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Construction of Knowledge Base for Emergency Power Supply Guarantee Mechanism and Intelligent Decision Support System Based on Knowledge Graph

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ABSTRACT This paper combines knowledge graph and intelligent decision-making technologies to conduct research on the construction of an emergency power supply guarantee knowledge base and an intelligent decision support system. Firstly, the paper sorts out the relevant theories and technologies of emergency power supply guarantee, knowledge graph and intelligent decision-making, completes domain ontology modeling, carries out collection, cleaning, knowledge extraction and fusion of multi-source heterogeneous data, and builds a standardized emergency power supply guarantee knowledge base. Secondly, adopting hybrid knowledge reasoning and multi-objective optimization algorithms, the overall design, function development and deployment of the intelligent decision support system are completed based on the front-end and back-end separation architecture. Finally, functional, performance and security tests are conducted, and a comparative analysis is carried out combined with a real-world case of power outage caused by a typhoon disaster. The results show that the system can realize the intelligent processing of the whole process including fault diagnosis, resource scheduling and emergency plan generation. Compared with the traditional manual mode, the emergency response speed, resource utilization rate and power supply reliability are significantly improved. This study can provide technical reference and practical experience for the intelligent construction of power emergency power supply guarantee.

INDEX TERMS Knowledge Graph, Emergency Power Supply, Knowledge Base, Intelligent Decision-making, Power Emergency.

I. INTRODUCTION

A. RESEARCH BACKGROUND AND SIGNIFICANCE

With the frequent occurrence of natural disasters such as extreme typhoons, heavy rainfall and ice disasters, urban power grids and power supply systems in industrial parks are highly prone to sudden accidents such as line faults, equipment outages and regional-wide power outages[1].

As the core backup guarantee facility after power grid failures, the rapid deployment and efficient scheduling capability of emergency power supplies are the key to reducing disaster losses and ensuring continuous power supply for critical loads[2]. Therefore, constructing an intelligent emergency power supply guarantee system has important practical significance.

At present, power emergency power supply guarantee mostly relies on manual experience and traditional ledger management, which has problems such as scattered and fragmented data, weak resource coordination ability, lagging fault judgment and scheduling response, strong generality of emergency plans and insufficient scenario adaptability[3]. Meanwhile, emergency disposal experience is difficult to precipitate and reuse, and the intelligence level of the guarantee mode is low, which cannot meet the high-precision and fast-response emergency guarantee requirements under complex disaster scenarios.

As a structured domain knowledge modeling technology, knowledge graph can realize the fusion of multi-source heterogeneous data and structured modeling of domain knowledge, and can effectively solve the pain points of fragmented power emergency knowledge and difficult solidification of experience[4, 5].

Applying knowledge graph to the field of emergency power supply guarantee can open up the semantic association of elements such as equipment, faults, scenarios and plans, and realize the intelligent upgrading of fault diagnosis, resource scheduling and emergency plan generation relying on intelligent reasoning. It provides new technical support for the construction of power emergency intelligent decision-making system, and has high theoretical and engineering application value.

B. RESEARCH STATUS AT HOME AND ABROAD

1) Research Status of Emergency Power Supply Guarantee Mechanism and Decision-Making

Foreign countries have carried out research on power emergency guarantee earlier. Developed countries in electric power such as Europe, the United States and Japan have established a standardized power emergency resource scheduling system, realized ledger management and preliminary scheduling optimization of emergency power supply resources relying on information platforms, and focused on research directions such as improving power supply reliability and optimal allocation of emergency resources under disaster scenarios[6, 7].

Domestic research mostly focuses on the fields of emergency power supply operation and maintenance management, disaster emergency disposal processes and scheduling optimization algorithms, forming a series of power emergency guarantee specifications and technical solutions[8, 9]. However, existing studies mostly focus on process optimization and algorithm improvement, lack systematic modeling and in-depth mining of domain knowledge, have low knowledge reuse rate and insufficient intelligent decision-making ability.

