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Technology Research on Panoramic Situation Awareness of Operation State of Smart Distribution Network

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Abstract. With the increasing complexity of power grid structure, operation scheduling becomes more difficult, and the risk of blackout is also increasing. Therefore, it is particularly important to be able to timely and effectively perceive the security situation of smart power grid. The panoramic situation awareness technology of smart distribution network operation state mainly includes situation detection technology, situation perception technology and situation prediction technology. In the stage of situation detection, the collection and storage points of power big data are analysed from two aspects of internal and external factors, and the security situation evaluation system of power grid is constructed. In the phase of situation perception, HDFS, Hadoop, Hive and other technologies are used to obtain the security situation assessment value of smart grid to realize the comprehensive evaluation of the security situation of power grid. In the phase of situation prediction, a deep neural network model is constructed to complete the panoramic situation prediction of smart grid operation state.

1. Introduction

Smart grid is a new type of power grid, which is based on physical power grid and highly integrates modern advanced sensor measurement technology, communication technology, information technology, computer technology and control technology with physical power grid. It aims to fully meet the power demand of users and optimize resource allocation, ensure the security, reliability and economy of power supply, meet the environmental constraints, ensure the quality of power, and adapt to the development of power market. It realizes reliable, economic, clean and interactive power supply and value-added services for users. China's power grid adopts the physical isolation based border security protection mode, which can effectively prevent the general virus software, that is, even if the general virus software passes the boundary protection of power dispatching system, it will not be able to enter the white list because it cannot obtain the trusted authentication feature code, and finally cannot obtain the execution authority. Therefore, the power dispatching system in China needs to guard against the advanced virus software which can evade the boundary protection and bypass the physical isolation and invade the dispatching system. This kind of advanced virus software can quickly identify the weak link of power grid, send false remote control command to cause circuit breaker to trip wrongly, inject false data into SCADA system, reset dispatching main system, refuse to execute operation command and so on, which leads to wrong setting and action of relay protection system, unable to control the whole system, and finally lead to system collapse and disconnection.



2. Structure of panoramic situation awareness of operation state of smart distribution network

Network Security Situation Awareness (NSSA) is applied to the field of network security. Its model mainly includes the acquisition of network security situation elements, situation understanding and situation prediction. The acquisition of situation elements mainly carries out real-time data acquisition and data standardization processing for network equipment, and analyses abnormal network activities through mathematical model. Situation understanding is mainly to identify the attack activity and find the attack source. Situation prediction is to judge the possible threats to the system through the identified attack activities, and then predict the change trend of the network in the next step. NSSA can not only fully understand itself, but also effectively identify network threats. The extraction of situation elements is the bottom and most basic step in situation awareness. Its purpose is to obtain the information of the perceived objects, especially the important information elements. With the development of power grid technology, the collection range of situation elements has been expanded.

At present, all kinds of information that can be collected mainly include topology structure, real-time operation information, equipment status information, power grid stability / dynamic data information, power grid transient fault information, power grid operation environment information, etc. The extracted important information and elements, conduct situation assessment, and form a comprehensive evaluation of power grid security status through comprehensive analysis and judgment. This step is the most important step in the whole situation awareness process. Based on the understanding of computer network situation awareness, when the power grid is connected to a large number of public networks, smart grid will face various security threats including equipment, network and data. In order to improve the security monitoring and intrusion prevention capability of power information network, it is necessary to analyse and process the collected information. At this time, it is necessary to evaluate the situation of network information in power grid. Power grid situation assessment can be understood as in the large-scale, high complexity network environment, on the basis of acquiring network monitoring data of various types of power grid and simple processing, according to the domain knowledge and historical data, with the help of some mathematical tools and models, after analysis and reasoning, make a reasonable explanation of various possible network attacks. Finally, it evaluates the current situation and predicts the situation with the evaluation data to prevent the occurrence of large-scale safety accidents.

