Membrane Technology
ISSN (online): 1873-4049

Research on Whole Process of Material Supply for Converter Station's Main Equipment Based on BIM + GIS

Yang Zhou[1], Weijie Huang[2], Yanshan Tian[3], Jing Wang[4,*], Jing Yan[4], Song Lin[4]

[1]*UHV Transmission Business Unit, State Grid Corporation of China, Xicheng District, Beijing 100031, China*

[2]*State Grid Hubei Zhongchao Construction Management Company, Hubei,430022, China*

[3]*State Grid UHV Engineering Construction Company, Beijing 100052, China*

[4]*Beijing north-star technology development Co., Ltd., Beijing 100044, China*

**Corresponding Author.*

Abstract:

Considering the problems with the main equipment of the converter station, such as difficult conditions, wide involvement, complex process and difficult transportation, on the basis of BIM+ GIS visualization technology support, research is carried out on multi-source data fusion of engineering material control, state information monitoring of the whole process of material supply, multi-node dynamic control and early warning of materials. A system for the whole process of material supply of the main equipment of the converter station is constructed, which realize the 3D visual display, fine control of important material supply, and warning of material supply status. Through the research, the information tracing mechanism of the whole process of material supply is established, and it supports the monitoring and warning of the material supply, effectively improves the efficiency of engineering material management, and lays the foundation for the promotion and application of the whole process control of engineering material supply.

Keywords: BIM + GIS; main equipment; material supply; whole process

INTRODUCTION

The material transportation of UHV projects faces multiple challenges such as mountain roads, tunnels and bridges, and the transportation of large equipment required for converter station construction is extremely difficult [1]. It is necessary to build a digital State Grid modern material management system in all links of the whole process management of materials from production [2], transportation to delivery based on the comprehensive integration of various engineering data and with the help of modern innovative technical means such as Beidou positioning, remote sensing, BIM and GIS, so as to improve the level of power engineering material management.

Project material management includes links such as procurement, transportation, receipt and dispatch [3], warehousing and settlement of materials. Each link is managed through activities such as planning, organization, coordination and control to ensure that engineering materials are delivered in a timely manner and can meet the needs of engineering projects. In recent years, with the extensive use of new technologies, new materials, new products and new equipment [4], the engineering material transportation industry has vigorously promoted refined management and driven the development of the entire industry's efficiency with scientific and technological innovation achievements. The application of BIM and GIS technologies in engineering construction and material transportation for lean management has become increasingly important for the material management of converter station main equipment [5]. Domestic and foreign scholars have carried out a large number of studies to promote the digital transformation of logistics and improve the standardization and visualization level of power logistics [6]. In 2015, Zheng Yun et al. constructed a visual model of building supply chain operation through BIM - GIS technology [7], which improved work efficiency and quality, but did not achieve an organic combination of the two. In 2019, Wang Jian [8] et al. initially realized the digital management of pipelines through network and GIS technologies based on the current power engineering information management, but did not achieve standardized management. In conclusion, the domestic power material management can only meet some practical needs, and further research is required.

RESEARCH ON KEY TECHNOLOGIES IN THE WHOLE PROCESS OF MATERIAL SUPPLY FOR CONVERTER STATION MAIN EQUIPMENT

Research on Power Material Multi - Source Data Fusion Technology

To support the standardized construction of converter station engineering material data and meet the needs of 3D visual management of the whole process of power material supply, research on the techniques and methods of acquiring and fusing multi - source data such as geographic information data, power grid data, material planning information, material ledger information and material transportation progress information is carried out. The interfaces for acquiring various types of data are

standardized, different types of data are organized in a standardized manner, and a standard working mode for multi - source data processing is established to ensure the registration and fusion use of various multi - source data.

Research on standardization of basic geographic and power grid information

Various fusion methods of vector data, such as texture - based methods and geometry - based methods [9] are studied. According to the requirements of material equipment information display, combined with the characteristics of materialsin station location and transportation in transit, a reasonable vector data fusion technical route is analyzed [10], and a data acquisition scheme that meets the display requirements is designed. Data such as images, terrain and power grid information are stored and fused in a standardized data format. The specific steps are as follows:

(1) Data collection:

Collect basic geographic information data as shown in Table 1. Raster data includes orthophoto and its registration data, digital elevation model (DEM), and satellite imagery; vector data includes county - level and above administrative boundaries, town - level place names, and village - level place names.