2) Application Research of Knowledge Graph in Energy Emergency Field

In recent years, knowledge graph technology has been widely applied in the power field. Existing studies mainly cover scenarios such as power grid fault diagnosis, power equipment operation and maintenance, and power grid risk early warning. By constructing a power domain knowledge graph, functions such as equipment association relationship mining, fault tracing and semantic retrieval are realized[10-12].

In the field of power emergency, some scholars have tried to apply knowledge graph to emergency plan management and emergency case analysis. However, there are few studies on the construction of exclusive knowledge bases, knowledge reasoning and intelligent decision-making for the subdivided scenario of emergency power supply guarantee, the domain knowledge system is imperfect, and the technical implementation is weak.

3) Deficiencies and Core Challenges of Existing Research

Based on the comprehensive analysis of domestic and foreign research status, there are still three core shortcomings in current relevant research:

First, there is a lack of standardized ontology models and knowledge systems in the field of emergency power supply guarantee, multi-source data cannot be effectively fused, and the problem of knowledge fragmentation is prominent.

Second, most existing decision-making systems rely on structured data and fixed algorithms, cannot mine implicit emergency knowledge, and have low intelligence in decision-making.

Third, the dynamic update mechanism of the knowledge base is imperfect, which cannot adapt to complex and changeable disaster emergency scenarios, and the practicability and scalability of the system are insufficient.

In view of this, this paper constructs an emergency power supply guarantee knowledge base and an intelligent decision-making system in a targeted manner to fill the gaps in existing research.

C. RESEARCH CONTENT

Taking the intelligent guarantee of emergency power supply under emergencies as the core goal, this paper carries out three core researches:

First, sort out the theoretical system and key technologies of emergency power supply guarantee, construct the domain ontology model of emergency power supply guarantee, complete multi-source data collection, preprocessing, knowledge extraction and fusion, and build a standardized domain knowledge base.

Second, combine knowledge reasoning and multi-objective optimization algorithms, design core functions such as emergency power supply fault diagnosis, resource scheduling and emergency plan generation, and complete the architecture design and development implementation of the intelligent decision support system.

Third, build a test environment, verify the system reliability through functional, performance and security tests, and carry out case application analysis combined with real disaster scenarios to verify the practical application value of the system.

II. RELEVANT THEORIES AND TECHNICAL FOUNDATIONS

A. BASIC THEORY OF EMERGENCY POWER SUPPLY GUARANTEE

1) Classification of Emergency Power Supplies and Whole-Process Guarantee System

Emergency power supplies are backup power supply equipment in scenarios such as power system failures and disaster-induced power outages. According to power supply characteristics and equipment types, they can be divided into four categories: diesel generators, UPS uninterruptible power supplies, mobile emergency power vehicles and energy storage emergency power supplies[13, 14]. There are obvious differences in power supply capacity, response speed and applicable scenarios of various types of equipment. The specific classification and parameters are shown in Table 1.

The whole process of emergency power supply guarantee covers seven links: disaster early warning, fault judgment, resource scheduling, on-site deployment, power supply operation and maintenance, fault recovery and resource withdrawal, forming a closed-loop emergency guarantee system. Each link is closely connected and directly affects the efficiency of emergency power supply.

TABLE 1. Comparison Table of Classification and Core Parameters of Emergency Power Supply Equipment

Equipment Type	Power Supply Capacity Range	Response Speed	Applicable Scenarios	Operation and Maintenance Characteristics
UPS Uninterruptible Power Supply	0.5-20kVA	Millisecond-level instantaneous response	Precision equipment, computer rooms, short-term emergency power supply	Maintenance-free, short battery life
Diesel Generator	20-2000kVA	Minute-level startup	Large-area power outages, long-term emergency power supply	Requires fuel supply, continuous operation and maintenance
Emergency Power Vehicle	50-1000kVA	Rapid deployment, minute-level response	Outdoor disasters, temporary emergency rescue power supply	Strong mobility, wide adaptability
Energy Storage Emergency Power Supply	10-500kVA	Instantaneous response, silent operation	Emergency power supply in residential areas and precision areas	Green and environmental protection, stable battery life

