" (mandatory fields marked with *). Supported features include "Photo upload" (automatically compressed to under 1MB), "Voice input" (transcribed into text), and "Automatic location fill" (asset latitude/longitude).

Temporary Storage and Submission: Supports "Temporary Storage" (temporary saving of incomplete forms) and "Submission" (triggering data validation upon submission; status updates to "Collected" upon successful validation).

Module 5: Map Positioning Integration ("Precise Location, Intuitive Navigation")

Deeply integrated with device geolocation collection applications, clearly distinguishing pending/collected assets on the map to support efficient field operations.

1） Map Positioning for Field Data Collection

Real-time Positioning: Automatically acquires current location (latitude/longitude) during collection. Compares coordinates against asset ledger entries; triggers pop-up alert "Significant positional deviation detected. Confirm correction?" when deviation exceeds 10 metres, with manual coordinate adjustment supported.

2） Locating Pending/Completed Assets on Map

Pending assets: Marked with "blue dots + exclamation marks" on the map. Clicking displays "asset name, model, collection requirements" and supports "one-tap navigation".

Collected Assets: Marked with a "green dot". Clicking displays "Collector, Collection Time, Key Data (e.g., equipment status)", with support for viewing collection photographs.

Module 6: Field Data Collection Reports ("Multi-dimensional statistics, decision support")

Automatically generates collection reports by cycle and dimension, supporting visualisation and export to meet management review requirements.

1） Multi-dimensional Statistical Reports

Statistical Dimensions	**Core Content**	**Visualisation Format**
Statistics by Work Session	Asset count, device type distribution, average collection duration per login	Session timeline + device type pie chart
Task-based statistics	"Task completion rate, average time spent, data pass	Personnel comparison

	rate" for each collector (Pass rate = Number of collections without anomalies / Total number of collections)	bar chart + Qualification rate line chart
Daily / Weekly / Monthly / Quarterly Statistics	"Total assets collected, new assets collected, pending assets, proportion of each device type" within the corresponding period	Period trend line chart + stacked bar chart by device type

2） Report export: Supports export to Excel (raw data) and PDF (including charts) formats, automatically adds "statistical time and generator" watermarks, and supports sharing to work groups.

Module 7: Offline Data Collection ("Collect without network, transmit automatically when connected")

Adapted for offline/poor network scenarios to ensure uninterrupted field operations and prevent data loss.

1） Offline Application Login: Supports "Offline Mode Login" (verifying locally cached user credentials). After login, only downloaded offline tasks and map data are displayed.

2） Offline Grid Map Display: Downloaded grid maps (including base maps and pending asset points) can be viewed, zoomed, and navigated normally. Unauthorised areas display as "greyed-out".

3） Manage offline data collection: Offline-collected data is temporarily stored in a local SQLite database (encrypted storage), supporting "view/edit/delete" of offline records to prevent accidental operations.

4） Online data synchronisation: Synchronisation automatically triggers upon network connection, uploading data sorted by "collection time". In case of data conflicts (e.g. multiple users collecting the same asset), the system applies "latest collection overrides earlier collection + retains historical versions". Synchronisation results are indicated via pop-up notifications (e.g. "Successfully uploaded 20 records, 1 conflict resolved").

7.2.8 Public Data Processing and Sharing Service Subsystem

Module 1: Planning and Sharing of On-site Electrical Connection Information (Transparent Data Sharing)

Core implementation of multi-dimensional aggregation for on-site connection information, supporting multi-role access while ensuring secure public data sharing.

1） Summary of Field Connection Schemes

Summary Content: Presents a solution list organised by "Solution ID, Project Name, Connection Type (e.g. User Access, Line Extension), Design Status (Preliminary Design / Site Survey / Final Draft), Coverage Area, Responsible Person", annotated with "Urgency Level (High / Medium / Low)".

Visual Presentation: Progress bars indicate current scheme phase (e.g., "Preliminary Design → Site Survey (60% Complete)"). Clicking a scheme reveals "Core Parameters (e.g., connection capacity, involved equipment)" and attachments (e.g., preliminary design drawing thumbnails).

Shared Access: Administrators may view all proposals; designers may only view proposals under their responsibility or awaiting collaboration; construction personnel may only view finalised construction proposals.

2） Aggregate Field Connection Requests

Request summarisation: Aggregate by "Request ID, Applicant (e.g. corporate user/community), Request Type (new connection/capacity expansion), Load Requirement, Submission Date, Processing Status (Pending Assignment/In Progress/Completed)". Supports filtering by "Processing Status" and "Region".

