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The business model of 5G base station energy storage participating in demand response

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Abstract. To achieve the goal of "carbon peak, carbon neutralization", the proportion of renewable energy access will continue to increase, which will bring a severe test to the balance adjustment ability of the new power system, and the demand for flexible adjustment and real-time balance of the power system will continue to increase. However, pumped storage power stations and grid-side energy storage facilities, which are flexible peak-shaving resources, have relatively high investment and operation costs. 5G base station energy storage to participate in demand response can share the cost of energy storage system construction by power companies and communication operators to achieve a win-win situation between the communication system and the power system. Based on the analysis of the feasibility and incremental cost of 5G communication base station energy storage participating in demand response projects, combined with the interest interaction mechanism of all parties in the project, this paper proposes a business model for 5G energy storage to participate in the grid collaboration and interaction to improve the profit model of various market players, thereby promoting the penetration rate of the project.

1 Introduction

5G communication base stations have high requirements on the reliability of power supply of the distribution network. During planning and construction, 5G base stations are equipped with energy storage facilities as backup power sources to cope with special situations such as power outages and load fluctuations, which are potential flexible resources for the power system. Therefore, how to revitalize the fragmented idle energy storage resources, make 5G base stations participate in the synergistic interaction with the distribution grid as a new energy storage allocation subject, and enhance the flexibility of the power system while reducing the construction and operation costs of base stations, so as to realize the mutual benefits of the grid and communication operators will become the focus of this research paper.

At present, many studies have been conducted at home and abroad on the participation of 5G base station energy storage in grid co-dispatch. In terms of 5G base station energy storage system, the literature [1] constructed a new digital 'mesh' power train using high switching speed power semiconductors to transform the traditional analog battery system into a digital battery system by energy digitization, which enhances the effectiveness of 5G base station energy storage system. The literature [2] addresses the capacity planning problem of 5G base station energy storage system, considers the energy sharing among base station microgrids, and determines the economic scheduling strategy of the storage system, which minimizes the daily operation cost of base station microgrids. The literature [3] investigates the operating state and lifetime of distributed energy storage devices based on load sensing of the grid, and designs a hierarchical partitioned energy optimization and deployment strategy to reduce the operating cost of client-side energy storage devices by selecting a comprehensive optimal control scheme.

In terms of 5G energy storage participation in key technologies for grid regulation, literature [4] introduces destructive digital energy storage (DES) technology and studies its application in mobile base station (BS) environment, and then proposes a large-scale distributed DES-based cloud energy storage (CES) platform to provide a new network-based energy storage service for local utilities. The literature [5] proposes an integrated monitoring method for battery energy storage systems (BESS) based on 5G and cloud technology, which enables fast, accurate, and flexible control of BESS and makes BESS more applicable in areas such as peaking and shifting, new energy consumption, and power bidding platforms. In the literature [6], an optimization strategy for microgrid participation in day-ahead market operation considering demand response is proposed considering the uncertainty of distributed renewable energy generation, electricity load and day-ahead market prices.

In terms of 5G energy storage participation in demand response, the literature [7] developed two energy storage system (ESS) scheduling algorithms to participate in the self-consumption and demand response (DR) programs in Korea. The literature [8] studies the expansion requirements of the power supply system based on the

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standard configuration of a typical base station, and investigates the feasibility and economics of 5G base stations participating in demand response on the basis of ensuring that they have basic energy storage and power backup functions. The literature [9] proposed a virtual power plant optimization scheduling model and found that incorporating the base station energy storage into the virtual power plant can effectively reduce the cost of power consumption at the base station and alleviate the pressure on the grid power supply. The literature [10] sorts out the key technologies necessary for 5G base stations to participate in demand response, foresees the application scenarios for 5G base stations to participate in power system interactions as demand-side resources, and explores potential business models for 5G base stations to participate in demand response.

The participation of 5G base station energy storage in demand response can realize the effective interaction between power system and communication system, leading to win-win cooperation between both sides. However, the current 5G base station energy storage project has not formed a perfect business model, resulting in a lack of enthusiasm to participate in the market and unable to withstand market risks. This paper explores the participation of 5G base stations in demand response, and on the basis of analyzing the feasibility and incremental cost of 5G base station energy storage participation in demand response, the specific business model of 5G energy storage participation in demand response is studied to enhance the participation rate of each market player.