Table 1. Acquisition of basic geographic information data

Data Type	Classification	Description
Raster Data	Aerial Photography Data	Better than 0.3 meters
	Digital Elevation Model (DEM)	Laser point cloud density should not be lower than 1 point/square meter
	Satellite Imagery	Better than 2.5 meters
Basic Vector Data	National Provincial Administrative Boundaries	1:4000000 scale
	National County - level Administrative Boundaries	1:4000000 scale
	Regional Boundaries	1:4000000 scale
	Province Names	1:4000000 scale
	City Names	1:4000000 scale
	County Names	1:4000000 scale
	Townships	1:4000000 scale
	Village - level Place Names	1:4000000 scale

(2) Data preprocessing: Clean and standardize different types of data.

(3) Data registration: Use geometric transformation methods to achieve spatial registration of multi - source data.

(4) Data fusion: Perform data fusion based on texture and geometric features to form a unified data set as shown in Table 2.

Table 2. Data processing set

Data Type	Data Volume	Data Source
Geographic Information Data	10GB	High - resolution satellite imagery
Power Grid Data	5GB	Power grid management system
Material Planning Information	1MB	ELP platform
Material Ledger Information	2MB	ECP platform
Material Transportation Progress Information	500KB	ELP platform

Research on fusion of material information, transportation tasks, trajectories and basic geographic information

Build a platform framework based on the geographic information system. Standardize the data obtained from the power logistics service platform (ELP) and the State Grid e - commerce platform (ECP) and store them in the database according to the data attributes. Study the methods of organizing text information such as schemes and ledgers in standardized fields and tables. For the position coordinate information in ELP, study the matching scheme with the basic geographic information [11] to achieve the registration and fusion of multi - source data [12,13]. Check the geometric topology, attribute expression, spatial relationship and logical consistency of the fused data to make the fused data optimal in terms of accuracy, currency and content richness [14,15]. The research process is shown in Figure 1.

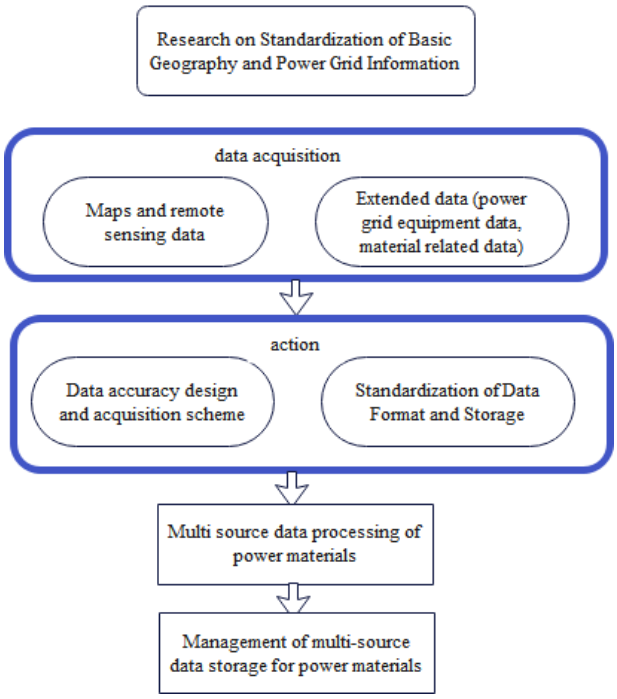

Figure 1. Research process

The specific steps are as follows:

(1) Data acquisition: Use Beidou positioning, remote sensing and other technologies [16,17] to collect material status information in real time and form a database table as shown in Table 3.

(2) Time series analysis: Perform time series analysis on the collected data to judge the trend of material status change.

(3) Spatial position matching: The material location information is matched with the preset transportation path to judge the status of transportation progress.

Table 3. Database table content

No.	Data	Source System	Source System Database Table Name	Source System Field
1	Physical "ID"	ELP	bs_physical_materiel	physical_materiel_id
2	Project Name	ECP	B_WINBID_PURREQ	ENG_NAME
3	Project Code	ECP	B_WINBID_PURREQ	ENG_CODE
4	Project Unit	ECP	B_WINBID_PURREQ	PROV_ORG_ID
5	Purchase Order Number	ECP	B_CON_TRANS_PLAN_ELP	PURORD_CODE
6	Line Item Number	ECP	B_CON_MAT_ITEM	PURREQ_ITEM_CODE
7	Material Category ID	ECP	b_con_mat_item	mat_max_id
8	Material Category Name	ECP	b_con_mat_item	mat_max_name
9	Material Subcategory ID	ECP	b_con_mat_item	mat_med_id
10	Material Subcategory Name	ECP	b_con_mat_item	mat_med_name
11	Material Subsubcategory ID	ECP	b_con_mat_item	mat_min_id
12	Material Subsubcategory Name	ECP	b_con_mat_item	mat_min_name
13	Planned Shipment Time	ELP	ts_task	ACTUAL_SEND_DATE
14	Actual Shipment Time	ELP	ts_task	PLAN_SEND_DATE
15	Trajectory Information	ELP	ts_location_info	LATITUDE

Research on standardization of material information, transportation tasks and transportation trajectory information

This research formulates a data docking scheme with ELP and ECP, and standardizes the interfaces of corresponding material information, material transportation tasks, transportation trajectory and other field information and acquisition frequencies.

