Research on Intelligent Technology of Dispatching and Control to Ensure Power Supply Based on Multivariate Information

Wang Kai¹, Zhang Rui¹, Song Lei¹, Lan Haibo¹, Wu Yi²,³, Pan Jianhua²,³, Wu Guosong²,³, *

¹State Grid Jibei Electric Power Company Limited, Beijing, 100053, China
²Nari Group Corporation/State Grid Electric Power Research Institute
³BeiJing Kedong Electric Power Control System Co., Ltd, Beijing 100192, China
*524869920@qq.com, liushengnanl@sgepri.sgcc.com.cn

Abstract: The development of power dispatch services to ensure power supply has put forward new requirements for the digitalization, intelligence and servitization of the dispatching system. Based on the data of power dispatch and control, the characteristics of power dispatch services to ensure power supply, and research on intelligent technology of dispatching and control to ensure power supply based on multivariate information, by establishing the data model of power supply services, and applying forms of expression such as knowledge graph, with deep neural network and rule learning technology, this paper explores and develops an intelligent robot of dispatching and control to ensure power supply based on multivariate information, which realizes the functions of interface integration of various service platforms, visualized monitoring of power supply information, and release and submission of power supply information, etc. By building intelligent applications according to the requirements of power dispatch services to ensure power supply, it effectively improves the risk prevention and control level and emergency response capacity of power system to ensure power supply, and comprehensively upgrades the safe and stable operation of power system to ensure power supply.

1. Introduction
With the development of the power grid, the environment faced by the power grid to guarantee its safe and stable operation during the power supply service period is more complex. Power outages due to infrastructure, technical transformation, planned repair, and bad weather result in weak operation of the power grids and increased power supply safety risks. In particular, there is no standard system and process for risk control of power grid operation during the power supply service period, and various departments have limited measures to prevent power grid operation risks. This has caused a serious shortage of risk coordination and control capabilities of power grids.

In order to adapt to the new characteristics of the power grid and respond to the increasingly complicated circumstances for safe operation of the power grid, the dispatching and control of operation should be supported by integrated intelligent technologies in the whole process before, during and after the operation, so as to transform the fault handling of power grids from experience-oriented to intelligence-oriented type as soon as possible. The controller has accumulated
rich experience in the process of dispatching and control operation and emergency response. It is necessary for them to share and exchange with one another the key data of power grid fault handling, such as the power grid’s operation data and fault handling plans, and refine their experience into knowledge, which realizes experience sharing among different dispatchers, enriches decision-making measures for accident judgment and post-event recovery, guides and helps controllers to actively, quickly, comprehensively and accurately control the key information of fault handling, provides corresponding assistant decision-making for fault handling, and effectively controls the occurrence and development of power grid accidents. Knowledge graph is an artificial intelligence technology, which is widely used in enterprises of search engines, artificial intelligence, etc. that have huge amount of data. It has been proved that it can better construct and query complex association relationships, understand user’s purposes from the semantic level, and improve the quality of knowledge construction and management. Therefore, knowledge graph and its related technologies are very appropriate to resolve the bottlenecks in current fault handling of power grids and improve the intelligent level of fault handling.

With the further construction of the dispatching and control Platform-as-a-Service (PaaS), based on the standardized structure of business data in the model, operation and real-time data cloud platform, in order to achieve the goal of applying big data technology to enhance the supporting capacity of intelligent dispatching and control technology to ensure power supply, the dispatching and control cloud uses cloud computing to virtualize resources such as servers, storage devices and network devices, and to build resource pools of computing, storage and network to provide guarantee for the informatization of dispatching services. According to the structure of the common data object of power grid dispatching, taking the power grid object as the design core of data standardization, this paper designs the model data cloud platform, operation data platform, real-time data cloud platform and big data platform, forming a standardized, integrated and standardized dispatching and control data architecture, which provides the underlying basis for the digitalization of dispatching and control services. At the same time, according to the design concept of service-oriented Internet, the characteristics of dispatching and control services, services are split and encapsulated, and a service-centered application construction method is designed, forming a clarified service system, improving the reusability of services, and rapidly constructing applications to catch up with the development of services based on Internet thinking such as fast iteration and service sharing.

