Study on Key Technologies of Power Dispatching Control System under the Background of Cloud Computing

Siming Zhou¹, Guanqiang Liu², Hai Qin¹, Tian Xia¹

¹Power dispatching control center of Guizhou Power Grid Co., Ltd., Guiyang 550007, Guizhou
²NARI-TECH Nanjing Control Systems Ltd., Nanjing, Jiangsu 211106

Abstract. In order to adapt to the development and application of power dispatch control systems in the future cloud computing environment, this study proposes to make full use of the elastic characteristics of cloud computing to construct a new power dispatch control system architecture. First, we analyze the shortcomings of the traditional power dispatch control system architecture, from the perspective of architecture complexity, operation and maintenance, universality and disaster tolerance. Secondly, combining the characteristics of the existing dispatch control system, we propose a new power dispatch control system architecture that conforms to the cloud computing platform. Finally, we emphatically analyzed the key technologies for key breakthroughs needed to realize the power dispatching control system architecture. Through the comparison of traditional and new power dispatch control system architectures, it can be considered that the new power dispatching control system architecture has greatly improved reliability, flexibility, safety and economy, and has certain advantages.

1. Introduction

With the development of cloud computing in recent years, domestic Internet companies and hardware equipment manufacturers have begun to get involved in the field of cloud computing. At present, the application of cloud computing in the power system is mainly concentrated in equipment virtualization and distributed storage for the purpose of big data analysis. There are only a few theoretical articles on the application of cloud computing in power dispatch control systems, and there are no practical applications in China. Wang D et al. proposed a new power grid power dispatching control system architecture based on cloud computing technology, and gave the actual application plan [1]. Yang SC et al. proposed a new architecture and key technical support for automatic intelligent dispatching of power grids based on situational awareness [2]. Through an in-depth analysis of the basic concepts and core features of cloud computing, Cao Yang pointed out that virtualization and distribution are the core technologies of cloud computing, and studied the advantages and disadvantages of cloud computing technology in the application of power dispatching systems [3]. Most foreign research on the application of cloud computing technology focuses on big data analysis, and the application of cloud computing in power dispatch control systems has not been reported [4].

Under the background of the development trend of cloud computing technology, this paper focuses on how the existing power dispatching control system can adapt to the future cloud computing environment, and tries to establish an application support framework and data processing mode suitable for cloud computing technology in the system by changing the mismatched architecture and design mode in the existing system, in order to give full play to the advantages of cloud platform elastic
computing and storage, eliminate the real-time processing performance bottleneck in the system, and improve the system's data access, storage, analysis, integration and expansion capabilities accordingly.

2. Drawbacks of Traditional Power Dispatching Control System

In the architecture of traditional power dispatching control system, a fixed topology is usually used, that is, each server runs a fixed module to achieve specific functions, and by the combination of multiple servers and multiple modules to realize the complete function of the power dispatching control system [5].

The architecture of traditional power dispatching control system is shown in Figure 1.

![Architecture of traditional power dispatching control system](image)

Figure 1. Architecture of traditional power dispatching control system

Such architectural model has shown multiple drawbacks as follow:

a) Complex architecture and high coupling. In order to ensure the reliability of the dispatching control system, the traditional architecture provides dual-unit backup guarantee for some core modules, so that when one of the nodes fails, the backup node will take over the original work [6]. The application of this technology makes the system architecture extremely large, and it is difficult to increase redundant nodes. Moreover, the equipment installation and configuration process would be very complicated, and the components need to be highly coupled and compatible.

b) Difficult to maintain. Although the main structure has a dual-unit backup guarantee, there are still a large number of single points of failure in the remaining parts, and once a single point of failure is encountered, the related investigation work will inevitably affect the complete operation of the system. In addition, in the traditional case, the deployment of dispatching control system operation and maintenance personnel is determined according to the number of system equipment, so with the development of smart grid, information resources will increase rapidly, and the corresponding management workload will also increase sharply, which means more manpower consumption and greater maintenance costs [7].

c) Poor universality. Different manufacturers produce their own functional systems, and different functional systems use different hardware structures, which requires special maintenance means or special technicians, so it is difficult to achieve unified specification.

d) Poor disaster tolerance. As the nerve center of smart grid, once the dispatching control system fails, local power grid events may quickly expand to the whole power grid, and even cause power grid collapse [8]. Therefore, it requires the dispatching control system to have better disaster tolerance. However, under the traditional architecture, due to the non-uniform application standards and strict
requirements for the operating environment, it is difficult to achieve large-scale and most application disaster backup. This means that each server needs the same server as a disaster backup. Obviously, the cost is too high. Therefore, it is difficult to have a general disaster recovery scheme under the traditional architecture.

