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Discussion on the Application of Cloud-side Collaborative Architecture Based on SDN in Power Information System

Haihong Wu, Xiaobo Xu*

Zhejiang ZD·POWER Technology Co., Ltd, Hangzhou, Zhejiang, China
**Corresponding author*

Abstract: *With the continuous improvement of the real-time, reliability and security requirements of the power information system, in order to solve the shortcomings of the flexibility and maneuverability of the traditional systems, this paper takes the cloud edge collaborative architecture based on SDN as an example to study its application in the power information system. Through analyzing the basic overview of SDN and cloud edge collaboration, the specific applications are summarized, including smart grid, power load management and distribution network automation, aiming to improve the efficiency and security of the system and provide technical reference for the future development of power information system.*

Keywords: *SDN; cloud edge collaborative architecture; power information system*

1. Introduction

As the central nerve of the power system, the power information system in modern society undertakes the comprehensive management and coordination of the power production, transmission, distribution and consumption. With the growth of power demand and the advancement of smart grid, the traditional power information system face many challenges, including surge of the data, the improved requirements for real-time performance, and the increases of system complexity. The rise of cloud computing and edge computing technology provides new ideas for solving these problems. Among them, the software-defined network (SDN), as a new network architecture, further realizes the flexible scheduling and centralized management of network resources through the separation of control plane and data plane.Therefore, this paper mainly discusses the application of cloud-based collaborative architecture of SDN in power information system, aiming to provide reference and reference for the future development of power information system.

2. An Overview of SDN and the Cloud-edge Collaborative Architecture

Software-defined network (SDN) is an innovative network architecture, whose core idea is to separate the control layer of the network from the data layer, and to make the network management more flexible and centralized. In the traditional network structure, each network device such as switch and router needs to independently process the task of packet forwarding and network decision. SDN centralized the network intelligence on a central node called SDN controller, which is responsible for processing the routing decision and traffic management of the whole network. Data layer devices such as switches become "dumb" devices that simply execute the instructions issued by the controller. This architecture not only simplifies the design of network devices, but also enables network administrators to adapt to changing needs more quickly and achieve efficient network traffic management and optimization[1].

Cloud edge collaborative architecture is combined with cloud computing and edge computing model. The cloud computing provides powerful computing, storage and analysis capabilities through centralized data centers, which is suitable for large-scale data processing and complex computing tasks. And the edge computing carries out data processing and analysis near the data source, which can reduce the data transmission delay and improve the real-time performance and response speed. In cloud edge collaborative architecture, the cloud and edge devices work together through the network, and complement complementary. The cloud is responsible for the centralized management of global data

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and big data analysis, and the edge devices process local data, providing real-time response and local storage, so that the cloud edge collaborative architecture can not only meet the demand of efficient processing large data, can also cope with the challenge of real-time and data privacy.

3. Analysis of the Advantages of Cloud-edge Collaborative Architecture based on SDN

3.1 Improve Network Flexibility and Controllability

In the traditional network architecture, the network equipment configuration and management often require manual operation, and the coordination between the devices is poor, resulting in slow network response speed and complex configuration. While through centralized control and dynamic management, SDN enables network administrators to control the whole network through SDN controller and quickly respond to the changes in business requirements. In this way, it can not only realize the on-demand allocation and dynamic adjustment of network resources, but also can easily modify and optimize the network topology structure. In addition, the programming interface of SDN makes it possible to customize and automnetwork functions, greatly improving the flexibility of the network. Through this way, the power information system can adapt more flexibly to different scenarios and requirements to ensure the efficient operation of the network.

3.2 Optimize the Resource Utilization Rate

Through the separation of control plane and data plane by SDN technology, the configuration and management of network resources can be centralized and dynamic, and the SDN controller can monitor network traffic and resource usage in real time, and flexibly allocate bandwidth and computing resources according to the needs of the power system. By assigning computing tasks to the cloud and edge devices, the cloud-edge collaborative architecture can significantly reduce latency and improve data processing efficiency. Among them, the edge devices deal with tasks with strong real-time and small data volume, while the cloud is responsible for complex computing and big data analysis. This division of labor and cooperation mode not only improves the overall resource utilization, but also reduces the amount of data transmission in the network and reduces the bandwidth consumption. In addition, the network virtualization technology of SDN allows multi-tenants to share the same physical network resources, and further improve the resource utilization efficiency through the dynamic creation and deletion of virtual network instances [2].