Realize the on - demand synchronization of data through the https restful api protocol to receive and parse messages containing task and production report request information, and provide corresponding input parameter formats and return values. Use an early warning model based on a rule engine and machine learning algorithm to warn of abnormal situations in the material supply process. The specific steps are as follows:

(1) Rule definition: Define early warning rules according to the material supply plan and transportation plan.

(2) Data input: Input the real - time collected material status information and natural disaster information into the early warning model.

(3) Early warning judgment: Judge abnormal situations based on the rule engine and machine learning algorithm and trigger the early warning mechanism.

(4) Define standardized interfaces: Define the material supply plan interface and the material transportation interface as shown in Table 4 and Table 5.

Table 4. Basic information of material supply plan interface

Interface Name	POST_Equipment Base_Equipment Supply_Supply Plan_DWS_MAT_SUPPLY_PLAN_INFO_DF
Interface Description	Provide material supply plan information for the equipment professional scene. Input parameters: project code and project unit, contract dimension, physical ID; return values: material code, contract code, logistics transportation status and other core fields. Provide three query methods: (1) Query by project code or project name and return the supply plan related data under the corresponding project code and project name; (2) Query by contract name and return the supply plan related data under the corresponding contract name; (3) Query by physical ID and return the supply plan related data under the corresponding physical ID.
Data Format	JSON
Request Method	POST
Interface URL	/ast/ecp/adb/v1/post_dws_mat_supply_plan_info_df
Others	None

Table 5. Basic information of material transportation interface

Interface Name	POST_Equipment Base_Equipment Supply_Supply Plan_DWS_MAT_SUPPLY_PLAN_INFO_DF
Interface Description	Provide material supply plan information for the equipment professional scene. Input parameters: project code and project unit, contract dimension, physical ID; return values: material code, contract code, logistics transportation status and other core fields. Provide three query methods: (1) Query by project code or project name and return the supply plan related data under the corresponding project code and project name; (2) Query by contract name and return the supply plan related data under the corresponding contract name; (3) Query by physical ID and return the supply plan related data under the corresponding physical ID.
Data Format	JSON
Request Method	POST
Interface URL	/ast/ecp/adb/v1/post_dws_mat_supply_plan_info_df
Others	None

Research on Monitoring of Status Information in the Whole Process of Material Supply

To meet the requirements of converter station engineering material management, this research combines BIM, GIS, Beidou, remote sensing and other technologies to carry out research on business tracking and monitoring of the whole process of material supply. By constructing a BIM + GIS digital power grid carrier, the material supply scheme, plan and status are associated with the BIM 3D scene, realizing the rapid retrieval and analysis of the status information of UHV engineering materials in production, transportation, delivery and other links.

Construction of BIM + GIS digital power grid carrier

This research uses BIM technology to construct a 3D model of the main equipment of the converter station and combines it with GIS technology to form a digital power grid carrier. The carrier not only displays the spatial layout and physical properties of

the main equipment of the converter station but also integrates the material supply scheme, plan and status information. The constructed BIM + GIS digital power grid carrier is shown in Figure 2.

Figure 2. BIM + GIS digital power grid carrier

(1) Model import and preprocessing:

Import design files (such as DWG, DXF, IFC, etc.) into BIM software.

Preprocess the model, including cleaning unnecessary layers, merging duplicate components and adjusting the coordinate system. As shown in Figure 3 and Figure 4, perform invalid value removal of image data and coordinate system conversion respectively.