2) Analysis of Key Influencing Factors of Emergency Power Supply Guarantee

Combined with power emergency disposal scenarios, the effect of emergency power supply guarantee is mainly affected by four types of factors:
First, equipment factors, including equipment capacity, operating status, battery life and deployment location.
Second, scenario factors, covering disaster type, power outage scope, fault level and emergency duration.
Third, resource factors, involving the number of operation and maintenance personnel, material reserves and transportation conditions.
Fourth, management factors, including plan adaptability, scheduling efficiency, operation and maintenance specifications and emergency response mechanisms.

Various factors are coupled with each other and jointly determine the overall efficiency of emergency power supply guarantee, which is the core basis for knowledge modeling and intelligent decision-making.

3) Evaluation System of Emergency Power Supply Guarantee Capability

To quantitatively evaluate the effect of emergency guarantee, this paper constructs a multi-dimensional evaluation system for emergency power supply guarantee capability, which includes 5 first-level indicators (response timeliness, resource utilization rate, power supply reliability, disposal economy and scenario adaptability) and 12 second-level indicators, providing quantitative standards for the evaluation of system decision-making effects and scheme optimization. The evaluation system is shown in Table 2.

TABLE 2. Evaluation System of Emergency Power Supply Guarantee Capability

First-level Indicator	Second-level Indicator	Indicator Description
Response Timeliness	Fault Response Time	The duration from the occurrence of a fault to the start of emergency guarantee
	Equipment Deployment Time	The duration from resource scheduling to on-site deployment completion
	Power Supply Recovery Duration	The total duration of restoring normal power supply in the power outage area
Resource Utilization Rate	Equipment Utilization Rate	The proportion of equipment put into use to the total reserve equipment
	Personnel and Material Utilization Rate	The effective input ratio of emergency personnel and materials
Power Supply Reliability	Power Supply Stability Rate	The proportion of no interruption and no fault during emergency power supply
Disposal Economy	Emergency Cost Control Rate	The rationality of the input cost of emergency guarantee
Scenario Adaptability	Scheme Matching Degree	The adaptation degree of the decision-making scheme to the disaster scenario

B. CORE TECHNOLOGIES OF KNOWLEDGE GRAPH

1) Basic Concepts and Construction System of Knowledge Graph

Knowledge graph is a structured knowledge representation method based on graph structure, which takes the triple of "entity-relationship-entity" as the core to realize the structured and associated storage and expression of domain knowledge[15].

The core construction system of domain knowledge graph includes four modules: ontology modeling, knowledge acquisition, knowledge fusion and knowledge storage. Different from general knowledge graphs, the domain knowledge graph for emergency power supply guarantee has the characteristics of strong professionalism, close entity association and high scenario adaptability, which can accurately depict the core elements and association relationships in the field of power emergency.

2) Key Technologies of Knowledge Extraction and Knowledge Fusion

Knowledge extraction is the core link of knowledge graph construction[16]. This paper adopts an entity and relationship joint extraction algorithm based on the BERT pretrained model to automatically extract core entities and semantic relationships such as emergency equipment, fault types, disaster scenarios, emergency plans and operation and maintenance personnel from multi-source data such as power emergency plans, accident reports, equipment ledgers and industry specifications.

In the knowledge fusion stage, entity alignment, attribute fusion and conflict resolution technologies are used to solve the problems of duplication, contradiction and heterogeneity of multi-source data, and realize the standardized unification of knowledge.

3) Principles of Graph Database and Knowledge Storage Technology

This paper adopts the Neo4j graph database to realize domain knowledge storage. Different from traditional relational databases, Neo4j stores entities as nodes and relationships as edges, which can efficiently handle complex semantic association queries and knowledge reasoning tasks[17].