Based on the detection, perception, evaluation and comprehensive analysis of the important information and elements of the situation, this paper summarizes and infers the development and change rules of the network situation in the power grid, so as to predict the development and change of the future situation. The prediction results will be submitted to the decision-making implementation link to regulate and control the power grid. Future situation prediction is the highest-level requirement in situation awareness.

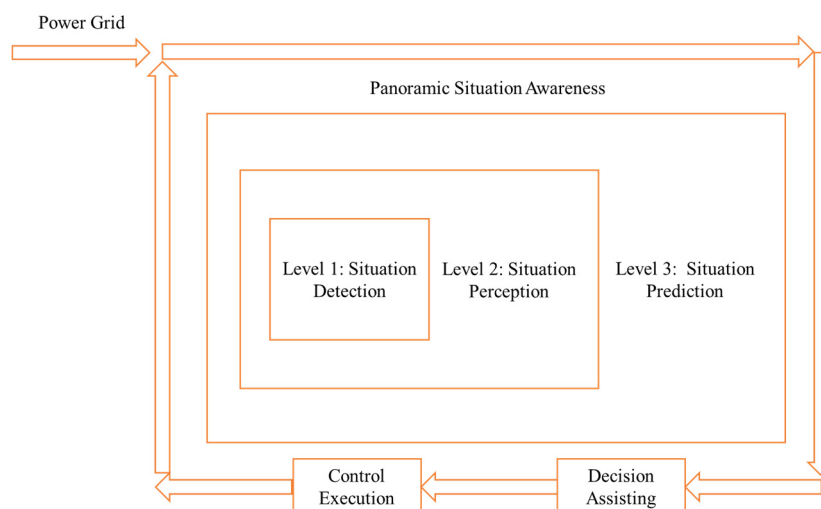


Figure.1 Power grid security situational awareness structure chart

3. Situation detection technologies

3.1. Data collection

Situation detection is the foundation of situation awareness to collect and acquire the important elements in the environment. With the continuous progress of technology, the elements of power system situation awareness collection gradually increase, which constitutes the situation awareness big data. Power big data refers to a large amount of data generated by smart grid in power generation, distribution, transmission, marketing and management. It is generated by a large number of sensors deployed on various devices, smart meters installed in the homes of power users, customer feedback collected by marketing system and other data sources, and converged to the centralized data centre for unified storage and management. Power big data is one of the supporting elements for building a stable, reliable, efficient and energy-saving smart grid. Through the analysis of power big data, it can improve the lean management level of smart grid, formulate more scientific production plan, optimize energy transmission scheduling, and establish more accurate user behaviour model. With the further development of smart grid construction, equipment sensors, smart meters and other terminal data collection devices have been intensively deployed, and the scale of collected data will increase exponentially, reaching the order of TB or even Pb. Power big data acquisition and processing are very fast. The increasing number of terminals requires the storage system to meet the demand of hundreds of thousands of high-throughput data access per second.

Situation detection big data has complex types and diverse data sources. Big data processing first collects data from data sources and performs operations. Data acquisition includes electrical quantity and non-electrical quantity. The acquisition results of electrical quantity are usually integrated in SCADA, WAMS and other monitoring systems. For the collected data, through appropriate, it can lay a good foundation for the subsequent data analysis. Due to the inevitable existence of noise and interference items in the process of data acquisition and transmission, there may be data errors or even omissions, missing. Especially when there are different data sources for big data, the phenomenon of similar, repeated or inconsistent data is easy to appear. Therefore, it is necessary to de-noising the data and recover the lost data, that is, data cleaning. Filtering is the most common noise reduction method, such as Wiener filter, Kalman filter and so on. Interpolation technology can usually recover the lost data effectively.

