Battery Energy Storage System Integration and Monitoring Method Based on 5G and Cloud Technology

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Abstract. The large-scale battery energy storage scatted accessing to distribution power grid is difficult to manage, which is difficult to make full use of its fast response ability in peak shaving and frequency modulation. With the rapid development of 5G and cloud technology, it is possible to realize interconnection of distributed battery energy storage system (BESS), cloud integration of energy storage system (ESS) and data edge computing. In this paper, a BESS integration and monitoring method based on 5G and cloud technology is proposed, containing the system overall architecture, 5G key technology points, system margin calculation. Therefore, rapid, accurate and flexible control of BESS can be realized, which make more use of BESS in peak shaving and shifting, new energy consumption, electric power bidding platform and other fields.

1 Introduction

In recent years, with the continuous increasing number of distributed energy storage system (DESS), the proportion of energy storage power station in the power grid gradually increases [1], and the amount of data generated by the power station operation is very large. Due to the current situation that ESS's decentralized access to the distribution network, the data transmission delay of the communication mode is large, so it is difficult to do centralized control of ESS and to make full use of its advantages of rapid response. 5G technology is mainly applied in 3 scenarios including Enhanced Mobile Broadband (eMBB), ultra-reliable and Low Latency Communication (uRLLC) and Massive Machine Type Communication (mMTC) [2-4]. 5G is suitable for automatic driving, industrial control and other occasions requiring less time delay and higher communication reliability.

Therefore, with the aid of 5G technology to the advantage of mMTC, a large amount of data, such as battery voltage, battery current, temperature and SOC, collected by the BESS, can be rapidly transmitted through 5G technology, and the control orders of power station can be issued quickly. It is helpful to realize reducing information transmission delay, centralized management of DESS, and do rapid response to dispatching command of grid.

In this paper, based on 5G and cloud platform to integrate multiple BESS. Firstly, the current situation of distributed access and distribution of energy storage system is analyzed, and then the typical BESS architecture is summarized. The BESS integration and monitoring method based on 5G and cloud technology is proposed, and the network architecture, edge computing function and other key points in system integration are expounded. Finally, the development of ESS in electricity market transaction, video transmission and network security are reviewed, prospected and forecasted.

2 Access status of DESS

The cooperation between energy storage and distributed new energy is an important mode in the development of new energy. With the investment of highly permeable distributed energy, energy storage technology is applied more and more widely in power grid. As an energy storage device, it can effectively alleviate the mismatch between load and power supply, and at the same time play an irreplaceable role in absorbing new energy and smoothing the volatility of new energy output [5].

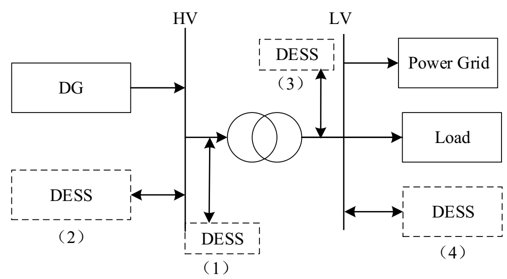

Fig. 1. Several typical cases of energy storage connected to the power grid

The distribution characteristics of new energy in space lead to the situation that energy storage is distributed connected to power grid. It increases the difficulty of centralized management of BESS. Typical modes of energy storage system accessing to power grid

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can be divided into several cases, accessing from (1) power supply side, (2) power grid side, (3) load side, and (4) third-party polymerization access, etc. [6-7], as shown in Figure 1

However, there are some problems in the decentralized access distribution network of the energy storage system, which also affect the access point to some extent:

- It is more flexible that energy storage system distributed connected to power grid, but the cost is higher, and some indices of ESS like charging and discharging efficiency, service life, power density index is not high [6].
- Distribution network area scheduling difficulty is increased [8].
- Power supply reliability of distribution power grid can be increased [9-10].

In each access mode, the DESS is connected to the distribution power grid in parallel or by switching the connection switch [11].

- In the parallel access mode, the DESS is in a parallel relationship with the power supply of the distribution network, so the reliability of the distribution network can be improved, but the operating cost of the energy storage system is relatively high.
- In the mode that DESS access power grid through the contact switch cannot improve the power outage times, but the power outage time is reduced. Because, it can switch the energy storage power supply when the power outage occurs. Moreover, the battery energy storage starts less times in this way, the operating cost is lower.

At present, power and capacity of distributed energy storage are relatively small. DESS can be integrated to a large capacity, which can be used in peak shaving, frequency modulation with its rapid response characteristics, the peak pressure of the power grid and power grid investment can be reduced, and stability of power grid operation can be increased.