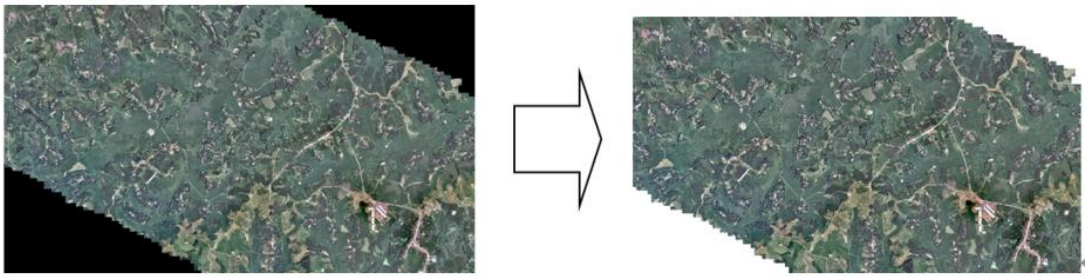

Figure 3. Removal of invalid values in image data

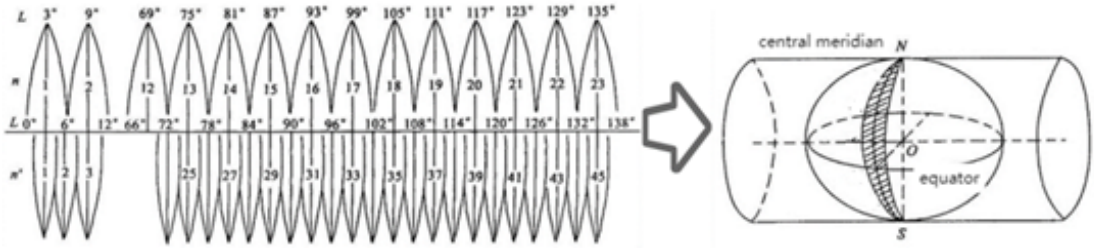

Figure 4. Coordinate system transformations

(2) Model refinement and attribute addition:

Refine the model according to actual needs, such as adding finer geometric details and texture mapping. as shown in the Figure 5.

Add attribute information such as name, specification and manufacturer to each component in the model.

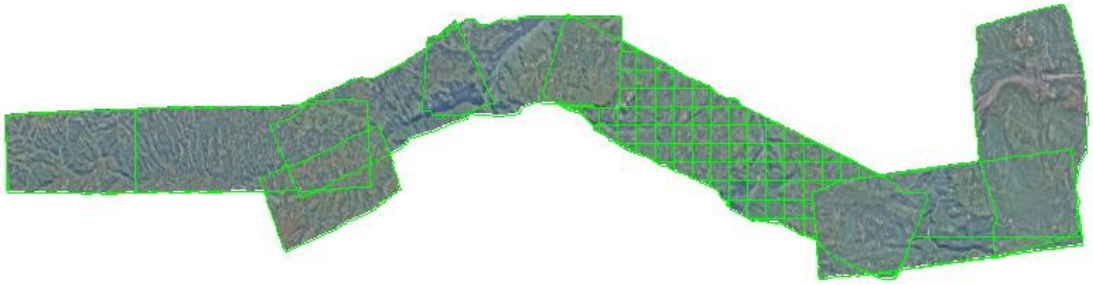

Figure 5. Mosaic dataset

(3) Model export and format conversion:

Export the BIM model to a format (Shapefile) recognizable by GIS software.

Perform format conversion and coordinate system adjustment on the exported model data to ensure compatibility with GIS data.

Monitoring and rapid retrieval of status information

By integrating Beidou positioning technology and remote sensing technology, this research realizes the real - time tracking and monitoring of material transport vehicles. At the same time, combined with the spatial analysis ability of GIS technology, the status information of the whole process of material supply can be quickly retrieved and analyzed. This information includes material production progress, transportation trajectory, delivery time, etc., providing strong technical support and information support for material management.

(1) Beidou positioning and remote sensing data integration algorithm:

Data acquisition: Obtain the real - time positioning data of material transport vehicles through the Beidou satellite navigation system.

Data fusion and processing: Perform time synchronization and spatial registration of Beidou positioning data and remote sensing image data; extract features and identify targets such as vehicles and roads through image processing algorithms; combine positioning data and image data to realize the real - time tracking and status monitoring of material transport vehicles.

(2) GIS spatial analysis algorithm:

Spatial query: Perform a spatial query in the GIS database according to the query conditions (such as geographical location and time range) entered by the user to quickly locate the status information of relevant materials.

Path analysis: Use the path analysis function of GIS software to optimize and calculate the material transportation path and provide suggestions for the best transportation route.

Buffer analysis: Set a buffer zone centered on the converter station and analyze the material supply status information within the buffer zone, such as material distribution and vehicle density.

Research on Early Warning of Status Information in the Whole Process of Material Supply

Based on information such as material supply plans, material transportation plans and natural disasters, combined with the characteristics of UHV engineering material transportation schemes and transportation paths, research and establish a typical model of emergency early warning for material supply process management and construct an emergency comprehensive early warning system for UHV engineering material supply.