3.3 Enhanced System Robustness and Security

In the cloud edge collaborative architecture based on SDN, the robustness of the system is mainly reflected in its effective response to network congestion, faults and attacks, ensuring the continuous operation of the power information system and the stability of the data flow. Through the centralized management of the SDN control layer, the network can dynamically adjust and optimize the data routing, and quickly reconstruct the network even when some network nodes fail, ensuring the uninterrupted critical operations. In addition, due to the high programmable and flexibility of SDN, the system security has been enhanced. As the SDN controller can monitor the network condition in real-time, and quickly identify and isolate the suspicious traffic, so as to effectively prevent and reduce the damage caused by external attacks or internal leakage to the power information system. This architecture strengthens the protection of the critical infrastructure in the power network, ensuring the safety and reliability of the power supply.

4. The Specific Application of SDN Cloud-side Collaborative Architecture in Power Information System

4.1 Smart Power Grid

4.1.1 Real-time Data Acquisition and Analysis

Data acquisition mainly depends on the sensor equipment distributed in the key nodes of the grid, such as voltage and current sensors, and intelligent metering equipment, these sensors monitor the grid in real time, and quickly transfer the data through the SDN management network. Due to the flexibility and programmability of SDN, the network can be adjusted in real time, which can optimize the data

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transmission path, reduce delay, and ensure the high speed and security of data transmission. In terms of data processing, the edge computing node can immediately conduct preliminary data analysis, such as condition monitoring, abnormality detection and trend prediction. For example, it can analyze the power grid frequency fluctuations by implementing fast Fourier transform (FFT), or using machine learning algorithm for fault prediction. These computing tasks are completed at the edge nodes, which can reduce the computing pressure of the central cloud, speed up the response. By collecting data on voltage and current every minute through the sensors deployed in the distribution network (such as the average value of voltage recorded at a monitoring point is 110V per minute and the current is 5A), the system can generate the load map and performance report of the power grid in real time by analyzing these data, and adjust the operation strategy of the power grid [3].

4.1.2 Remote Monitoring and Control of Electric Power Equipment

Firstly, the power equipment remote monitoring depends on a large number of sensors and intelligent devices, these devices continue to collect various parameters, such as voltage, current, temperature, etc. These data were initially processed with the edge device the data and then efficiently transmitted to the cloud platform using the flexible routing function of SDN. And apply advanced data analysis and machine learning algorithms to conduct in-depth analysis of the data to predict potential failures and maintenance requirements. Secondly, the control strategy based on SDN makes the power system control more centralized and automated. The SDN controller can dynamically adjust the network configuration based on the analysis results from the cloud platform, optimizing power flow direction and load distribution. For example, if it is predicted that the electricity demand in a certain region will increase, the SDN controller can adjust the routing and network resources in advance, ensuring a stable power supply in the region. In addition, remote control also involves the implementation of emergency measures, where the SDN controller can quickly isolate the problem area and reconfigure the network to maintain the stable operation of the system. For example, by real-time monitoring data, the system can automatically disconnect the power of the damaged equipment to prevent the fault from spreading.

4.2 Power Load Management

4.2.1 Load Forecasting and Scheduling

In modern power system, load forecasting and scheduling is one of the key components, especially in the SDN based cloud edge collaborative architecture, this process is more important. Through accurate load forecasting and effective scheduling, the optimal allocation of power resources can be realized, which ensures the power supply and demand balance, and improves the efficiency and reliability of the power system. Load forecasting refers to the use of historical data and various forecasting models to estimate power demand for a certain period of time, a process that usually includes short-term (hour or day), mid-term (weekly or month), and long-term (annual) forecasting. In SDN cloud edge collaborative architecture, load forecasting can use the big data analysis ability and edge computing real-time processing capacity from the cloud, by using time series analysis method and historical load data, to predict future load changes through time series model like ARIMA (autoregressive moving average model) or seasonal adjustment ARIMA (SARIMA). The machine learning methods can also be used to predict the load, such as using support vector machine (SVM), decision tree, random forest or deep learning model to predict load, these models can handle a large number of nonlinear data, and provide more accurate prediction, or combined with multiple linear regression or logistic regression method, which can analyze the influence of temperature, humidity, time, holidays and other factors on power load.