Aiming at the structured and semi-structured characteristics of emergency power supply guarantee knowledge, a hybrid storage architecture of "MySQL+Neo4j" is adopted. MySQL stores structured data such as equipment ledgers and user information, and Neo4j stores knowledge graph triple data, taking into account the stability of data storage and the efficiency of knowledge query.

C. INTELLIGENT DECISION SUPPORT TECHNOLOGIES

1) Multi-Modal Hybrid Knowledge Reasoning Technology

To improve the accuracy of emergency decision-making, this paper constructs a hybrid reasoning mechanism combining rule-based reasoning and graph neural network reasoning.

Explicit emergency knowledge reasoning is realized based on SWRL rules to complete fault matching, plan invocation and resource screening; implicit association knowledge in the knowledge graph is mined based on graph neural network to realize unknown fault tracing and potential risk prediction, making up for the limitations of a single reasoning method.

2) Multi-Objective Optimization Decision Algorithm for Emergency Scheduling

Emergency power supply resource scheduling needs to take into account multi-dimensional objectives such as response speed, resource utilization rate, emergency cost and power supply reliability, which is a typical multi-objective optimization problem.

This paper adopts an improved genetic algorithm, takes the shortest scheduling time, the highest resource utilization rate and the lowest emergency cost as optimization objectives, constructs a multi-objective optimization scheduling model, and realizes the optimal allocation and accurate deployment of emergency power supply resources.

3) Power Emergency Situation Awareness and Early Warning Technology

By integrating meteorological data, power grid operation data, equipment status data and disaster early warning data, real-time perception of power emergency situation is realized.

Based on historical disaster data and knowledge graph association rules, a risk early warning model is constructed, which can predict the weak areas of the power grid and the power outage risk level in advance, realize the pre-reserve and pre-scheduling of emergency power supply resources, and improve the initiative of emergency guarantee.

D. SYSTEM DEVELOPMENT TECHNOLOGY STACK

1) Front-End and Back-End Separation Architecture and Development Framework

The system adopts the Spring Boot+Vue front-end and back-end separation development architecture. The back-end realizes business logic development, data processing, knowledge reasoning and interface encapsulation based on the Spring Boot framework, which has the advantages of light weight, high adaptability and easy expansion.

The front-end builds a visual interactive interface based on the Vue framework to realize functions such as knowledge base display, situation monitoring, decision result visualization and system operation interaction. The front and back ends realize data interaction through API interfaces, with low coupling and convenient operation and maintenance.

2) Data Visualization and Dynamic Display Technology

Based on ECharts visualization technology, dynamic visual display of information such as emergency resource distribution, power grid risk situation, equipment operation status and decision data statistics is realized. It supports chart linkage, data filtering and situation refresh, providing managers with an intuitive and comprehensive emergency situation perception interface and improving decision-making efficiency.

3) Distributed Processing Technology for Massive Data

Aiming at multi-source massive power emergency data, distributed data processing technology is adopted to realize batch processing and real-time update of structured, semi-structured and unstructured data, improve the efficiency of data preprocessing, knowledge extraction and knowledge update, and ensure the massive data processing capability and operational stability of the system.

III. CONSTRUCTION OF EMERGENCY POWER SUPPLY GUARANTEE KNOWLEDGE BASE BASED ON KNOWLEDGE GRAPH

A. DESIGN OF DOMAIN KNOWLEDGE SYSTEM FOR EMERGENCY POWER SUPPLY GUARANTEE

1) Domain Demand Analysis and Knowledge Boundary Definition

Combined with the whole-process business requirements of power emergency power supply guarantee, the core service scenarios of the knowledge base are defined as four scenarios: disaster-induced power outage emergency disposal, equipment fault emergency guarantee, daily operation and maintenance management, and emergency plan optimization.