3 BESS architecture

BESS is mainly composed of four parts: Battery System (BS), Power Conversion System (PCS), Battery Management System (BMS) and Energy Storage System. However, from the perspective of traditional control architecture, the regulation architecture of energy storage system connected to the grid side can be divided into two parts: The upper advanced application deployed in the dispatching side, and the operation and maintenance platform deployed in the lower. The former can control the operation of the energy storage system under different strategies, while the latter can monitor real-time information of the ESS on the spot. It can reduce the pressure of massive BMS data on the control network, and meanwhile, the operation and maintenance functions can be seen through the public network.

The aggregation management of distributed energy storage devices which connected to user side can be realized based on 5G and 4G wireless communications or wired monitoring networks such as TCP /IP. And after the security isolation and encryption, it can be access to power system control network.

A typical BESS monitoring architecture is shown in figure 2. The system realizes the functions of information collection, integration and monitoring of the energy storage station. Grid tide and load data, wind power and photovoltaic data are also connected, as well as related forecasts.

In this system architecture, the collected data is uploaded to the data center. Then, it can be obtained by ESS from the data center, and be used to generate day-ahead plan curve and other power strategy. There are two data sources for the energy storage monitoring system: one is to access the data center through the power data network; the other is to directly collect the underlying data of the energy storage station. The two ways complement each other.

The intelligent operation and maintenance platform of energy storage power station is the information monitoring platform of energy storage power station, which can monitor the running status of energy storage power station in real time. In addition, the platform features include health awareness and intelligent fault diagnosis. By mining, extracting and analyzing the existing massive data, the multi-dimensional evaluation of the operation performance and effect of the energy storage system is realized.

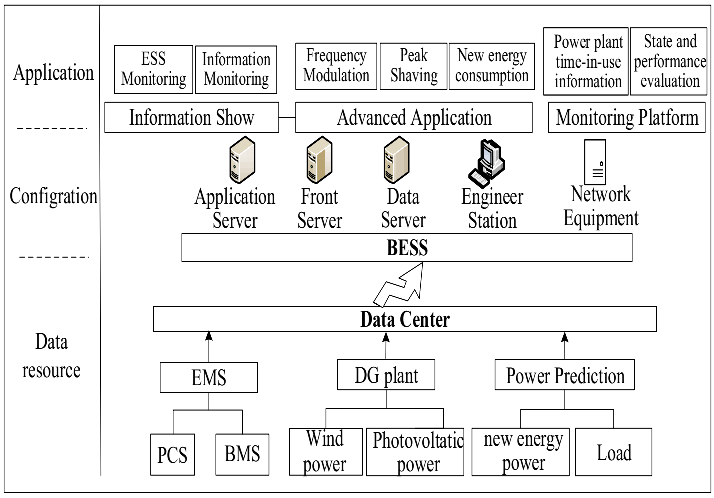

Fig. 2. Architecture of energy storage monitoring system.

4 System integration and monitoring

4.1 The system integration architecture

The exist f Special networks can be established by 5G technology with high bandwidth, high reliability, low latency, safety and other quality guarantees, which is suitable to BESS of different types and scales. Cloud computing is a centralized processing mode, by which the ESS can be managed uniformly. On this basis, the ESS architecture based on 5G and cloud technology is proposed, as shown in Figure 3.

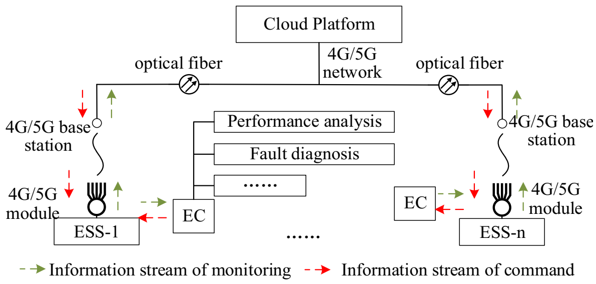

Fig. 3. Energy storage monitoring architecture based on 5G and cloud technology

As can be seen from Figure 3, multiple BESS is connected to the cloud platform through the private network: the single ESS is connected to 5G communication module, so the core data can be transported to 5G base station by wireless way. The base station is connected to 5G core network through fiber transmission. Then, core data can travel to the cloud platform at the remote end, where they are analyzed. After that, the overall control command is output and sent to the ESS through 5G two-way communication network. It can be achieved that the centralized control and unified management of ESS.

