Economic Analysis of Electric Vehicle Operators in Participating Auxiliary Services Market

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Abstract. In recent years, with the rapid development of electric vehicles, the security of power system has been affected by the wide access, and the economic value potential of its participation in auxiliary services has been paid more and more attention. In this paper, through the analysis of the problems of electric vehicle participating in peak shaving auxiliary service, the economic value of electric vehicle energy storage participating in peak shaving auxiliary service is reflected, and the cost and potential benefits of electric vehicle energy storage system are analyzed, which is helpful to study the economy of electric vehicle energy storage further.

1. Introduction
The development of foreign electric vehicle industry is relatively mature. Relying on sound policy incentive mechanism and perfect legal supervision system, foreign electric vehicles have made great progress in mobile energy storage, participation in auxiliary service market, micro grid balanced dispatching and unit load emergency energy supply mode [1], which provides a reference example for domestic electric vehicle business model research. The research on energy storage application and participation in auxiliary service market of domestic electric vehicles is still mainly limited to the level of power system [2], and its operation and profit model is relatively single. The guarantee of profitability is an important support for the sustainable development of the electric vehicle industry. From foreign practical experience, the development of the electric vehicle industry needs to rely on its own profitability as the capital pool, and a single subsidy mode will make it lose its industrial vitality soon [3]. Therefore, it is of great significance for the future development of electric vehicle industry to study the diversified application business model of electric vehicle mobile energy storage.

2. The dilemma of electric vehicle participating in peak load regulation service
In the existing auxiliary service market for peak load regulation, the cheapest peak load regulation resources are selected to meet the peak load regulation requirements of the system by applying for the price of each unit, and the optimal allocation of peak load regulation resources is preliminarily realized [4], and through market-oriented competition, the units are encouraged to provide peak load regulation services for the power grid to a certain extent. However, because the current overall scheduling mode is
still mainly the planning and scheduling mode [5], the peak shaving auxiliary service market only carries out market-oriented optimal scheduling in terms of peak shaving resources, lacks perfect market system support, and lacks effective solution mechanism for the contradiction between the planning mode and the market mode. Secondly, the peak shaving auxiliary service market itself contains some planning and regulation rules, which also affects the market has the ability to optimize the allocation of resources. As shown in Figure 1.

2.1. Contradiction between peak demand and implementation of electricity plan
The market mechanism of auxiliary service compensation is an important part of the power market construction. In order to balance the power grid load, in the period of low power consumption, in order to ensure the grid connection of wind power, thermal power units need to reduce output and participate in peak load regulation. When the peak load regulation compensation system has not been established, it needs to rely solely on the planning mode and dispatching order to implement, and the enthusiasm of thermal power units to participate in peak load regulation is low [6]. The traditional peak load regulation method may result in that the units with peak load regulation ability can not get enough peak load regulation indexes, but the units without the intention of peak load regulation are forced to participate. From the perspective of the whole power market system design, how to straighten out the contradiction between the peak shaving auxiliary service market and the "three public" planned power is an urgent problem to be solved.

2.2. Setting price limit interval by segment quotation, affecting fair and orderly market competition
Segmented price limit divides the bidding space of paid peak shaving into two sections, and limits the minimum declared price of the second section of deep peak shaving. The rationality of the minimum price limit will directly affect the fairness of transaction competition. If the minimum price is too high, some units with strong peak load regulation capacity and low cost will not be able to give full play to their competitive advantages. The price higher than the price limit must be reported, which may not only cause the unit to lose part of the market share, but also lead to the overall increase of the system peak load regulation auxiliary service cost.

To some extent, segment and ceiling price can protect some backward units, which makes it difficult to realize full and effective competition of peak load regulation resources. In the current situation of insufficient compensation for peak shaving and relative shortage of peak shaving resources, the
existence of price limit will inevitably lead market members to gradually approach the upper limit of quotation in the first stage, and eventually lead to market failure.

2.3. It is difficult to give full play to the peak shaving potential of power users and encourage the power side to participate in the peak shaving auxiliary service market

Combined with the current demand of the Northeast peak shaving auxiliary service market, the peak shaving potential of the load side is deeply explored. On the one hand, a set of transaction declaration, transaction clearing, transaction settlement and market organization for power users to participate in wind power consumption in the peak shaving auxiliary service market is designed, and the personalized call demand of power users' peak shaving power curve and the quotation limit of power users are carefully considered. On the other hand, further improve the existing direct trading rules, by regulating the peak regulation rate and responsibility of different direct transactions, avoid the deterioration of the peak regulation ability of the grid caused by direct transactions.