Use information technology to establish an emergency early warning trigger mechanism, research and determine the linkage mechanism trigger boundary conditions [18], establish a standardized emergency information linkage mechanism for different levels of emergency responses [19], dock the early warning information that needs to be processed in important management links such as production, shipment, in transit and delivery, implement the emergency management responsibilities of different levels [20], and mark them prominently in the 3D scene to assist the orderly development of on - site emergency response work.

(1) Set alarm and early warning thresholds for the transportation speed, impact acceleration and inclination angle of large equipment according to transportation safety requirements.

Alarm for transportation speed: Set the alarm threshold for the transportation speed of large equipment to 80 km/h and the early warning threshold to 70 km/h to ensure the safety and stability of the transportation process.

Alarm for X, Y, Z - axis impact acceleration: For the equipment body, according to the provisions in the general part of the technical specifications of the bidding documents "the impact acceleration shall not be greater than 3g", set the alarm threshold for X, Y, Z - axis impact acceleration to 3g to prevent the equipment from being subjected to excessive impact during transportation.

Alarm for X, Y, Z - axis inclination angle: According to the provisions in the general part of the technical specifications of the bidding documents, the equipment body shall meet the requirements of transportation dimensions, weight and inclination not greater than 15° during highway transportation. Set the alarm threshold for X, Y, Z - axis inclination angle to 15° to ensure that the inclination degree of the equipment during transportation complies with the regulations.

(2) Immediately trigger the early warning mechanism when an abnormal situation is monitored and send early warning information to relevant personnel.

(3) Start the corresponding emergency response process according to the level and type of the early warning information.

PLATFORM DESIGN ARCHITECTURE AND FUNCTIONS

Overall Architecture

The platform serves the construction of UHV projects to meet the whole-process management and control requirements of converter station material supply. It realizes the whole-process remote monitoring and command application of converter station materials through the interaction of the large screen terminal and the WEB terminal. Its business functions cover 3D visualization management of materials, material supply monitoring management, material supply early warning management, etc. The system framework is implemented with a microservice architecture, and technologies such as BIM, GIS, artificial intelligence analysis, cloud services, and data mining are used to support business functions. Finally, the whole-process management data of material supply is applied to UHV project construction management. The overall architecture is shown in Figure 6.

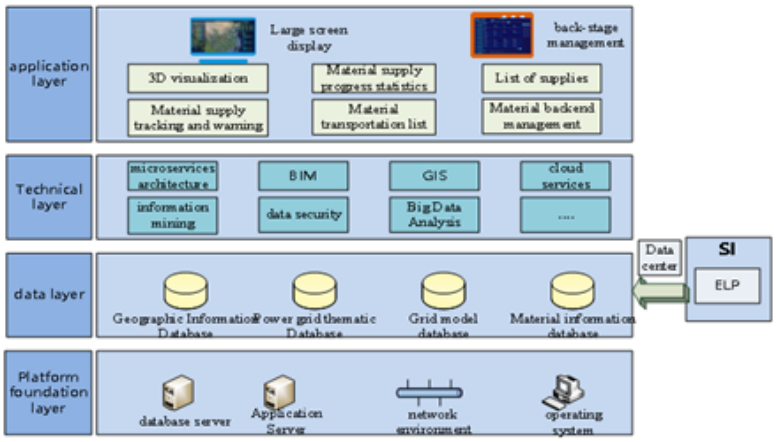

Figure 6. Overall structure drawing

Business Architecture

The whole-process management and control system of material supply is applied in the field of UHV material management and has functions such as material supply progress statistics, material supply list, material supply early warning tracking, and material transportation list. The overall business architecture of the whole-process management and control system of material supply is shown in the Figure 7. The comparison of business architecture compliance is shown in Table 6.