3. New Power Dispatching Control System Based on Cloud Computing

3.1 Cloud Computing Model

Power dispatching control problems in multiprocessors and distributed systems, have always been the research focus of computer science. At this stage, with the development of cloud computing, task scheduling under the cloud platform has also been favoured by many scholars, and more and more researchers have invested in the task scheduling research under cloud computing. Cloud computing power dispatching control can be understood as a mapping process. Through virtualization technology, the software and hardware facilities of the cloud platform are abstracted as resources, and the user's request is regarded as a task. The role of power dispatching control is to allocate necessary and appropriate cloud resources to perform tasks for users' submitted tasks based on the status and prediction information of both resources and tasks under certain constraints [9]. After the task is completed, the processing result is returned and resources are released. Therefore, a good power dispatching control mechanism can coordinate and allocate resources in the cloud environment, effectively improve system performance, shorten task running time, and reduce resource consumption.

There are two basic starting points for cloud computing power dispatching control: on the one hand, transparently allocate resources for tasks submitted by users; on the other hand, through a certain algorithm scheduling, the resources in the cloud and the tasks submitted by the user are matched with the maximum utilization rate, the utilization efficiency of the resources in the cloud is improved, and the user is provided with better and more efficient services. Cloud computing is the inheritance and development of distributed computing and grid computing, so it has a larger scale and complexity, and the resources in the cloud environment are heterogeneous, dynamic, distributed, and autonomous. Therefore, for cloud platforms, a good and efficient scheduling strategy is essential.

The cloud computing power dispatching control is very similar to the dispatching control process of grid computing. Cloud computing power dispatching control model is shown in Figure 2.

![Power Dispatching Control Model Based on Cloud Computing](image)

Figure 2. Power Dispatching Control Model Based on Cloud Computing

In general, the execution process of cloud computing power dispatching control is as follows [10]:

a) Decompose the application according to the application configuration file;
b) Resource selection based on resource pool and resource pool configuration file;
c) Perform task mapping and calculate the resources required by the task;
d) Assign resources to the tasks submitted by users based on resource configuration files and resource pool usage.

Task scheduling problem is an NP-hard problem, because resources and tasks are dynamically changing, which is not conducive to task scheduling [11]. Therefore, the scheduling algorithm can only find a relatively optimal solution to the task scheduling problem, and the scheduling service quality QoS is used as the evaluation standard.

The objectives of cloud computing power dispatching control include the following aspects:

a) Shortest span. The span refers to the completion time of the task, that is, the time it takes from the cloud computing system to execute the first task submitted by the user to the end of the last task. The length of the span directly affects the user experience. The shorter the span, the less time it takes, and the less the user needs to pay, and this is what the user expects.

b) Quality of service (QoS). Service quality refers to the pros and cons of the performance of the system as reflected by the cloud computing platform when providing services. The level of QoS directly determines whether users will continue to use the cloud computing platform. QoS in the cloud platform is mainly reflected in the performance of task scheduling, that is, the allocation of virtual resources [12]. In a heterogeneous cloud computing platform, how to efficiently schedule virtual resources is the key to improving service quality.

c) Load balancing. Load balancing is a key indicator for measuring system resource scheduling in cloud computing, which refers to the balanced use of virtual resources under the cloud computing platform to avoid the situation where some nodes are overloaded and some nodes have no tasks to do. In order to achieve this effect, it is necessary to use a reasonable task scheduling strategy to balance the relationship between resources and tasks while making full and reasonable use of virtual resources.

d) Economic benefit. Cloud computing is a pay-as-you-go service, so for service providers and users, cost is a factor that needs to be balanced [13]. For users, reducing service fees is what they want; while for service providers, it is desirable to reduce costs while ensuring overall revenue.

3.2 System Architecture

In order to solve many problems existing in the traditional dispatching control system, this study applies cloud computing technology to the architecture design of dispatching control system. The whole system adopts network architecture, as shown in Figure 3.
Compare the traditional and new architectures from the overall architecture of the dispatching control system, information processing subsystem, information transmission subsystem, human-computer interaction subsystem, etc., as shown in Table 1.