Associated Display: Clicking a request automatically links to the corresponding "Preliminary Design Task" (if applicable), displaying "Task Assignment Progress" to prevent request oversights.

3） Preparation for on-site connection plan summarisation

Preparation Contents: Compile "foundational data (e.g., regional grid load, existing equipment capacity), pending survey points (e.g., site inspection locations), and required documentation (e.g., topographical maps, equipment specifications)" for scheme design, annotating "document completeness status".

Reminder Function: When documentation is missing (e.g., "Site topographic map absent"), a red alert prompts administrators to supplement it, with support for "One-click Document Request" (automatically pushing requirements to the archives management department).

4） Field Connection Implementation Personnel Allocation Summary

Assignment Summary: Grouped by "scheme number, task type (preliminary design / field survey / construction), assigned personnel, contact details, planned completion date, actual completion date". Supports filtering by "personnel" or "time period".

Progress Tracking: Tasks not completed on time are highlighted in yellow. Clicking reveals "delay reasons (e.g., 'complex site conditions')", allowing administrators to reassign personnel.

Module 2: Connecting Scheme Design (Closed-Loop Task Management)

Enables end-to-end task allocation and processing for connection scheme design, ensuring seamless progression from "Preliminary Design" to " ".

1） Assigning and Confirming Preliminary Design Tasks

Task Assignment: Administrators select the "Site Connection Plan", designate designers, set planned completion dates, and upload "Design

Requirements (e.g., 'Must accommodate 1000kVA load connection')". The system automatically pushes task notifications to designers' mobile devices.

Task Confirmation: Upon receiving the notification, designers may either "Accept" or "Return" the task (returning requires stating a reason, e.g., "Lack of grid data access rights for this area"). Upon acceptance, the task status updates to "In Design" and a "Preliminary Design Task List" is generated.

2） Allocation and Confirmation of Field Survey and Data Collection Tasks

Task Allocation: Upon completion of the preliminary design, the administrator assigns field survey tasks to surveyors based on the design proposal. This specifies the "survey locations, required data (e.g., 'on-site equipment positions, topographical conditions'), and survey tools (e.g., 'laser rangefinder')".

Task Confirmation: Upon receiving the assignment, survey personnel may view the "survey point locations on the map". After confirmation, an "On-site Survey Form" is generated (containing mandatory fields such as "equipment spacing" and "soil type"), with support for offline form downloads.

3） Collecting Field Information and Data

Data Entry: Surveyors input data on-site via digital forms, supporting "manual entry + photo upload" (e.g., capturing images of field equipment or terrain, automatically linked to survey points). Forms cannot be submitted if mandatory fields remain unfilled.

Data validation: The system automatically checks data validity (e.g., "equipment spacing must not be less than 5 metres"). Abnormal data is highlighted in red with a "Validation Rule" prompt, allowing surveyors to amend and resubmit.

Offline Support: Data is temporarily stored locally when offline; automatically synchronises to the backend upon reconnection. Upon successful synchronisation, the task status updates to "Survey Completed".

Module 3: Map functionality for on-site connection planning (permission-based map access)

Core implementation of permission-based access and interaction with grid maps, supporting field connection scheme design and on-site surveys.

1） Access grid maps according to user permissions

Hierarchical permission control: Configures map access permissions based on the RBAC model to ensure "data minimisation sharing":

Administrators: Access to full-area grid maps, viewing all field connection schemes, survey points, and equipment distribution;

Design Personnel: Access only the coverage area map for their assigned scheme, viewing grid equipment and load data within that zone;

Surveyors / Construction Personnel: Access only maps of their operational zones, viewing survey points and data collection requirements;

Permission Activation: Upon login, maps within authorised scope load automatically; unauthorised areas remain hidden by default and cannot be manually unlocked.

2） Map Interaction Features (Field Operation Support)

Point Marking: Annotate "preliminary design reference points and field survey points" on the map, distinguished by colour (blue = design points, orange = survey points). Clicking a point displays "Point point description, required data collection".

Equipment Association: Existing power equipment within the area (e.g., transformers, lines, switches) is displayed on the map. Clicking an item reveals "equipment parameters (e.g., 'capacity 500kVA') and operational status", aiding design scheme alignment with the existing grid.

Offline Map Download: Supports downloading grid maps within authorised areas (including offline base maps, equipment distribution, and survey points). Maps remain viewable and survey annotations editable offline after download; annotated data synchronises automatically upon reconnecting to the network.