Fully tapping the value of power grid in fault handling of multi-heterogeneous data, using intelligent voice interactive technology, improving the disposal and coordination ability of power dispatching and control to ensure power supply, enriching measures for accident judgment and post-event recovery decision-making, and increasing the effective ways for improving controllers’ capability to deal with power grid accidents, this project, based on the power grid in fault handling of multi-heterogeneous data, and taking the application of knowledge graph technology in artificial intelligence as a means and intelligent voice interactive technology as support, this project has an in-depth research on the intelligent technology of power grid in fault handling and risk prevention and control measures of power grids to ensure power supply, which effectively improves the risk prevention and control level of power grids to ensure power supply and accident handling capability, and comprehensively enhances the safe and stable operation of power grids to ensure power supply. Based on artificial intelligence, deep learning and other related technologies, and according to the characteristics of the dispatching and control services to ensure power supply and the dispatching and control cloud data and service itself, this paper designs an intelligent application framework for the dispatching and control services to ensure power supply, so as to ensure that the dispatching and control operation should be supported by integrated intelligent technologies in the whole process before, during and after the operation, and transform the power supply services from experience-oriented to intelligence-oriented type as soon as possible.
2. Business Analysis of Intelligent Dispatching and Control to Ensure Power Supply

2.1 Scope of Business
The intelligent dispatching and control technology to ensure power supply adopts basic technologies of natural language processing and artificial intelligence such as speech recognition, natural language understanding, speech synthesis, corpus, knowledge base and active learning, establishes the knowledge graph in the field of power dispatching, solves the problems of poor safety perception capability of power grids, and low accuracy and slow response of fault handling caused by the difference and lack of knowledge reserve of control operators during the period of power supply services, and promotes the leap of power grid’s fault handling from traditional manual to machine intelligent assistant method.

Based on the standard specification of structured design, various business data of the dispatching and control center such as model, operation and power grid data are collected in the dispatching and control cloud. Among them, the model data includes the basic models of power grid such as institutional framework, power container, primary equipment, automation equipment and protective equipment, and the operation data includes history data of measurement, quantity of electricity, events, faults, alarms, plans, forecasts, loads, etc. Since there are various types and a large amount of data, the quick search of business data such as ledger history, faults and abnormal conditions can help controllers to make better use of the data and assist the management of the dispatching and control to ensure power supply.

According to design specifications of the intelligent and service-oriented system, we should build service interfaces in the dispatching and control cloud to connect its public services, basic services, model services, data services, computing services, display services and interactive services, so as to assist the dispatching operators to quickly locate relevant services and meet the corresponding business requirements.

![Figure 1](image)

Figure 1 Analysis of the Business Scope of Intelligent Dispatching and Control to Ensure Power Supply

2.2 Business Requirements of Intelligent Dispatching and Control to Ensure Power Supply
Currently, the artificial intelligence technology is developing rapidly. In order to adapt to the new characteristics of the power grid, and respond to the increasingly complex circumstances of safe operation of power grids, the dispatching and control operation should be supported by the integrated intelligent technology in the whole process before, during and after the event, transform the power grid’s fault handling from experience-oriented to intelligence-oriented type as soon as possible, simplify the tasks complexity of the controllers, improve the operation and management efficiency, use data to strengthen the support for the power grid, and promote the development of intelligent and digital dispatching. The specific requirements are as follows:

(1) Comprehensiveness of Power Supply Information
Based on the information related to power grid operation and faults, the dispatching operators need to integrate all kinds of information for analysis and make corresponding decisions on dispatching and
control to ensure power supply. Therefore, they build data interfaces with other business platforms in the framework of intelligent dispatching and control to ensure power supply, so as to realize the collection and integration of ubiquitous information, associate and analyze various types of information such as dispatching and control cloud, OMS, DSA, meteorological system, etc. and determine the accuracy of data analysis and push.

(2) Accuracy of Power Supply Information

Based on ubiquitous information, they sort out the monitoring information, equipment ledger, defect repair, external meteorology and other ubiquitous information related to the operation of distribution network under major scenarios of dispatching and control to ensure power supply, strengthen the data combination and extension method, extract the data model of the power supply services, conduct multiple rounds of combination on the original data based on the deep neural network and rule learning technology, and extract data resources that are more suitable for large-screen visualized presentation. They release data resources by using knowledge graphs or other methods, and realize the positioning and retrieval of data resources with clear and convenient ways of visualized presentation. They determine the visualized information (telemetry, teleindication) of critical users and paths of power supply services, display requirements to the visualized large screen and provide high-confidence data services.