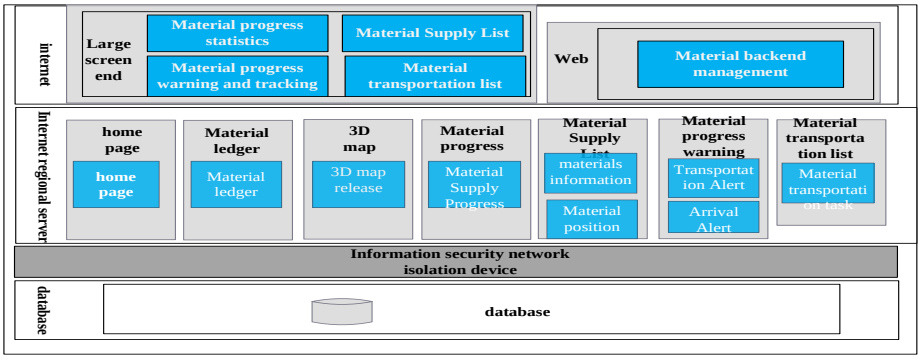

Figure 7. System business architecture diagram

Table 6. Business architecture compliance comparison

Business Domain	Physical Resources	
Business Function		
System Architecture: Business Function	Business Architecture: Business Function	Compliance Description
3D Map Display	3D Map 3D Model	Compliance
Material Supply Progress Statistics	Material Supply Progress Statistics	Compliance
Material Supply List	Material Supply Plan Material Production Information Material Transportation Information Material Arrival Information	Compliance
Material Supply Progress Early Warning Tracking	Material Supply Progress Early Warning Tracking	Compliance
Material Transportation List	Material Transportation List	Compliance
Material Backstage Management	Material Backstage Management	Compliance

Technical Architecture

The technical architecture of the platform is shown in the Figure 8.

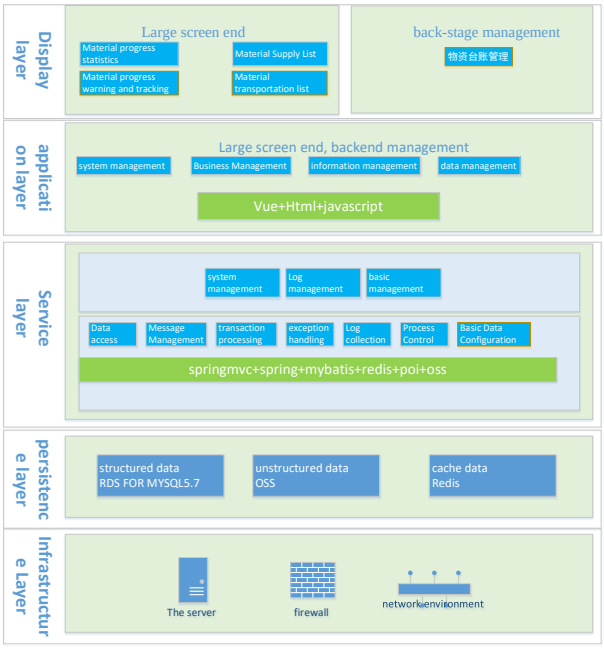

Figure 8. Technical architecture diagram

The technical architecture introduces the composition of the system from the technical implementation level and is divided into the infrastructure layer, the persistence layer, the service layer, the application layer, and the presentation layer. The technical architecture compliance comparison is shown in Table 7.

The infrastructure layer provides the software and hardware environment support for the platform. The hardware includes database servers, application servers, isolation devices, and network environments. The software includes operating systems, middleware, JDK, and other basic support software.

The persistence layer is the data support of the system. The system data can be structured data and unstructured data. Structured data is stored in a database, and unstructured data is stored in files.

The service layer provides functional services for users, that is, the functional applications seen in the system. It includes functions such as material supply progress statistics, material supply list, material supply progress early warning tracking, material transportation list, and material backstage management.

The application layer is the specific form of the system and includes the interaction between the system and applications.

The presentation layer is the interactive response display form of the system. It includes the function interaction display of the large screen terminal and the backstage management system.

Table 7. The technical architecture follows the contrast

Name of This System	Name of Overall Architecture: System	Compliance Description
Whole-process Management and Control of Material Supply	Whole-process Management and Control of Material Supply	Compliance
Integration Scenario		
System Architecture: Integration Scenario	Technical Architecture: Integration Scenario	Compliance Description
Application Integration	Page Integration	Reference
Data Structure	Storage Method	Compliance Description
Structured Storage	RDS FOR MYSQL 5.7 Database Storage	Reference
Unstructured Storage	File Method	Reference
Product Standard		
System Architecture: Software Product	Technical Architecture: Software Product	Compliance Description
Linux7.8 + 64-bit Version	Server Operating System	Compliance
RDS FOR MYSQL 5.7	RDS FOR MYSQL 5.7 Database System	Compliance
SG-UAP	Unified Application Development Tool	Compliance

Main Function Modules

The main function modules of the system include basic information comprehensive management, 3D scene visualization display, converter station material supply progress management, and material supply status monitoring and early warning. The Figure 9 is the system home page display:

Figure 9. System homepage display

Basic information comprehensive management

Basic information comprehensive management includes the maintenance and application of information such as material names, equipment manufacturers, unified identity codes of power grid assets (referred to as "physical ID" for short), contract codes, production codes, and material codes, as shown in the Figure 10.