3.2. Data storage

Traditional relational database can't store unstructured data and has poor scalability, so it is difficult to process massive data. Big data storage and management technology should not only ensure the reliability and readability of files, meet the real-time and effectiveness of data processing, but also try to reduce the cost and improve the economy. Big data storage and management technology is mainly divided into two modes: stream processing and batch processing. When on-line monitoring and other high real-time services, it is appropriate to adopt the flow processing mode. At this time, the data is regarded as a stream, and the data stream is analysed and processed directly and the results are returned. In other cases, batch processing mode is used to store data to provide support for subsequent analysis and processing. In the big data environment, storage and management technology tends to be distributed. In the transmission process of network data information, the number and type of logs are provided by one or more application systems. In view of the differences of the system itself, there will be great differences in the various behaviour parameters generated. When the number of logs is combined together, due to the lack of corresponding benchmark processing parameters, it is inevitable that accurate data nodes cannot be obtained under the overall interpretation Fruit. From the perspective of situation awareness technology, it is not limited to a single network operation system, but by disrupting the original pattern in the log data, and resetting the vertical and horizontal cross characteristics. When the data information is rebuilt to form a whole, then the detection technology checks the information as a whole. This form can greatly improve the detection efficiency of data information, and can accurately check each byte, chain block, etc., to ensure the detection quality and detection accuracy. In the application process of

this heterogeneous fusion technology, it is not only limited to the single information generated by the log, but also collects and integrates a large number of source data generated in the operation of computer system, and then carries out vertical fusion processing on the data and delivers it to the independent unit of the database for unified storage. Because the data information is disordered and reorganized, the information format generated after the reorganization will belong to the same benchmark.

4. Situation perception technologies

4.1. Data analysis

In order to alleviate the access pressure of cloud storage system, the collected data first enters the front-end buffer pool for decoding. In addition to the data collected regularly by the data source, the relatively static information such as equipment and personnel constitutes the archive database, which is stored in the relational database and directly copied to the cloud storage system. When the archive database is updated, the update should be synchronized to the cloud storage system to ensure the accuracy of the calculation results. The parallel computing environment accesses the cloud storage system, calculates the data according to the business logic, and writes the calculation results into the cloud storage system. The online query system obtains the data satisfying the user's request from the cloud storage system and returns it to the user. Some queries for archival data need to calculate the result data. Therefore, the cloud storage system also synchronizes the calculation results to the relational database so that users can query the data through the relational database.

(1) The distributed file system (HDFS) module is one of the core modules of the whole big data analysis system, which is used for the persistent storage of all kinds of power big data. HDFS is composed of one metadata server and several data servers. The files are divided into 64MB data blocks and distributed to different data servers. Each data block has three copies distributed on different nodes. When a replica is not accessible, the system will automatically create a new replica to maintain load balancing.

(2) Hadoop is an open source implementation of MapReduce parallel programming framework proposed by Google. MapReduce program is composed of map function and reduce function. Map function transforms an input (key, value) pair into a group of intermediate result (key, value) pairs at a time; reduce function processes a set of values with the same key, produces the final result and writes it to the distributed file system HDFS.

(3) Hive is a data warehouse system based on Hadoop platform, which is used to analyze and calculate big data. Hive provides a SQL like query language hiveql (HQL), which provides a familiar interface for data analysts. HQL query is compiled into a set of MapReduce programs by hive parser. Like a relational database, hive organizes data into tables and stores it in HDFS.

(4) Monitoring tools and scheduling tools. The monitoring tool is used to monitor the operation status of the system and the execution status of data analysis jobs; the operation scheduling tool schedules the data analysis jobs according to the scheduling policy and resource status specified by the administrator, and analyzes the association or dependency between jobs.

(5) The development tool set includes SQL translation, parallel ETL tools, index management, task management and other tools. It provides a web-based graphical interface for system administrators and simplifies the configuration management of the system.

The system diagram of panoramic situation awareness of smart grid operation status is shown in the following figure:

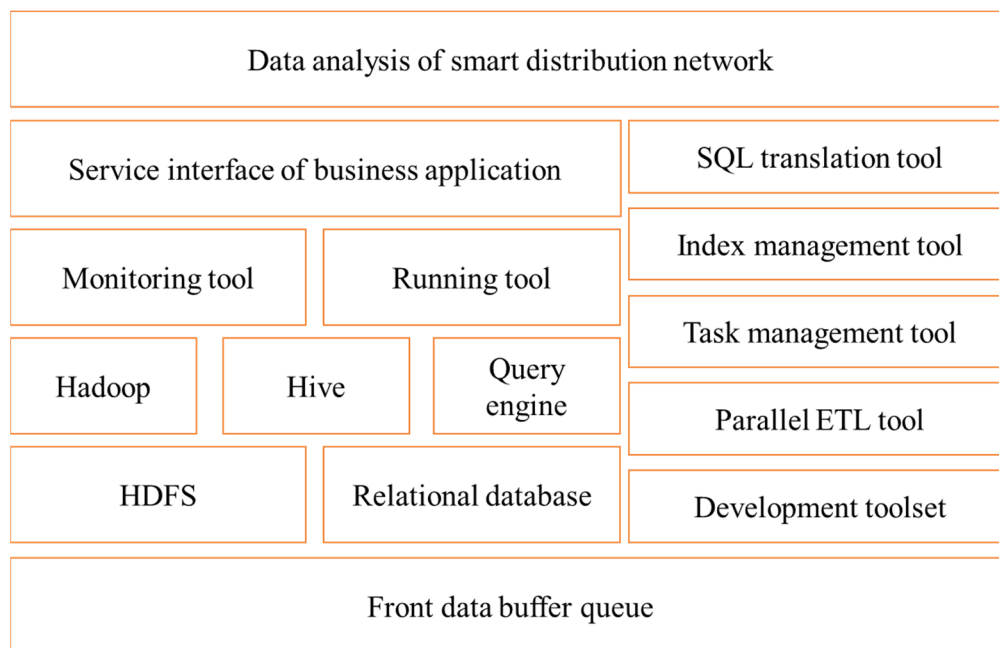


Figure.2 Architecture of power big data analysis system

4.2. Data visualization

The visualization technology in situation awareness system refers to the model visualization function of data information. Relying on the operation mode of data information, a three-dimensional framework is established to enable technicians to interpret the data model more intuitively. In terms of technical characteristics, visualization is a progressive data model, which can be divided into three stages. First, data conversion phase. This process is to detect and process the data information, and then transform the data information into the form of tables. In the process of data mapping, through the real-time characteristics of the system itself, the mapping of data information can be completed in a very short time delay, and then the data information will be stored in the form of system. Second, image mapping stage. This process is to determine the formed data table, through the setting of system parameters, the data information in the table is mapped by image, and the structure and attribute are used as the information carrying platform to realize the conversion and docking of the data table. Third, view conversion. In the actual conversion process, the space coordinate is the main method. First, a certain data parameter is determined, and then the image model is built by the image mapping information. At this time, the system will automatically adjust the information, such as proportion, position, pattern and complete the view conversion under the effect of multiple parameters.

5. Situation prediction technologies

5.1. Prediction of evaluation value

Future situation analysis is the basis of large power grid operation control system based on situation awareness technology. The so-called future situation is actually the change of boundary data of power grid operation in a period of time in the future, including load forecasting, wind power, photovoltaic power and other new energy power forecasting, operation state changes of thermal power, hydropower and other conventional units, scanning fault set updating considering equipment defects, and grid topology changes considering power transmission and transformation equipment outage. Among them, load forecasting, wind power, photovoltaic power and other new energy power forecasting need to be based on the current temperature, humidity and other factors; when the water level of hydropower station changes and the incoming water changes, the power generation capacity of the hydropower plant will change; when the coal from thermal power plant changes or equipment failure, its output capacity will

change; when the transmission and transformation equipment has planned outage or equipment defects, It is necessary to change the scan fault set and the power grid topology. These changes constitute the boundary conditions of large power grid operation control, and are also the basis of situation awareness analysis. For the power flow distribution index, node voltage offset index, transformer load rate, system load rate, system overload degree and out of limit index, the system is randomly disconnected, and the power flow calculation and simulation is carried out by MATLAB 2016a, and the index data, active power margin, voltage margin, frequency offset index and power angle stability are obtained. Qualitative indicators are randomly generated data within the risk range according to experts and system specifications. The influence of external factors on the security situation of large power grid is expressed by the frequency of blackouts. The comprehensive weight of each index data is obtained by deep neural network, and the evaluation value of large power grid security situation is obtained by weighted average method.