Cloud computing is a centralized processing approach. Requirements of unified management of ESS can be satisfied by it. Applications like peak shaving, frequency modulation and new energy consumption can be put in Cloud computing module. However, the data number of BMS such as voltage, current, temperature, SOC and other is too large to transport. Sending them to cloud side will result in delay of network transmission and waste network resources.

However, Edge Computing (EC) [12] is an effect way to solve this problem. Original data can be saved and executed near the data sources, which is helpful to relieve pressure of cloud storage and computing, as well as releasing the capacity of 5G channel. And the latency requirement is usually less than 10 milliseconds, which can ensure the transmission is not affected by the network bandwidth and load. Therefore, the raw data is stored and processed on the ESS terminal in the way of edge calculation.

4.2 System network of 5G

Different BESS has different scale, different battery type and diverse accessing approach to distributed power grid. So, the system integration mode should also be different. It is necessary to study the optimal integrated network of ESS based on its characteristics.

4.2.1 5G end-to-end network slice

Network Slicing refers to dividing the physical Network into several relatively independent virtual networks based on different requirement of network delay, bandwidth, security and reliability. Network slicing can be implemented by Software Defined Network (SDN) and Network Function Virtualization (NFV) [13].

5G end-to-end network refers to the network between the terminal of the energy storage monitoring system and the cloud platform. Different ESS user has their own characteristics and application scenarios, which occurs to different requirements for network broadband, scale, security, time delay, reliability and so on. With the help of network slicing technology, personalized and customized network slice can be made, which can replace special physical network. And the cost of network construction can also be saved.

4.2.2 Network mode

Network construction is one of the core problems in ESS integration. More research should be conducted with considering cost of slice, scale of ESS, as well as access characteristics and other factors.

The non-standalone (NSA) and the Standalone (SA) architectures are two independent architectures that are optional in the integration of 5G-based BESS. The NSA is developed on existing 4G network and 4G infrastructure. Some services and functions of 4G can be deployed, which saves construction costs. But it cannot play the features of 5G large access and low latency. While SA is a re-built 5G network. All 5G communication modules are adopted. The construction cost is relatively high, as well as information transmission efficiency. The time delay is extremely low. The requirements of system integration can be realized.

Therefore, it should be combined and considered that the future construction planning of BESS and the development of communication technology, especially operating cost when selecting the appropriate networking mode.

4.3 Local Monitoring based on edge computing

The original data is stored in the terminal of the monitoring system for edge computing, and can be accessed by cloud terminal. In the edge computing module, massive data can be analyzed and evaluated. The running status of energy storage power station can be mined, including battery performance evaluation and fault diagnosis, etc. It is helpful to system operation and maintenance. For BESS, data analysis, state assessment and system fault diagnosis are the main contents of edge computing. The results of edge computing are uploaded to the cloud to provide reference for cloud computing.

4.3.1 Data analysis and performance evaluation of BESS

One of the aspects of edge computing is data analysis and state assessment. At the terminal of the system, the state evaluation, performance evaluation and fault analysis of the batteries in the energy storage power station are carried out through horizontal and vertical data analysis.

Through edge computing, system operation data and evaluate system operation status. Be able to discover system abnormality in time and report early warning information. According to the early warning information and combined with the operating constraints of the system, the dispatcher can timely adjust the operating conditions of the energy storage to ensure the system safety. Data analysis and status assessment are the initial sources of information for the expert knowledge base shown in Figure 3. In the process of data analysis and state assessment, the expert knowledge base is constantly enriched, which makes the coverage of the expert knowledge base wider, greatly facilitates the dispatcher to analyze the fault scientifically and improves the work efficiency.

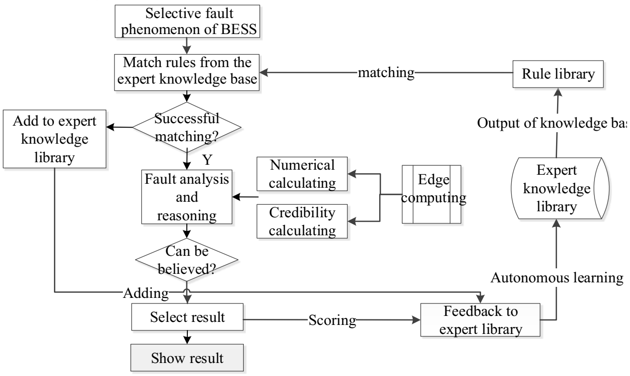

Fig. 3. Analysis and evaluation decision process based on ARTIFICIAL intelligence

4.3.2 Energy storage system fault diagnosis

Fault diagnosis is the process of judging system running state and abnormal situation. As shown in Figure 3, in the event of a system failure, the fault characteristics are matched with the rule base. Then, numerical reasoning and credibility reasoning are carried out through edge calculation to select the most likely fault type, fault location and cause for demonstration.