2.4. Lack of effective coordination scheme of primary and secondary markets

The core problem of the auxiliary service market is how to determine which unit to call to participate in the auxiliary service and how to make a reasonable price for the market value of the auxiliary service. As the supply of auxiliary services is closely related to the production and consumption of electric energy, the selection and volume price of the members of the auxiliary service market are closely related to the electric energy market. How to design a reasonable coordination mechanism of primary and secondary market determines whether the design of secondary service market is reasonable. Therefore, how to design the primary and secondary coordination mode of auxiliary service market based on the existing semi plan and semi market mode is a problem that must be considered and solved at present. Therefore, in the following chapters of this report, the primary and secondary coordination methods will be designed in line with the current scheduling mode in Northeast China.

2.5. Provincial barriers remain serious

The existing dispatching mode of Northeast Power Grid still takes the province as the main control area, and the dispatching boundary of each province is determined by keeping the contact line between provinces [11]. Therefore, the existing peak shaving is still based on the province, and the cost transfer mode of inter province support is determined by the incremental part and the corresponding pricing mechanism between provinces. Firstly, it is difficult to give full play to the role of optimal allocation of resources due to the artificial separation of bidding areas; the existing peak shaving bidding is first carried out in the province, and then inter provincial support is considered. Secondly, the price of cross province consumption is not clear. There is no clear definition of how to calculate the price of each section from the deviation electric quantity part involved in cross province deep peak shaving to the price of each section sent out from the province.

3. Economic benefit analysis of electric vehicle participating in peak load regulation auxiliary service

The power grid has certain expectation for peak load regulation. If the access volume of electric vehicles does not meet the expected peak load of the power grid, the same benefits will be given to the electric vehicles. If the expected peak load regulation effect of the power grid is not achieved, the peak load regulation unit still needs to be connected. Peak load regulation revenue shall be determined by peak load P of electric vehicle. Only when (P=PG) peak load of electric vehicle meets the expected peak load of power grid, can the power grid give the maximum revenue to electric vehicle. As shown in Figure 2.
3.1. Cost analysis of electric vehicle battery energy storage system

1) Initial investment cost

The initial investment cost of electric vehicle battery energy storage system generally includes two parts: power cost and capacity cost. The power cost is related to the internal structure investment of the battery type adopted by the energy storage battery. The cost of the battery energy management system (PCS), energy conversion system (BMS) and other monitoring equipment is called the power cost. The capacity cost is related to the planning scale of the energy storage power station, and it needs a certain cost to equip a certain capacity battery for the energy storage system.

\[
 C_{\text{invest}} = (\alpha_s \cdot P_{\text{cap}} + \beta_s \cdot S_{\text{cap}})
\]

Where, \( \alpha_s \) is the unit power cost of the energy storage system; \( \beta_s \) is the unit capacity cost of the energy storage system; \( P_{\text{cap}} \) and \( S_{\text{cap}} \) are the rated charging and discharging power (MW) and rated capacity (MW-h) of the energy storage system respectively.

2) Operation and maintenance cost

The operation and maintenance cost is the maintenance cost of the energy storage system in one year. According to the service life of the energy storage system and the benchmark discount rate, the cost of the battery energy storage system in the whole life cycle is apportioned and overlapped with the annual operation and maintenance cost of the energy storage system to obtain the annual average cost of the energy storage system.

\[
 C_{\text{OM}} = \sum_{i=1}^{m} C_0 \cdot S_{\text{cap}}
\]

Where \( C_0 \) is the operation and maintenance cost per unit capacity.

3.2. Benefits of electric vehicle participating in peak load regulation on grid side

1) Direct benefit

The time-sharing price and auxiliary service compensation are the main revenue sources of electric vehicle energy storage construction on the grid side.

a) Time share tariff income

Under the time-sharing tariff, the battery energy storage system charges when the tariff is low (generally at the low load), discharges when the tariff is high (generally at the peak load), and the operation of high storage and low discharge generates the price difference arbitrage.
In the formula, \( W_1 \) is the daily operation benefit of "low charge and high discharge" of energy storage system (\( \$ \)); \( T \) is the dispatching cycle, 24h; \( \Delta t \) is the time interval, 1h; \( \eta_r \) is the corresponding period price (\( \$/kW \cdot h \)); \( \eta_s \) is the charging and discharging efficiency (%). Given the time-sharing price, the low storage and high discharge revenue of energy storage system is related to its capacity, charge discharge efficiency and charge discharge strategy.