And scheduling is to optimize the power resource allocation according to the forecast results, to ensure the power supply economy and reliability. Scheduling policies can be more flexible and automated in the SDN environment. In forecasting high load periods, the system can balance the grid load by adjusting the pricing strategy to encourage consumers to use power during off-peak hours, or directly control certain equipment to reduce power use. At the same time, according to the forecast data, the power generation and the purchase of additional power strategies are dynamically adjusted to meet the demand in the most economical way. Finally, combined with the application of virtual power plants (VPP), scattered renewable energy and storage equipment are assembled to form virtual power plants to more flexibly respond to the load changes of the power grid. For example, a city uses historical load data and weather forecast in the summer, predicting the maximum daily electricity demand for the next week through neural network models, forecasting the weekdays peak demand is 20% higher than the weekend, therefore, the grid operators adjust the power generation plan and demand response strategy

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according to the forecast, which effectively avoid the occurrence of power shortage [4].

4.2.2 Power Demand Response

Power demand response aims to realize the optimal dispatch of power consumption through intelligent control means and algorithms, so as to respond to the real-time demand and state changes of the power grid, and use the edge computing node to collect users' power use data and power grid status in real time. For example, through smart meters and sensor networks, data is collected every 15 minutes, including power, current, voltage and other parameters. According to these data, the SDN controller optimizes the data flow and processing logic according to a centralized way. In terms of dynamic pricing mechanism, by analyzing real-time data, the SDN controller can adjust electricity prices to reflect the supply and demand status and operating costs. For example, during peak hours, electricity prices may be increased by 10% to 20% to encourage users to reduce electricity consumption, and vice versa[5]. While in terms of automation demand response, the operation state of large power equipment can be automatically adjusted according to the power grid load demand and users' preset preferences. For example, for commercial users, heavy load devices are automatically turned on during off-peak hours and are delayed or turned off during peak hours, reducing the power grid pressure through programmed control. In addition, user participation and feedback mechanism can be set up, allowing users to see real-time electricity price and electricity statistics through the user interface. At the same time, users can choose automatic or manual mode to participate in demand response. The system provides energy saving suggestions and potential cost savings through statistical analysis. Taking a factory as an example, after adopting the power demand response system, the monthly electricity bill of the factory was reduced from 10,000 yuan to 9,000 yuan, reducing the electricity bill by 10%, and helping the power grid reduce the load by 5% during peak hours.

4.3 Distribution Network Automation

4.3.1 Fault Detection and Isolation

In the fault detection, the SDN controller is used to collect the real-time data of each node in the power system, including voltage, current, power and other parameters, and deploy sensors and intelligent devices were arranged at the edge computing nodes, so as to realize the real-time monitoring of the operating state of the power equipment. Later, the powerful computing power of the cloud was used to conduct in-depth analysis of the uploaded data of edge nodes, and big data technology and machine learning algorithms like support vector machine (SVM) and decision tree were used to identify potential failure patterns. Or use the state estimation method (using the measurement data and system model) to calculate the power system state technology, so as to dynamically adjust the frequency and range of data acquisition, improving the accuracy of the state estimation. Such as using the weighted least squares method (WLS) to accurately estimate the system state, so as to determine the specific location of the fault[6].

In fault isolation, once the fault is detected, SDN controller can respond quickly and issue instructions to isolate the fault area, and the controller can dynamically configure the network path to isolate the fault area from other normal areas, avoiding fault diffusion. For example, when a short circuit occurs, the controller can cut off the line power supply in time to prevent other parts of the grid affected. Or mainly by means of automatic recovery, combined with the cloud-side collaborative architecture, to achieve the automatic recovery after the fault, through the pre-set strategy, the system can automatically restore the power supply after the fault is removed.

4.3.2 Recovery and Management of Power Failure

The cloud-edge collaborative architecture based on SDN adopts automatic recovery means, mainly conducts global analysis in the cloud, and combines historical data and current network state to formulate the optimal power recovery scheme. When the edge node receives the instruction, the power redistribution and recovery operation in the outage area will be executed quickly, and this method can reduce the outage recovery time by more than 50%. In the later management process, intelligent dispatching and optimization means can also be used to realize the intelligent dispatching of the distribution network, dynamically adjust the power resource allocation, which optimizes the power load, and avoid power overload and equipment damage[7].

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5. Conclusion

To sum up, the application of the cloud edge collaborative architecture based on SDN in the power information system not only provides a powerful technology platform, makes the power system can be more efficient, flexible and safe management resources, but also promote the further development of smart grid technology. By improving the data processing capacity and network response speed, the architecture provides the necessary technical support for achieving more intelligent power management and maintenance. Despite the current challenges of network latency, data security and system compatibility, with continuous technological advances and solution innovation, the cloud edge collaborative architecture based on SDN is expected to play a more critical role in the future power information system, opening a new path for the sustainable development and optimal management of power systems.

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