Dynamic and intelligent knowledge base of experts provides favorable conditions for fault diagnosis. After fault diagnosis, the system will score each possible cause, automatically supplement the expert knowledge base, and push the most likely cause to the analyst. Analysts can also intervene in the scoring situation according to the actual analysis results, or confirm and supplement the fault causes, so as to achieve the interaction of analysis and realize the continuous improvement of expert knowledge base, so as to improve the accuracy of fault results and provide scientific basis for the rapid positioning of fault causes.

5 Development trend analysis of 5G based BESS monitoring and control technology

It is one of the development trends of energy storage system monitoring technology to build an "end-side-cloud" energy storage monitoring system based on 5G and cloud technology. It is necessary to fully integrate deep learning and multi-type energy storage characteristics, and develop intelligent energy storage network based on 5G and intelligent energy storage operation platform based on cloud technology. The role of energy storage system is gradually expanding, but also need to pay attention to the following five aspects.

5.1 Market transaction participation

Energy storage station is one of the components of the "virtual power plant". Using communication, control, computer and other technologies, energy storage station can participate in power market and have convergent scale benefits in a unified way. As one of the flexible scheduling resources of the "virtual power plant", battery energy storage can be accurate controlled through 5G communication and participate in auxiliary services market such as peak shifting, voltage modulation and so on. When there are no scheduling tasks, it can be operated in the "peak-valley" mode and earning in the electricity power market.

5.2 Status analysis and diagnosis

It is necessary to explore new technologies and new ideas that can be used for state diagnosis, operation and maintenance of energy storage power stations. For example, it is some requirement that real-time transmission of the monitoring screen of the BESS to the control end, or real-time transmission of the running state of energy storage at the control end. The virtual reality technology is conducive to comprehensive monitoring and rapid control of the energy storage system.

5.3 System terminal edge computing extension

The edge calculation at the terminal of the energy storage system is not limited to battery performance analysis, operation status assessment and fault diagnosis. The data presentation mode should also be updated, and the collected data should be presented through portrait, so as to reflect the running state of the system more intuitively and facilitate the timely detection of faults.

5.4 Development of testing methods and standards

It is possible to establish a functional test and detection platform for distributed energy storage devices, considering new communication modes such as 5G and new data sharing and computing modes such as cloud technology. At present many kinds of upgrading of communication technology application in various fields in society, therefore, needs to be perfect as soon as possible to adapt to the new communication technology of the energy storage equipment monitoring related detection method and the formulation of the standards, for distributed battery energy storage in the rapid development of new type of power system safe, reliable, efficient and economic operation to provide technical support.

5.5 Network security issues

Many new technologies and different networking methods are adopted by 5G communication technology to meet the business requirements of different scenarios, and the use of new technologies and new services will also bring new security requirements. The traditional energy storage monitoring system has gradually weakened its ability to resist illegal access and network attacks. In the integration process of BESS based on 5G and cloud technology, full consideration should be given to network information security of integrated monitoring system, and more reasonable and effective information encryption measures should be taken to resist illegal access and network attacks, so as to ensure system-level information security of distributed energy storage aggregation monitoring.

6 Conclusion

In this paper, firstly, the current situation of decentralized access of BESS is analyzed. Secondly, the characteristics of energy storage monitoring system architecture is summarized. Then, a BESS integration and monitoring method based on 5G and cloud technology is proposed. The monitoring architecture of the BESS based on 5G and cloud technology is designed, and upward transmission of battery data and downward transmission of control commands are realized through 5G modules and 5G base stations. The requirements of centralized control management after decentralized access of energy storage is satisfied. In addition, edge computing is adopted to carry out status assessment and fault diagnosis to alleviate the pressure of cloud computing. Finally, the development trend of integrated application of BESS based on 5G and cloud technology is analyzed, and the possible business requirements and development direction are prospected.

Technical support can be provided by this integration and monitoring method for the research of energy storage system polymerization, battery operation big data analysis function development, energy storage equipment operation and maintenance management, upgrade and transformation, etc. Furthermore, the test method and standard formulation of 5G and cloud technology application in ESS are also important research directions. Data analysis, state assessment and system fault diagnosis are the main contents of edge computing. And such approaches can also be used in metallurgy and other high-tech industries. In the next stage, the application effect analysis and evaluation of the ESS monitoring system based on 5G and cloud technology will be carried out based on the measured data.

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