2 The potential analysis of 5G base station energy storage participation in demand response

The 5G base station energy storage battery is an important equipment for the base station to participate in demand response. The major difference between it and the general energy storage battery is that its primary function is power supply backup, which is required to provide uninterruptible power supply (UPS) for the base station communication equipment when the distribution network fails to ensure the reliability of power supply for the base station power equipment. Therefore, to analyze the potential of 5G base station energy storage to participate in demand response, we must first analyze the load characteristics of 5G communication base stations and participate in demand response under the premise of ensuring the normal operation of 5G base stations.

5G base station users, as the source of base station communication data traffic generation, their daily usage behavior to a certain extent leads to the dynamic change of communication traffic load in different moments and different spaces. In terms of time characteristics, affected by the living habits of users, the communication load of base stations fluctuates within 24 hours a day, and there are obvious load peaks and valleys; in terms of spatial characteristics, the communication load of base stations in office areas during working hours is significantly higher than that in residential areas, while the communication load of base stations in residential areas is significantly higher than that in office areas during non-working hours. Many places around us such as commercial areas, office areas, residential areas and other areas have obvious fluctuations in the number of users with human movement behavior, which makes the communication load of base stations in different geographical areas have obvious differences and a certain degree of complementarity sex.

At present, the energy storage capacity of 5G base stations is mainly configured with reference to the peak power consumption corresponding to the peak load of the base station. Since the communication load of the base station is not always in the peak state, there is a certain redundancy in the configuration of its energy storage, which also provides a potential dispatching potential for the energy storage of the base station to participate in the coordination and interaction of the power grid.

People's moving behavior and living habits make the communication load of base stations at different times and in different regions different. In the period of high communication load, due to the large number of access users and the large amount of business, the capacity stability and reliability of the backup power supply are required to be high, and the dispatchable capacity is low; during the period of low communication load, the urgency of the demand for backup power is relatively low. With the improvement of the reliability of the mains power supply, the energy storage of the base station is in an idle state for a long time when the mains supply is normal, and the dispatchable capacity is high.

3 The incremental cost analysis of 5G base station energy storage participation in demand response

Through the analysis of the potential of 5G base station energy storage to participate in demand response, it is concluded that it has certain feasibility, and then the incremental cost of participating in demand response is analyzed.

3.1 Analysis of incremental electricity cost

The incremental cost of the 5G base station energy storage system participating in demand response can be divided into two aspects, one is the negative externality cost, and the other is the increased electricity cost of participating in the coordinated dispatch of the power grid. Figure 1 shows the specific changes in the cost of 5G energy storage participating in grid coordination and dispatching.

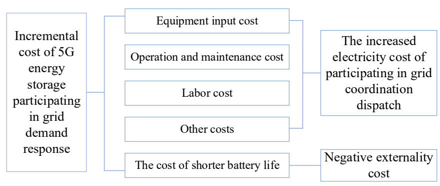

Fig. 1. Incremental cost of 5G energy storage participating in grid coordination dispatch.

It can be seen from Figure 1 that the cost of electricity consumption increased by participating in the coordinated dispatch of the power grid includes equipment input cost, operation and maintenance cost, labor cost and other costs. Among them, the equipment input cost refers to the equipment input cost increased by the transformation of the original energy storage power station or the addition of corresponding supporting equipment after the 5G energy storage power station participates in the coordinated dispatch; The operation and maintenance cost refers to the maintenance and replacement of the energy storage battery of the 5G energy storage base station and the maintenance of the base station failure after the energy storage of the 5G base station participates in the coordinated scheduling of the power grid, and 5G base stations apply more high-tech, due to immature technology or other reasons, more failures will occur on the original basis, its operation and maintenance costs will increase; The labor cost refers to the labor cost incurred by the need to add specialized personnel to conduct routine maintenance and inspection of the energy storage facilities after the 5G energy storage power station participates in the coordination and dispatch, and coordinate the energy storage facilities to participate in the demand response after the power grid sends a demand response signal; Other costs mainly include bank loan interest, network access inspection fees, design, construction and reconstruction costs of 5G energy storage power stations, electricity price costs and other additional costs. After the 5G base station energy storage participates in the coordination and interaction of the power grid, it can make use of the peak-valley electricity price difference and obtain carbon emission subsidies. In the long run, the incremental electricity cost of 5G base stations due to their participation in grid coordination scheduling will be reduced.

3.2 Analysis of Negative Externality Cost

Negative externality costs mainly refer to the costs caused by the decline of battery status and shortened battery life due to activities such as grid peak regulation and frequency regulation.