Figure 10. Basic information backstage management

3D scene visualization display

Based on high-resolution satellite images, DEM data, power grid information, converter station 3D models, and other data, combined with material-related information such as transportation networks, railway stations, material stations, transfer stations, material receiving points, vehicle branch points, and material transportation control points, a 3D basic scene for the whole-process management and control of converter station material supply is constructed. The key functions of 3D scene visualization include map image terrain display, converter station equipment 3D model display, material station location display, key material transportation scheme route display, key material transportation trajectory display, converter station material information display, and converter station material supply progress visualization display, as shown in the Figure 11.

Figure 11. 3D visualization scene

Converter station material supply progress management

It realizes the business tracking and monitoring of the whole process of converter station project material supply, including the monitoring of the status information of each link such as material production, transportation, and arrival. It can timely judge whether the materials are shipped in time, whether they arrive at the designated transfer station on time during the transportation process, and whether they arrive at the construction material station on time. According to the dimensions of material types, transportation paths, and carriers, it statistics the execution status of material transportation plans and progress, judges normal and delayed situations, and realizes the quick retrieval and analysis of the whole-process information of various materials.

(1) Converter Station Material Distribution and Query

It mainly realizes the acquisition of material manufacturer information (manufacturer name, location), display on the 3D map, and query and positioning of key materials, as shown in the Figure12.

Figure 12. Converter station material visualization display

(2) Converter Station Material Supply Progress Statistics

It statistics the supply progress of converter station materials (main transformers, smoothing reactors, GIS) of the converter station project, including the quantity of materials not shipped (not produced, in production), the quantity of materials in transit, and the quantity of materials already arrived.

(3) Material Supply Progress Details

It retrieves and queries the detailed supply progress information of converter station materials (main transformers, smoothing reactors, GIS), including material names, material numbers, material types, material manufacturers, material status (including not started, in production, to be shipped, in transit, already arrived), planned material production completion time, actual material production completion time, planned material delivery time, actual material delivery time, planned material arrival time, actual material arrival time, and realizes the retrieval, query, and positioning display on the map of the detailed supply progress information of converter station materials.

(4) Transportation Process Monitoring and Early Warning

It manages the situation of convoy personnel, including the names and contact information of commanders, drivers, and escorts. It tracks the time when the convoy arrives at the intermediate transportation nodes and judges the transportation progress status. It monitors the vehicle status, including Beidou positioning, vehicle speed, acceleration, and other information. It gives early warnings for abnormal situations such as not arriving at the transportation nodes on time, deviating from the driving path, and speeding, and sends prompt messages to project management personnel. It contacts the site in the first time to verify the relevant situation.

Material supply status monitoring and early warning

It realizes the feedback of material supply early warning information, including material production progress status monitoring and early warning, material transportation progress status monitoring and early warning, material arrival progress status monitoring and early warning, and natural disaster early warning. Material production progress status monitoring is to feedback early warning information about impending or already delayed production, and display the warning information on the large screen or send text messages. Material transportation progress status monitoring compares the transportation path with the planned path. If there is a discrepancy or the transportation status exceeds the limit, it sends prompt messages to project management personnel. Material arrival progress status monitoring monitors the arrival progress of key materials and feeds back the early warning information about impending or already delayed arrival. Natural disaster early warning obtains emergency information about natural disasters and weather and material transportation trajectory information, matches the weather information with the transportation trajectory. If a natural disaster warning occurs during the transportation of important

materials, it automatically sends the warning information to the corresponding responsible persons. The above monitoring and early warning information is displayed on the large screen terminal and the mobile terminal, and multiple push methods are used to notify relevant personnel. The push methods include text messages, application messages, map display, etc., to ensure that the early warning information is accurate and timely. When the material supply progress returns to normal, such as when the material equipment arrives on time, the early warning information disappears, providing accurate information for timely reminders.

CONCLUSION

The whole-process management and control platform for converter station main equipment materials takes the "physical ID" as the link to realize the management of the whole process of converter station main equipment materials from production, transportation to arrival. By collecting and integrating the system data of each link, combined with the monitoring and early warning of the key elements of the whole process of main equipment, it monitors and displays the information about overdue, broken chains, and abnormal values in the business processes of main equipment materials in the production, transportation, and arrival stages, further enhancing the real-time management and control ability of main equipment materials in the whole business chain, promoting the "meticulous" quality management of UHV project construction, and strongly supporting the creation of high-quality and excellent projects.