The knowledge boundary is defined, focusing on six core knowledge fields: emergency equipment, disaster scenarios, power grid faults, emergency resources, emergency plans and disposal cases, eliminating irrelevant redundant data, and ensuring the professionalism and pertinence of the knowledge base.

2) Domain Ontology Modeling for Emergency Power Supply Guarantee

Ontology modeling is the core foundation of knowledge graph construction. Based on domain requirements, this paper defines six core ontologies: equipment ontology, fault ontology, scenario ontology, resource ontology, plan ontology and case ontology.

Through ontology hierarchy division, attribute definition and relationship constraint, a standardized domain ontology model for emergency power supply guarantee is constructed, and the core attributes and association relationships of each ontology are clarified. The core attributes of the ontology are shown in Table 3.

TABLE 3. Core Ontology Attribute Table in the Field of Emergency Power Supply Guarantee

Core Ontology	Core Attributes	Associated Ontologies
Equipment Ontology	Equipment type, capacity, location, operating status, battery life	Fault ontology, resource ontology
Fault Ontology	Fault type, fault location, fault level, influence scope	Scenario ontology, equipment ontology
Scenario Ontology	Disaster type, disaster level, occurrence area, emergency duration	Fault ontology, plan ontology
Resource Ontology	Number of personnel, material type, reserve location, available status	Equipment ontology, plan ontology
Plan Ontology	Applicable scenarios, disposal process, resource configuration, response level	Scenario ontology, case ontology
Case Ontology	Disposal scenario, used resources, disposal effect, experience summary	Plan ontology, fault ontology

3) Definition of Core Concepts and Semantic Relationships

Based on the ontology model, the core semantic relationships in the domain are defined, mainly including five core association relationships: equipment-adapted scenario, fault-corresponding equipment, scenario-matched plan, plan-allocated resource and case-optimized plan. The structured expression of knowledge is completed in the form of triples, realizing the interconnection of knowledge in different fields and providing semantic support for subsequent knowledge reasoning and intelligent decision-making.

B. COLLECTION AND PREPROCESSING OF MULTI-SOURCE HETEROGENEOUS DATA

1) Classification and Characteristic Analysis of Multi-Source Data Sources

The data sources in this paper cover three types of multi-source heterogeneous data:

Structured data, including emergency equipment ledgers, personnel and material ledgers, and power grid operation statistical data;

Semi-structured data, including power industry emergency standards, emergency plan documents and equipment technical manuals;

Unstructured data, including annual power disaster accident reports, emergency disposal news and on-site disposal records. Various types of data complement each other to ensure the comprehensiveness of knowledge coverage.

2) Processing Methods for Structured and Semi-Structured Data

For structured data, preprocessing is completed through data cleaning, deduplication, format standardization and missing value filling, and the data is directly imported into the database for storage.

For semi-structured standard and plan documents, document parsing, chapter splitting and keyword extraction are carried out to strip invalid content, extract core business knowledge, and convert it into modelable structured data.

3) Cleaning and Standardization Processing of Unstructured Data

For unstructured text data such as accident reports and on-site records, text segmentation, stop word removal and noise filtering technologies are used to complete data cleaning, unify text expression specifications, eliminate colloquial, fragmented and invalid redundant information, and provide a high-quality data foundation for subsequent knowledge extraction.

C. KNOWLEDGE EXTRACTION AND FUSION FOR EMERGENCY POWER SUPPLY GUARANTEE

1) BERT-Based Joint Extraction of Entities and Relationships

A fine-tuned BERT pre-trained model is adopted to carry out joint extraction of entities, relationships and attributes on the preprocessed text data, accurately identify core domain entities and corresponding semantic relationships and attribute information, and generate standardized knowledge triples.

Compared with traditional extraction algorithms, this model has stronger adaptability and higher extraction accuracy for professional texts in the power field.

2) Alignment and Entity Linking of Multi-Source Heterogeneous Knowledge

Aiming at the problems of homonymy and synonymy of entities caused by multi-source data, entity alignment and linking processing are carried out to unify entity naming specifications and attribute standards, integrate and summarize the knowledge of the same entity scattered in different data sources, and realize the unified association of global knowledge.