Now we analyze the negative externality cost caused by 5G base station energy storage participating in demand response. Firstly, the depth of discharge (DOD) of the base station energy storage battery and its battery life are established to quantify the model, and the cycle times of the energy storage battery under different discharge depths are calculated. Taking the Lithium Iron Phosphate Battery as an example, the DOD and cycle life model of the base station energy storage battery is established. After polynomial fitting of the relationship between the capacity retention rate n and the number of cycles of lithium iron phosphate battery m, the mathematical relationship obtained is shown in formula (1), where A, B, and C represent the fitting coefficients.

$$\eta = A\times n + B\times n^2 + C\times n^3 + 1 \tag{1}$$

When the maximum discharge capacity of the battery cannot reach more than 80% of the rated capacity, it can be considered that the service life of this group of batteries has been exhausted. Therefore, take 0.8 for η in formula (2-1), and calculate the cycle times of the lithium iron phosphate battery under different DOD through the fitting coefficient, as shown in Table 1.

Table 1. The number of battery cycles under different DOD.

DOD%	n times
40	4220.59
60	3644.39
80	2860.94
100	2115.32

Then it is concluded that the life of the energy storage battery under the actual operating conditions when 5G energy storage participates in the coordinated dispatch of the power grid is shown in formulas (2) and (3):

$$n_{eq} = \sum_{t}^{T} \frac{E_t}{E} \tag{2}$$

$$N = \frac{n_{100}}{n_{eq}} \tag{3}$$

In the formula, n_{eq} is the equivalent number of cycles of the energy storage battery under working conditions, E_t is the total discharge energy of the energy storage battery in the t period, E is the maximum energy of the energy storage battery ; N is the running time of the energy storage battery, n_{100} is the cycle times of the energy storage battery under the corresponding DOD.

Finally, the negative externality cost of 5G energy storage participating in grid coordination dispatch can be obtained as shown in formula (4).

$$F_c = \frac{E_{all}}{N\times E_f}\times T_c \tag{4}$$

Among them, F_c is the negative externality cost of 5G energy storage participating in the grid coordination dispatch, E_{all} is the total amount of charge and discharge when participating in the grid interaction, N is the running time of the energy storage battery, E_f is the discharge amount of the energy storage battery at different discharge depths, T_c is the cost per unit of energy storage battery.

After the 5G energy storage power station participates in the coordinated dispatch, the battery life will be shortened, the number of cycles will be reduced, and its negative externality cost will increase.

4 The business model study of 5G base station energy storage participation in demand response

The project business model is a key factor in promoting the participation of 5G energy storage in demand response projects. It affects the participation rate of users and the popularity of the project, which ultimately affects the execution effect of the entire project. The previous article has analyzed the potential and incremental cost of 5G energy storage participating in demand response projects. It can be concluded that the project is feasible to a certain extent, but it has a certain cost. At present, the project has not formed a complete business model, and the profit model is not clear, resulting in a lack of enthusiasm for its participation in the market and its inability to resist market risks. Therefore, this section will study the business model of 5G base station energy storage participating in demand response.

4.1 Analysis of related subjects

To study the business model of 5G base station energy storage participating in grid demand response, it is necessary to first sort out the value demands of various relevant entities, and analyze the interest interaction mechanism of 5G base station energy storage participating in grid coordination and interaction, such as power grid companies, 5G operators, tower companies and other relevant entities. The main participants of 5G base station energy storage participating in grid demand response are base station operators and power grid companies, both of which have sufficient motivation to promote the implementation of the project.

Base station operators include communication operators who build their own base stations and specialized base station operators. For base station operators, while ensuring the coverage of 5G networks, the massive 5G base stations also cause the cost of electricity to increase exponentially. Therefore, base station operators need to find ways to effectively reduce electricity costs. The participation of 5G base stations in demand response is a potential way to reduce the cost of electricity consumption. Base station operators can reduce the cost of electricity and obtain additional benefits by participating in demand response. On the premise of satisfying reliability and communication quality, charging the energy storage battery when the electricity price is low, and using the energy storage battery to supply power to the base station equipment when the electricity price is high, can reduce the cost per kilowatt-hour of electricity used by the base station. Further, it is possible to cooperate with the power supply company to obtain a lower electricity price from the power supply company by implementing a grid-friendly electricity consumption method. In addition, controlling the base station equipment to participate in the auxiliary service can obtain the benefits due to the provision of the corresponding service from the auxiliary service market. Under the condition that the electricity market is gradually built and mature, the benefits obtained through the electricity price difference and ancillary service payment will effectively reduce the energy cost of base station operators, alleviate the impact of the significant increase in power consumption of 5G base stations, and improve the profitability of base station operators.