![Diagram showing the architecture of the new power dispatching control system.](image)

**Figure 3. Architecture of new power dispatching control system**

| Item                          | Traditional power dispatching control system | New power dispatching control system |
|-------------------------------|---------------------------------------------|-------------------------------------|
| Overall architecture         | Localized resource                          | Networked resource                   |
| Information processing subsystem | Core server dual unit standby; physical switching after failure; can withstand the abnormality of a unit; no remote disaster recovery | All servers are standby for each other; synchronous memory switching after failure; able to withstand n-1 server exceptions; multiple sites are disaster recovery sites for each other |
| Information transmission subsystem | Traditional special telecontrol channel; point to point | Dispatching virtual private data network; “point to multipoint” network structure |
| Human-computer interaction subsystem | Web services; dispatching workstation; management workstation | Web services; virtual workbench; authorized mobile terminal |

The new dispatching control system uses virtualization technology to transform the traditional servers into cloud computing data center for unified management.
a) Realize the decoupling of hardware and software is realized. Each module of the dispatching control system no longer depends on a specific server, but the operation resources are specified by the cluster control center in the form of virtual machine [14]. Similarly, any changes to the hardware will not affect the operation of virtual machines in the resource pool.

b) Realize the virtual machine system managed in the form of files. After the modules of the system become files, it means that they can be managed in the form of files, move, modify and copy on the resource pool, and achieve high-level reliability guarantee with the cooperation of certain monitoring means.

c) Realize the centralized management of multiple servers. At this time, the management unit is the resource pool [15]. Through the management center, the operation status of all servers and virtual machines can be monitored, and operation instructions can be issued to any link, greatly simplifying the maintenance difficulty of the system.

4. Key Technologies of Cloud Computing Power Dispatching Control System

4.1 Repackaging of Dispatching Master Station System
The dispatching center and each sub plant station use the data dedicated line service provided by the communication operator to access the communication transmission network through leased optical channel, and build VPN on this basis to establish the power dispatching data network. The SCADA server of the dispatching center and the communication integration server of each substation are a node in the network, and are connected according to "point to multipoint" to realize dispatching communication through VPN.

The dispatching master station system is repackaged, the server and network equipment in the original dispatching control system architecture are fully utilized, and it is integrated into a resource pool by virtualization technology. Each original server becomes an equal member of the pool, has the same topology connection mode and the same management configuration mode, and has a comprehensive dual network redundancy structure at the physical level. Each module of the master station system is encapsulated in the form of virtual machine files, and its specific operation resources are allocated by the resource pool control center. The communication between each module of the system is completed by the virtual logic network.

4.2 Construction of Dispatching Control Data Center
At the physical level, the power dispatching control system communicates with the outside world through a unified outlet to form a local cloud computing data center. At the same time, the construction method of cloud computing data center can be copied in different environments, integrate dispatching automation resources in multiple places, and build multiple remote cloud computing data centers. On this basis, the interconnection of dispatching control systems in different regions is constructed to make the dispatching resources call across regions, realize the application level disaster recovery mechanism, and form a strong reliability guarantee. Multiple cloud computing data local dispatching master station systems reach a cooperative relationship with remote cloud computing data centers to realize mutual disaster recovery support. Under normal conditions, the local master station system completes the synchronization of virtual machine files with the remote cloud computing data center regularly, and establishes a resource mapping mechanism to ensure normal network communication after system migration. When an exception occurs, because the remote end has completed the synchronization of virtual machine files, it can quickly organize relevant resources according to needs, execute virtual machine files, and finally realize the overall remote restart of the system. The two sides that backup each other shall establish a detection mechanism with both automatic and manual modes, prompt when the other party's fault is detected, and carry out disaster recovery with the consent of the administrator, so as to avoid the failure of heartbeat detection caused by long-distance network transmission.
4.3 Construction of Dispatching Terminal System

The dispatching terminal system runs multiple scheduling applications on the hosted virtual machine in the form of creating programs running sandbox, and sends them to different terminals through the network. There is only one source program in the terminal system. In case of multiple users, multiple memory copies will be copied to ensure the consistency of the scheduling operation platform used by different users. In order to ensure system reliability, the new dispatching control system architecture replaces the standby mode of key modules in the traditional architecture by running memory redundancy. In the process of function upgrading, all users can upgrade synchronously only by changing the source program file. In addition, the man-machine interface of network transmission can be transmitted not only to fixed workstations, but also to on-site mobile devices through 4G network, making the dispatching work more intuitive and efficient.