(3) Intelligence of Power Supply Information

Relying on artificial intelligence technologies such as big data analysis and neural deep learning, they analyze the data correlation under different power supply scenarios, conduct applied classification of the sampled data, and meanwhile study the correlation and fusion technologies between power grid operation and ubiquitous information, so as to realize the correlation between power grid operation data and power supply scenarios based on ubiquitous information. The visualization patterns are intelligently arranged. The dynamic association and polymorphic presentation of visualization patterns and data labels are realized.

(4) Timeliness of Power Supply Information

Based on the submission and release technology of important power supply information of real-time operation data, according to the definition and classification of visualization patterns, they provide data push that includes real-time operation data, report presentation, data analysis report and other multi-form presentation plans, conduct research based on data services, accurately submit power supply information with different presentation methods such as tables, graphics, and texts, clearly express the technology, and achieve the automatic generation function of power supply report according to the customized pattern, which helps to release important power supply information to the dispatching unit or other relevant units.

3. Research on Key Technologies of Intelligent Dispatching and Control to Ensure Power Supply

In this paper, the visualization presentation and push service framework of intelligent dispatching and control of power supply information mainly includes key technologies such as word segmentation algorithm of power signature, natural language understanding, and clustering algorithm, which provides technical support for the construction of intelligent interaction and visualization system framework of power supply information.

3.1 Word Segmentation Algorithm of Power Signature

Generally speaking, word segmentation algorithms are involved in two cases. One is to segment the search terms and then match them in the index. The other is to segment the data of models, operation and documents and then establish a search index. Based on the power thesaurus and the accuracy requirements of power word segmentation, this paper adopts the word segmentation method of maximum forward matching to realize the word segmentation algorithm based on power signature.

The overall process of power word segmentation is as follows: 1) Function words are filtered first from the input words, which include useless modal particles, adjectives, etc. 2) Power thesaurus and
maximum forward matching algorithm are used to split character strings of the sentence and obtain word segmentation results. 3) The list of word segmentation is formed and then return. For example, for the search term “what is the power generation capacity of unit #6 of power plant A”, “power plant A, unit and power generation capacity” are all special words in the power thesaurus, and the final result of split is an array [power plant A, #6, unit, power generation capacity]. The overall process is shown in the following figure:

In this process, the focus is the maximum forward matching algorithm, which has high operation efficiency and is suitable for word segmentation algorithms that need to be called frequently. The time complexity is O (n). The specific algorithm flow is as follows:

**Algorithm 1** Maximum forward matching algorithm.

**Input:** Texts with word segmentation or search terms, power thesaurus

**Output:** Array of word segmentation results

1: Calculate the character length of the input string
2: Record the start position of matching
3: While The start position recorded is less than the string length. do
4: Record the word with the maximum length in the forward direction
5: If The word has already matched a word in the thesaurus. then
6: Output the word and move the pointer to the next position
7: Else
8: Segmentation by a single word, output a single word and move the pointer to the next position
9: Return word segmentation arrays of the device name

3.2 Natural Language Understanding Algorithm

Natural language understanding algorithm technology is mainly reflected in word segmentation. This project adopts N shortest path algorithm.

N Shortest Path is actually a variant of K Shortest Path (KSP), which refers to the first K shortest paths in a single source path of DAG. The algorithms to find the solution of KSP include deletion algorithm, improved deletion algorithm (MS Algorithm) and recursive enumeration algorithm (REA). Until the last ten years, people have been studying the improved algorithm and new algorithms of KSP.

NShortPath does not necessarily find N paths in the end. What is realized here is not any of the above algorithms, but the “NShortPath” algorithm separated from SharpICTCLAS.
However, in NShortPath, what needs to be recorded is the nodes between from and to. For example, in the figure above, we need to learn about what edges D the node #4 has, and record the start position and cost of these edges. The final result of this process is

Its basic idea is a variant of Dijkstra algorithm. Taking 1-the shortest path as an example, we first find the shortest path with Dijkstra, and then goes along the shortest path. When walking to a certain node, we should check whether there is another path for the next node on the path to reach it (check it from PreNode). If so, we take the first of these other paths (they are all path nodes on the shortest path). Then we apply it to the N-shortest path. There are N PreNodes in the N-shortest path, which simply correspond to the PreNode in the n-shortest path respectively.