In the future, combined with the application effect of pilot projects, through the promotion of new technology achievements, the management and control technology and application achievements of main equipment materials can be fully promoted in the production, transportation, and arrival stages of converter station main equipment materials, improving and gradually realizing the information sharing and traceability of the whole process of planning, procurement, transportation, and arrival of UHV project converter station main equipment, promoting the business integration, process connection, and data integration of the whole life cycle management of main equipment, and enhancing the lean management level of converter station main equipment materials.

ACKNOWLEDGMENTS

The paper should indicate: "Funded by the Science and Technology Project of State Grid Corporation of China (Contract No. SGZB0000TGJS2300998)"

REFERENCES

[1] Ge Rundong. Research on the Management Mode of Power Heavy Cargo Transportation. Energy and Energy Conservation. 2017: 75 - 76; TM73; U16.

[2] Han Xuan. Research on the Power Grid Material Management System Based on Modern Logistics Supply Chain. Proceedings of the Forum on Intelligent Building and Economic Development from the Perspective of New Quality Productive Forces (III). 2024: 70 - 71; F426.61; F251; TM727

[3] Liu Chang. How to Do a Good Job in Material Supply Management of Engineering Projects. Railway Procurement and Logistics. 2022, 17(08): 45 - 49; F426.92; F251.

[4] Huang Wei. Discussion on Strengthening the Whole-process Control of Material Quality. Railway Procurement and Supply. 2014, 3: 39 - 40; F426.92; F251.

[5] Xiong Yan, Chen Yuping. Research and Application of BIM Technology in Fine Management and Control during the Construction Stage. Jiangxi Building Materials. 2022, (06): 166 - 167; TU17; TU71.

[6] Li Haibo, Yan Zixiang, He Yan, Peng Jinyun. Design and Application of a Power Material Monitoring Platform Based on the Intelligent Supply Chain. New Technology & New Products of China. 2017, (10): 12 - 15; F274; F426.61.

[7] Zheng Yun, Su Zhenmin, Jin Shaojun. Application Research of BIM - GIS Technology in the Visualization of Building Supply Chain. Construction Technology. 2015, 44(06): 59 - 63; TU17; P208.

[8] Wang Jian. Analysis of Pipeline Information Management System. China Management Informationization. 2019, 22(16): 84 - 87; TM75.

[9] Lü Bin. Research on the Method of Creating Terrain Models by Fusing Elevation Gray Maps and Terrain Image Maps. Pearl River. 2024: 238 - 244 + 289; TV221; TP391.41.

[10] Zhang Biao, Chen Nan. Research on the Map World Vector Data Fusion Tool Based on ArcGIS Add - in. Geospatial Information. 2021, 19(7): 42 - 45.

[11] Wang Xiaohua. Thoughts on the Standardization of Basic Geographic Information Metadata. Standardization of Surveying and Mapping. 2016: 7 - 9; P208.

[12] Li Jing. Research on the Standardization of Basic Geographic Information Data. Southwest Jiaotong University Press. 2008: 118 - 122; P208.

[13] Huang Yuanhuai. Research on the Fusion Analysis of Multi - source Vector Data. Engineering Technology Research. 2022: 230 - 232; P208.

[14] Zhai Meng. Technology and Method of Map World·Fujian Data Fusion. Surveying and Mapping & Spatial Geographic Information. 2015, 38 (10): 184 - 186.

[15] Dong Yawen. Discussion on the Fusion of Vector Data Attribute Characteristics. Central South Forest Inventory and Planning. Volume 41, Issue 2, May 2022: 29 - 31.

[16] Wang Jing. Application Research and Embedded Terminal Realization of GPS/GSM Vehicle Monitoring System. Science of Surveying and Mapping. 2009: 256 - 257; TP277.

[17] Shang Chunpeng. Application Research of MIMU/GPS Integrated Navigation System. Microcomputer Information. 2010: 156 - 158; U463.6.

[18] Ren Ye. Application of Barcode Technology in the Whole Supply Chain Management of Power Materials. Modern Business Trade Industry. 2022, 43(17): 35 - 36.

[19] Dong Xu. Construction and Application of the Power Material Supply Chain Risk Monitoring and Early Warning System. Enterprise Reform and Management. December 2021: 40 - 41.

[20] Zhang Shengxue. Research on Establishing a Whole-process Management and Control Mode of Material Quality. Petroleum & Petrochemical Material Procurement. November 2014: 50 - 55.