In order to ensure system reliability, the new dispatching control system architecture replaces the standby mode of key modules in the traditional architecture by running memory redundancy. Under normal operation, the system assigns two different servers to run the same virtual machine file, generates two copies of the same memory data, and performs the same input and output work to the two copies of memory data at the same time. Under abnormal operation, if the main virtual machine or host server fails, the standby server will take over the original work within a few milliseconds to ensure the continuous operation of the virtual machine. At the same time, the data center will select another standby server and generate standby memory data again.

4.4 Data Transmission and Secure Storage

Through the analysis of the storage technology of power dispatch control data, including data separation, data recovery, data storage, data backup and other aspects. In the cloud computing environment, electric power companies can select different storage locations for corresponding data information through important coefficients and basic performance through the highly centralized storage technology of private cloud, so that different types of data can be isolated from each other, so as to effectively avoid data loss and leakage problems. The use of cloud computing can back up the information of power companies in real time, enabling power companies to restore data in a short period of time when emergencies occur.

5. Conclusion

The widespread adoption of cloud computing technology will bring a brand new revolution to the power dispatch control system. In order to adapt to the development and application of power dispatch control systems in the future cloud computing environment, this study proposes to make full use of the elastic characteristics of cloud computing to construct a new power dispatch control system architecture. First, we analyze the shortcomings of the traditional power dispatch control system architecture, from the perspective of architecture complexity, operation and maintenance, universality and disaster tolerance. Secondly, combining the characteristics of the existing dispatch control system, we propose a new power dispatch control system architecture that conforms to the cloud computing platform. Finally, we emphatically analyzed the key technologies for key breakthroughs needed to realize the power dispatching control system architecture.

References

[1] Wang Ding, Qian Kejun, Gao Yidan, et al. Cloud computing platform technology and its application in power grid dispatching[J].Power System and Clean Energy, 2015, 31(4): 72.
[2] Yang Shengchun, Tang Biqiang, Yao Jianguo, et al. Automatic intelligent dispatching architecture and key technologies of power grid based on situation awareness[J].Power System Technology, 2014, 38(1): 33-39.
[3] Cao Yang, Gao Zhiyuan, Yang Shengchun, et al. Application of Cloud Computing Mode in Power Dispatching System[J].China Electric Power, 2012, 45(6): 19-22.
[4] Ren-Bo WU, Quan-Xi YU, Wang J, et al. Research on Key Technology of Power Dispatching Control System Based on Cloud Computing[J]. Techniques of Automation and Applications, 2019, 23(2): 56.

[5] Xiao X. Research on Integrated Construction Model of Main Distribution Network of Power Dispatching Control System[J]. Telecom Power Technology, 2019, 18(3): 101-105.

[6] Chen Jiaqian, Qian Haifeng, Lu Bing, et al. Design of Human-Machine Interface of City-County Electric Power Dispatching and Control Integration System[J]. Zhejiang Electric Power, 2013, 032(005):65-68.

[7] Chen A, Xie D, Yu S, et al. Comprehensive evaluation index based on droop control for DC distribution system dispatching[J]. International Journal of Electrical Power & Energy Systems, 2019, 106:528-537.

[8] Xing Y, Lang Y, Li Q, et al. Discussion on pattern of centralized operation and maintenance for multilevel smart power dispatching control system[J]. Power System Protection and Control, 2018, 46(15):142-148.

[9] Lin J. Cloud Computing Based System Design for Power Grid Dispatching and Control Training Simulation[J]. Automation of Electric Power Systems, 2017, 41(14):164-170.

[10] Wang J, Wang L, Dong G, et al. Research and Implementation of The Fault Information System FOR Relay Protection Based on Cloud Computing Technology[J]. Journal of Physics Conference Series, 2020, 1650:032003.

[11] Huang Y, Wang X, Liu X. Research on the Information Security Status Quo of the Application of Cloud Computing in Power Dispatching Automation System[J]. Information and computer, 2017, 000(021):188-189.

[12] Yuan B, Xu Y. Construction analysis of cloud computing technology in new power dispatching automation system [J]. Automation application, 2019 (01): 120-121.

[13] Sun Ke. Application of cloud computing model in power dispatching system [J]. Low carbon world, 2017 (16): 57-58.

[14] Chen Yong. Application of cloud computing mode in power dispatching system [J]. Introduction to scientific and technological innovation, 2016,13 (31): 75-76.

[15] Pan Yuanli, Li Quan. Architecture analysis of power dispatching automation system based on cloud computing technology [J]. Hebei Electric Power Technology, 2016,35 (01): 4-7.