For power grid companies, in order to cope with the strong uncertainty brought about by the integration of a large number of renewable energy sources, the power system needs more flexibility to adjust resources to achieve real-time balance of power generation and load. Although the power of a single 5G communication base station is small, the total number of 5G base stations is huge, which is a typical distributed resource. The participation of 5G base station energy storage in demand response enables the power grid to obtain a large number of flexible resources that can be dispatched, improving the operational flexibility of the power system. If a large number of 5G base stations can be effectively coordinated and dispatched to give full play to their power flexibility, a considerable aggregation effect can be formed to provide support for the consumption of renewable energy.

To sum up, base station operators participate in demand response mainly to reduce the operating cost of base stations, and to make profits through demand response to share the high cost of base station construction. The power grid company wants to obtain flexible resources through this project and reduce the investment and operation cost of the energy storage system. The two have certain common interests. But grid companies are also required to absorb some of the incremental costs of 5G base station operators participating in demand response in order to make them profitable.

4.2 Design of business model

In the business model of 5G energy storage participating in the collaborative interaction of the power grid, market players can be divided into energy storage service providers, operators, end users, and power grid companies based on interests. The service flow and capital flow between various market players are shown in Figure 2.

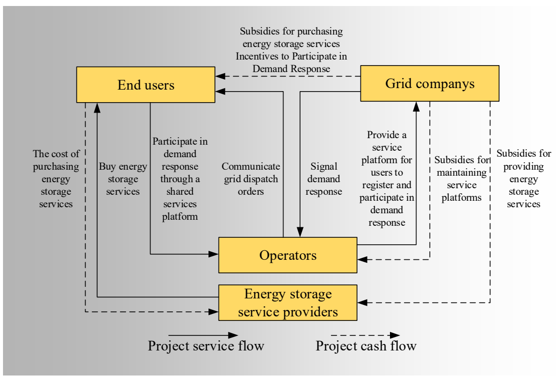

Fig. 2. 5G base station energy storage participates in demand response business model.

From the service flow in Figure 2, the main responsibility of the grid company is to set up a demand response program and propose a demand response when needed; The main task of energy storage service providers is to provide energy storage services for end users, including transforming 5G energy storage system equipment, checking whether the status of the energy storage system meets the requirements for grid access, and viewing energy storage resource usage information and data; The responsibility of the operator is to provide a shared service platform for end users to register and participate in demand response, and to help many users better participate in demand response projects organized by power grid companies; The end users' responsibility is to publish the demand and price of energy storage sharing, sign contracts with operators, and participate in demand response regularly and quantitatively according to the contract. In special cases, the energy storage service provider and operator can be served by the same unit, that is, not only providing energy storage services, but also coordinating users to participate in demand response.

The project capital flow can be obtained from Figure 2. The power grid company mainly provides subsidies for other market players to maintain the operation of the project, and needs to provide certain incentives for end users to share the incremental costs arising from their participation in demand response; End users need to pay energy storage service providers for energy storage service fees, including the cost of ancillary services such as energy storage system renovation, energy storage system inspection, and energy storage resource inspection.

According to the project capital flow, the income of 5G energy storage power station can be obtained as formula 5.

$$I = \sum_{j=1}^{T}(V_{DR} \times Q_{DR,j}) + F_A \tag{5}$$

Among them, I is the income of the 5G energy storage power station participating in the demand side response, V_{DR} is the subsidy price of the user's response to the electricity, $Q_{DR,J}$ is the electricity that the user participates in the demand-side response in a single day, T is the total number of days that users participate in demand response, and F_A is the subsidy of the power grid company for end users to purchase energy storage auxiliary services.

In traditional energy storage demand response projects, power companies need to build their own energy storage systems, and also manage and maintain energy storage equipment. The resulting costs include construction costs, hardware costs, and maintenance costs. In the 5G base station energy storage participation demand response business model, although power companies need to provide various incentives and subsidies to end users, energy storage service providers and operators, the total cost is still lower than the traditional self-built self-operated model. At the same time, this model can encourage end users to participate in demand response projects and increase the penetration rate of projects.

5 Conclusion

The rapid development of 5G communication networks will bring about the massive construction of 5G base stations. For the power system, the huge number of 5G base stations is a potential resource of flexibility. Promoting the participation of 5G base stations in demand response can revitalize the idle energy storage resources of communication base stations, reduce the electricity cost of base stations, and increase the flexibility of the power system, thereby achieving mutual benefit and win-win results between the communication system and the power system. Based on the analysis of the potential and incremental cost of 5G base station energy storage to participate in demand response, this paper designs a business model for 5G base station energy storage to participate in demand response in combination with the interest demands of relevant entities. This paper can provide a reference for the related research and practical application of 5G base station participation in demand response, and promote the common development of power system and communication system.

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