3) Knowledge Conflict Detection and Intelligent Resolution Strategy

Knowledge conflict detection rules are constructed. Aiming at the problems of attribute contradiction, relationship conflict and data inconsistency in multi-source knowledge, the resolution strategy of "authoritative data priority, latest data priority" is adopted, combined with manual review based on domain rules, to complete intelligent resolution of knowledge conflicts and ensure the accuracy and authority of knowledge in the knowledge base.

D. KNOWLEDGE REASONING, UPDATE AND STORAGE MANAGEMENT

1) Hybrid Knowledge Reasoning Mechanism Combining Rules and Deep Learning

Combining explicit rule-based reasoning and implicit deep learning reasoning, a hybrid reasoning mechanism is constructed.

Relying on SWRL rules to realize explicit knowledge reasoning such as fault matching, plan invocation and resource screening;
Relying on graph neural network to mine implicit associations between entities to realize risk prediction, fault tracing and scheme optimization, and comprehensively improve the knowledge utilization rate.

2) Incremental Dynamic Update Strategy of Knowledge Base

An incremental knowledge base update mechanism is designed. For newly added emergency cases, equipment data and industry specifications, there is no need to reconstruct the knowledge base in full, only the extraction, fusion and warehousing of newly added knowledge are completed, which greatly reduces the update cost and ensures that the knowledge base adapts to the latest business scenarios and technical specifications in real time.

3) Hybrid Storage Architecture Design and Performance Optimization

A MySQL+Neo4j hybrid storage architecture is adopted to optimize the data storage structure and index strategy. Exclusive indexes are established for high-frequency query knowledge to improve the efficiency of knowledge retrieval, reasoning and invocation. Meanwhile, a knowledge base authority management mechanism is built to ensure knowledge security and standardized management.

IV. DESIGN AND IMPLEMENTATION OF INTELLIGENT DECISION SUPPORT SYSTEM FOR EMERGENCY POWER SUPPLY GUARANTEE

A. OVERALL SYSTEM DESIGN

1) System Design Objectives and Core Design Principles

The core design objective of the system is to realize the intelligent management and decision-making of the whole process of emergency power supply guarantee, and solve the problems of low efficiency, weak intelligence and poor knowledge reuse in the traditional mode.

The design follows four principles: practicability, intelligence, scalability and security, which fits the actual business needs of power emergency and takes into account the system stability and subsequent iteration space.

2) Four-Layer Overall System Architecture Design

The system adopts a four-layer hierarchical architecture as a whole, which is divided into data layer, knowledge layer, service layer and application layer from bottom to top.
The data layer is responsible for multi-source data collection and storage;
The knowledge layer completes knowledge graph construction, knowledge reasoning and knowledge management;
The service layer encapsulates various business algorithms and interface services;
The application layer provides visual operation and decision display functions. Each level operates independently and collaborates with each other.

3) System Function Modules and Overall Data Flow Design

Four core function modules are divided based on business requirements. The overall data flow follows the closed-loop logic of "data collection → preprocessing → knowledge modeling → knowledge reasoning → decision generation → visual output", realizing the whole-process automatic transformation from original data to intelligent decision-making schemes.

B. DETAILED DESIGN OF CORE FUNCTION MODULES

1) Basic Resource and Knowledge Base Management Module

This module is the basic core of the system, including four sub-functions: equipment resource management, personnel and material management, knowledge base maintenance and knowledge visualization. It supports knowledge entry, editing, query, update and visual display, realizes standardized and integrated management of emergency resources and domain knowledge, and provides data and knowledge support for upper-level decision-making.

2) Risk Assessment and Power Grid Fault Diagnosis Module

Relying on the reasoning ability of the knowledge graph, automatic identification of power grid faults, fault tracing and risk level assessment are realized. It can accurately locate fault locations, judge the influence scope of faults, predict power outage risks, identify weak links of the power grid in advance, and output risk assessment reports and fault disposal suggestions.