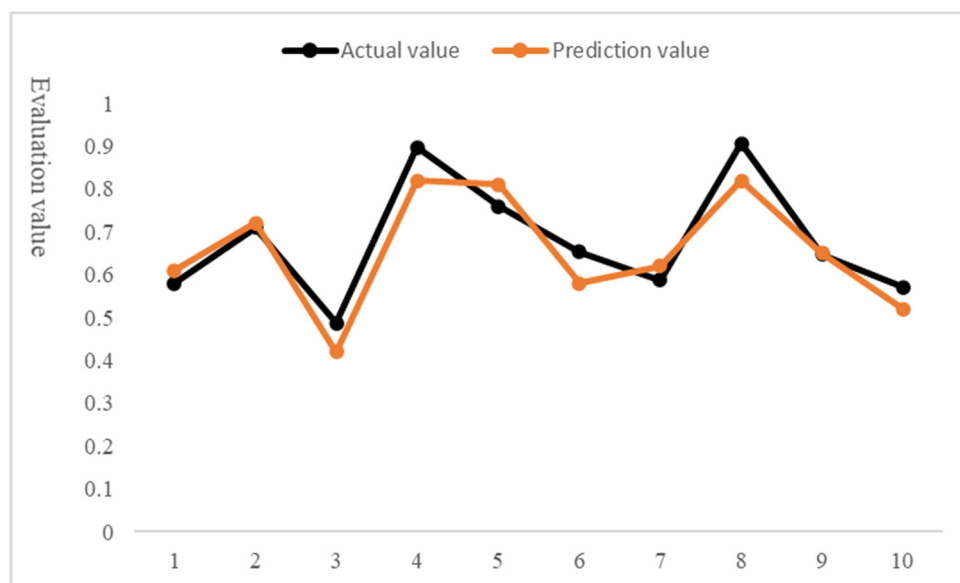


Figure.3 Comparison of prediction value and actual value of grid situation

5.2. Decision making

As an important implementation technology under the situation awareness system, decision technology is driven by the dynamic operation mode of security system. If there is a security threat in a certain detection link, the system will automatically formulate the spatial structure, store and integrate the information with potential security risks, and then comprehensively determine the information attributes in the internal security events. This process belongs to an integrated application mode, which not only focuses on the current network environment, but also analyses the dangerous behaviour and dangerous path of the information itself through the integration of various kinds of information. Under the internal system multi wire control self-test, it can accurately execute an information threat and locate the dangerous information in the spatial dimension. In view of the nature of network security incidents, it not only focuses on information retrieval processing, but also integrates all kinds of information interaction behaviours, such as users, locations, events, etc. through the construction of a comprehensive evaluation system, the essential behaviours of security incidents are predicted and evaluated, and then more accurate results are obtained. The application of decision-making technology mainly takes the motivation of network attack as the main body, such as the identity of the attacker, the way of attack and the intention of attack. Then, the object is the benchmark of security information. The object is the protection target of the network elements and security protection system, while the location is the main body of the motivation of various behaviours in the information architecture, such as the attack area and the attack site of network virus. And the way of attack. In the multi-threaded control mode, a three-

dimensional security protection system can be constructed, and the decision-making information can be provided to the system in real time, so as to increase the actual protection quality.

6. Conclusions

The safe and stable operation of power grid involves national security and national economic development. Situation awareness technology has been applied to a certain extent in the safe operation of power grid, but it is still based on static simulation, which cannot really realize the dynamic understanding and prediction of power system dispatching. This paper takes the network security of power dispatching system as the research object, constructs the basic model of power grid situation awareness, and puts forward the basic structure of panoramic situation awareness technology of smart grid operation state, including situation awareness, situation understanding and situation prediction. The construction of panoramic situation awareness system for smart grid operation status based on multiple technologies can effectively predict the maximum threat attack path that the system may suffer, and provide strong decision-making basis for decision-makers.

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