When traversing through the graph, unlike Dijkstra’s shortest path, the N-shortest path starts from the second node, and the edges that the current node may reach need to be sorted and recorded into the PreNode array according to the sum of the accumulated i-th short length and the length of the edge, and the sorting is completed by CQueue.

Then after dequeue from CQueue, as the path length is in ascending order, we should just update weightArray [current node] [which-th short path] in sequence.

In addition, CQueue is a queue different from ordinary queues. It maintains a current pointer (the blue part in the figure below), which will be used when solving the i-th short path.

1-Solution of the shortest path
The whole calculation process maintains a stack of paths. For the figure above,
1) First, push the last element into the stack (node #6 in this example). When this element pops out of the stack, the whole task comes to an end.
2) For the PreNode queue of each node, a current pointer is maintained, and the initial state points to the first element in the PreNode queue. This pointer is maintained by CQueue and is not strictly a
concern of the algorithm.

3) The current element in the PreNode queue is sequentially taken out from right to left (dequeue of the current element) and pushed into the stack, and the queue pointer is redirected to the first element in the queue. As shown in the figure above: PreNode of element #6 is 3, PreNode of element #3 is 1, and PreNode of element #1 is 0.

4) When the first element is pushed into the stack, the content output from the stack is a queue. In this example, 0, 1, 3, 6 is the shortest path.

5) The contents are popped out of the stack sequentially, and each time the element is popped out, the PreNode queue pointer corresponding to the element when being pushed into the stack is moved down to the next position. If you cannot move it down at the end, proceed to step 5 (that is, to pop out of the stack), and if you can still move it, proceed to step 3.

For this example, the “0” is popped out of the stack first, and the next one on the path is 1. Consequently, this element corresponds to the PreNode queue of node #1 “A”. The current pointer of this queue cannot be moved down, so the “1” in the stack continues to be popped out. Similarly, this element corresponds to node #3 “C”, so the PreNode queue pointer corresponding to node #3 “C” is moved down. Since it can be moved, the 2 of the queue is pushed into the queue. The PreNode of node #2 “B” is 1, so the 1 is pushed into the queue again, and so on, until 0 is pushed. At this time, the shortest path is obtained, that is 0, 1, 2, 3, 6, as shown in the figure below.

![Figure 6 Calculation of Path Nodes in "NShortPath" Algorithm](image)

Subsequently, 0, 1 and 2 are all popped out of the stack. After 3 is popped out of the stack, since the PreNode queue pointer corresponding to element #6 can still be moved down, 5 is pushed into the stack and its PreNode is put into the stack in sequence until 0 is put into the stack. At this time, the third shortest path is output: 0, 1, 2, 4, 5, 6. As shown in the following figure:

![Figure 7 Calculation of Path Nodes in "NShortPath" Algorithm](image)

After the output is completed, it is followed by popping out of the stack. At this time, there is no PreNode queue pointer corresponding to any stack element that can be moved down, so the last element 6 in the stack is also popped out of the stack, and the output task has come to a complete end then. We have three shortest paths, which are

0, 1, 3, 6,
0, 1, 2, 3, 6,
0, 1, 2, 4, 5, 6,

3.3 Clustering Algorithm

Cluster analysis method can identify samples according to their attribute values in a disordered sample
collection, and group similar observations into a number of clusters, so that samples within one cluster have high similarity. Therefore, the cluster analysis method can accurately and scientifically classify the load characteristics of users, which is helpful for the analysis of resource characteristics of flexible load of commercial buildings and residential users. At present, the basic clustering methods mainly include hierarchical clustering method, partitioned clustering method, density-based clustering method, grid-based clustering method and fuzzy clustering method.

Hierarchical clustering method. It is also called tree clustering algorithm or system clustering algorithm. The basic idea of this algorithm is to establish clusters of data hierarchically to form a tree.

Partitioned clustering method. It adopts the strategy of minimizing the objective function, initially selects a certain number of cluster centers or data points, and groups the data into various clusters based on certain principles.

Clustering method based on density and grid. It is widely used in various fields represented by spatial information processing. The main idea is to divide the data in space into different groups according to the aggregation density, and the data with similar density is divided into one group.

Fuzzy clustering method. It uses a membership function to associate the relationship between objects and clusters, and each cluster overlaps with one another.