3) Intelligent Scheduling Module for Emergency Power Supply Resources

Based on the multi-objective optimization scheduling algorithm, combined with disaster scenarios, fault levels and resource distribution, the optimal emergency power supply scheduling scheme is automatically matched to realize the precise allocation of equipment, personnel and materials. It supports dynamic scheduling optimization for multiple scenarios and multiple objectives, and greatly improves resource utilization rate and emergency response speed.

4) Intelligent Generation and Deduction Module for Emergency Plans

Combined with scenario matching rules and historical disposal cases, personalized emergency plans adapted to the current disaster scenario are automatically generated. It supports online editing of plans, process deduction and effect simulation, can predict plan loopholes in advance and optimize schemes, and improve the scenario adaptability and operability of emergency plans.

C. IMPLEMENTATION OF KEY SYSTEM TECHNOLOGIES

1) Power Semantic Retrieval Technology Based on Knowledge Graph

Different from traditional keyword retrieval, the system realizes semantic-level intelligent retrieval, which can accurately match associated knowledge, equipment resources, disposal cases and emergency plans according to users' fuzzy needs and scenario descriptions. It supports multi-dimensional associated retrieval, and the retrieval accuracy and efficiency are greatly improved.

2) Multi-Mechanism Fusion Intelligent Decision Generation Method

Integrating rule-based reasoning, case-based reasoning, deep learning reasoning and optimization algorithms, a multi-mechanism intelligent decision-making system is constructed. Based on historical disposal experience, existing business rules and real-time scenario data, scientific, accurate and implementable emergency decision-making schemes are generated to avoid subjective deviations of manual decision-making.

3) Multi-Dimensional Evaluation and Optimization of Emergency Decision Schemes

Relying on the guarantee capability evaluation system constructed above, multi-dimensional quantitative evaluation of the generated decision schemes is carried out in terms of response timeliness, resource utilization rate, economy and reliability. The optimal scheme is automatically screened, and manual fine-tuning is supported to realize the organic combination of intelligent decision-making and manual intervention.

D. SYSTEM DEVELOPMENT AND DEPLOYMENT IMPLEMENTATION

1) System Development Environment and Core Tool Selection

The hardware environment for system development is a high-performance server, and the software environment is based on the Windows Server system. The back-end adopts Java development language and Spring Boot framework, the front-end adopts Vue+ECharts, the database adopts MySQL8.0 and Neo4j4.4, and the algorithm model is implemented based on Python. The development tools have strong adaptability and stable operation.

2) Implementation of Database Structure and Core Interface Design

The table structure design of the business database and knowledge graph database is completed, and core API interfaces such as knowledge query, reasoning calculation, resource scheduling, plan generation and data visualization are encapsulated to realize efficient data interaction between modules, with good interface compatibility and scalability.

3) System Deployment Scheme and Operating Environment Configuration

The server local deployment mode is adopted to complete environment configuration, program deployment, database initialization, interface debugging and other work, and build a complete system operating environment. It supports all-weather stable operation and meets the needs of normal power emergency guarantee and sudden disaster emergency disposal.

V. SYSTEM TESTING AND APPLICATION CASE ANALYSIS

A. COMPREHENSIVE SYSTEM TESTING

1) Test Environment Construction and Test Case Design

A test environment consistent with the actual application scenario is built. Test cases are designed around core functions such as system knowledge base management, fault diagnosis, intelligent scheduling, plan generation and data visualization. Meanwhile, performance and security test cases are designed for system response speed, concurrency capability, security and availability to fully cover the core business of the system.

2) System Function and Operational Performance Testing

Full functional testing is carried out to verify the integrity, accuracy and stability of each module function. All core functions can be realized normally without functional loopholes.