In addition to several common clustering methods, currently the popular clustering algorithms also include clustering algorithm based on support vector machine, clustering algorithm based on kernel method, clustering algorithm K-Narest-Neighbor (K-NN) based on neural network, etc.

4. Design and Application of Business Framework of Intelligent Dispatching and Control to Ensure Power Supply

Based on the research results of key technologies such as power thesaurus, word segmentation of power signature, multi-factor relevance ranking, knowledge graph of dispatching and control and considering the service bus of dispatching and control cloud, this paper designs a set of overall framework which is comprehensive, accurate, fast, intelligent and scalable and meets the requirements of the framework of the search engine.

As shown in the above figure, the business framework of intelligent dispatching and control to ensure power supply mainly consists of four parts: basic support, knowledge graph, basic services and applications.

1) Basic support: it mainly uses the model data platform and operation data platform of dispatching and control cloud to obtain structured data, and uses D5000 and OMS systems to obtain the operation data of power grid equipment.

2) Knowledge graph: modeling knowledge graph according to dispatching and control services, covers: label system, model entity, operation entity, attribute entity and relationship definition. It uses the data like model data, dispatching regulations, faults and so on to import the stock and incremental data into the knowledge graph and store them in the graph database.

3) Basic services: the service bus of dispatching and control cloud, and basic services are used to realize model data service, power grid event service, power grid data service, intelligent reasoning
service, etc., and to realize the search of data. Service-oriented scalability is used to provide scalability for subsequent business changes. At the same time, the dispatching and control cloud services are connected to public services, data services, computing services and other standard services of dispatching and control cloud to realize the search of services.

4) Applications: with the above-mentioned basic support, knowledge graph, basic services, etc. as the support for data and rules, functional modules such as the service station of power supply information, the monitoring of power supply objects, and submission and release of important power supply information are realized.

5. Conclusion
The research on the system framework technology of intelligent dispatching and control to ensure power supply associates the data of the dispatching and control cloud such as model data, operation data, D5000, and OMS through data interfaces, adopts basic technologies of natural language processing and artificial intelligence such as speech recognition, natural language understanding, speech synthesis, corpus, knowledge base and active learning, establishes knowledge graph in the field of power dispatching, solves the problems of poor safety perception capability of power grids, and low accuracy and slow response of fault handling caused by the difference and lack of knowledge reserve of control operators during the period of power supply services, promotes the leap of power grid’s fault handling from traditional manual to machine intelligent assistant method, realizes the accumulation, solidification and inheritance of knowledge in the field of power dispatching, improves the risk prevention and control capability of power supply safety and the fault handling capacity of power grids, and open up new fields of application of artificial intelligence technology in power dispatching.

References
[1] Xu Hongqiang. Architecture of Dispatching and Control Cloud and Its Application Prospect. Power System Technology. 2017, 41 (10): 3104-3111.
[2] Xu Hongqiang. Structured Design and Application of Power Dispatching Universal Data Object for Dispatching and Control Cloud. 2018, 42 (07): 2248-2254.
[3] Xu Li. Text Keyword Extraction Method Based on Weighted Text Rank. Computer Science. 2019, 46 (S1): 142-145.
[4] Cheng Yusi, Shi Yuntao. Domain Specific Chinese Word Segmentation. Computer Engineering and Applications. 2018, 54 (17): 30-34+109.
[5] Chen Zhangfan, Pang Fan, Zhang Ting, Tian Yun. Research and Application of Methods for Intelligent Understanding and Matching of Power Equipment Information. Computer Knowledge and Technology. 2019, 15 (15): 250-251+254.
[6] Guan Saiping, Jin Xiaolong, Jia Yantao, Wang Yuanzhuo, Cheng Xueqi. Knowledge Reasoning Over Knowledge Graph: A Survey. Journal of Software. 2018, 29 (10): 2966-2994.
[7] Zhao Haibo, Huang Yongli, Chen Sheng, et al. Professional Intelligent Search Engine Based on Running Database of Power Plant. Electric Power Automation Equipment, 2003, 23 (8): 25-28.
[8] Shang Xuewei, Zhao Lin, Fan Zelong, Ye Fei, Fan Guangmin, Guo Lingxu. Architecture and Key Technologies of Wide-area Data Bus Based on Dispatching Data Network. Automation of Electric Power Systems. 2018, 42 (11): 109-114