The performance test results show that the response time of a single knowledge query of the system is ≤ 0.5s, the concurrent access supports 500 users online at the same time, and the complex decision calculation time is ≤ 2s, which fully meets the real-time requirements of emergency disposal. The core performance indicators of the system are shown in Table 4.

TABLE 4. Core Performance Test Results of the System

Test Indicator	Test Standard	Measured Result	Test Conclusion
Knowledge Query Response Time	$\leq$ 1s	0.42s	Qualified
Intelligent Decision Calculation Time	$\leq$ 3s	1.85s	Qualified
Maximum Concurrent Access Volume	$\geq$ 300 users	Stable operation for 500 users	Qualified
Data Accuracy	$\geq$ 98%	99.2%	Qualified

3) System Security and Usability Verification Testing

System security is verified through authority testing, data encryption testing and abnormal access testing. The system's hierarchical authority control is effective, data transmission and storage are safe and reliable, and it can effectively resist abnormal access. Usability tests show that the system has simple operation, intuitive interface and clear process, which fits the operation habits of power emergency business, and has good practicability and operability.

B. ANALYSIS OF TYPICAL ENGINEERING APPLICATION CASES

1) Disaster Scenario Case Background and Emergency Requirements

A typhoon disaster-induced power grid outage scenario in a coastal city is selected as the application case. The typhoon has high wind level and wide influence scope, leading to faults of multiple distribution network lines in the urban area and large-area power outages in multiple residential areas and industrial parks. It is urgent to quickly deploy emergency power supply equipment and restore power supply in key areas.

The core emergency requirements of this case are rapid fault judgment, accurate resource scheduling and efficient formulation of power supply guarantee schemes.

2) System Operation Process and Intelligent Decision Results

The disaster scenario, fault data and resource information are input into the system. The system automatically completes fault diagnosis, risk assessment and resource matching, generates the optimal emergency power supply scheduling scheme based on knowledge reasoning and optimization algorithms, clarifies the type, quantity, deployment location, operation and maintenance personnel configuration and power supply guarantee duration of emergency power supply equipment in each area, and automatically generates a special emergency plan adapted to this typhoon disaster.

3) Application Effect and Comparative Analysis with Traditional Schemes

A multi-dimensional comparison is made between the system decision scheme in this paper and the traditional manual disposal scheme, and the results are shown in Table 5. Compared with the traditional mode, the system in this paper can greatly shorten the emergency response duration, improve resource utilization rate, reduce emergency costs and improve power supply reliability, with significantly improved comprehensive guarantee efficiency and strong engineering application value.

TABLE 5. Comparison of Application Effects between Traditional Schemes and Intelligent Decision Schemes

Evaluation Indicator	Traditional Manual Scheme	Intelligent Decision Scheme in This Paper	Optimization Effect
Total Emergency Response Duration	128min	45min	Shortened by 64.8%
Emergency Resource Utilization Rate	68.5%	92.3%	Increased by 23.8%
Emergency Guarantee Cost	286,000 yuan	192,000 yuan	Reduced by 32.9%
Power Supply Stability Rate	85.2%	98.7%	Increased by 13.5%

VI. CONCLUSION AND PROSPECT

Focusing on the demand for intelligent emergency power supply guarantee, this paper constructs a knowledge graph knowledge base for emergency power supply guarantee, and designs and implements an integrated intelligent decision support system, which effectively solves the problems of fragmented data, difficult reuse of experience and lagging decision-making in traditional power emergency guarantee. Verified by tests and cases, the system can significantly improve emergency scheduling efficiency and resource utilization rate, and has good practicability and engineering application value.

Meanwhile, there are still some problems in the research, such as insufficient adaptability to complex scenarios and limited real-time dynamic decision-making ability. In the follow-up, the power emergency intelligent decision-making system can be further improved by optimizing knowledge reasoning algorithms, accessing real-time monitoring data and expanding diversified application scenarios, so as to promote the upgrading of power emergency guarantee towards intelligence and precision.

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