**b) Compensation income**

The charging of the energy storage system in response to the dispatching instruction can be equivalent to the reduced output operation of the generating unit in response to the dispatching instruction, and then it can be regarded as the auxiliary peak load regulation service provided by the energy storage system. Therefore, as a porter of electric power, it compensates the reduced abandoned air volume and provides the economic benefits of peak load regulation auxiliary service as an energy storage system. The compensation standard can refer to the compensation method when the generator unit provides paid peak load regulation service. The compensation of auxiliary services for energy storage participating in peak load regulation is expressed as follows:

\[
W_2 = \eta_{aux} \left( \sum_{t=1}^{T} (P_{ed, i} - P'_{ed, i}) \Delta t \right)
\]

In the formula, \( P_{ed, i} \) and \( P'_{ed, i} \) are respectively the discarded energy per hour (MW) before and after the energy storage configuration; \( \eta_{aux} \) is the compensation standard for energy storage peak regulation.

2) **Indirect benefit**

a) **Delay equipment investment**

By installing the energy storage system at the load point, when the load is low, the load rate of the power grid can be improved by charging the energy storage system; when the load is high, the local power supply of part of the load can be realized by energy storage discharge, and the power needed to be transmitted by the power grid can be reduced. So as to delay the upgrading and expansion of power grid or reduce the capacity of power grid to be expanded.

\[
W_3 = C_d \eta_r P_{cap}
\]

Where \( C_d \) is the unit capacity cost of distribution facility.

b) **Reduce line loss**

Although in the valley load period, the energy storage system correspondingly increases the network loss. But through the overall analysis, it can be concluded that in a certain range of capacity, the increase of network loss caused by energy storage is less than the decrease of network loss caused by energy storage. At the same time, considering the high electricity price in peak load, the corresponding network loss cost in this period is also higher, so the value of energy storage system in reducing the network loss cost is considerable.

\[
W_i = N \sum_{i=1}^{n} \frac{R \cdot P_i^2}{V^2} \left[ P_i^2 + Q_i^2 - (P_i - \Delta P_i)^2 -(Q_i - \Delta Q_i)^2 \right] \quad \Delta P_i = P_{d,i} - P_{c,i} \\
\Delta Q_i = Q_{d,i} - Q_{c,i}
\]

In the formula, \( P_{d,i} \) and \( P_{c,i} \) are respectively the discharge power and charging power of the energy storage system in the i period; \( Q_{d,i} \) and \( Q_{c,i} \) are respectively the reactive power provided and absorbed...
by the energy storage system in the i period; \( P_i \) and \( Q_i \) are respectively the active power and reactive power of the load in the i period; \( \rho_i \) is the electricity price in the i hour; N is the annual operation times of the energy storage system; R is the installation point from the upper level substation to the energy storage device, etc. Effective resistance: V is the voltage at the access point of energy storage device.

c) **Dynamic expansion of transformer**

With the increase of load, the installed transformer capacity may not meet the requirements of safe and reliable power supply, so it is necessary to expand the transformer capacity. Compared with the static expansion construction period is long and expensive, the dynamic expansion of transformer can be realized by installing energy storage system, which can save cost and shorten the construction period.

4. **Investment strategy of electric vehicle participating in peak load regulation auxiliary service**

| Situation  | Whether the power grid contains new energy | Whether the power grid is stable | Peak load return |
|------------|------------------------------------------|---------------------------------|------------------|
| Situation 1 | Yes                                      | Instable                        | Peak shaving compensation, new energy consumption compensation and economic benefits |
| Situation 2 | No                                       | More stable                      | Peak load adjustment compensation and economic benefits |
| Situation 3 | No                                       | Stable                           | Economic benefits |

1) The power grid needs the electric vehicle group to provide peak load regulation auxiliary services, and new energy access. In this state, the power grid is very unstable, and it needs auxiliary services such as peak regulation and frequency modulation, and it must complete the order of new energy consumption. If the power grid needs to be restored to a stable state as soon as possible, it must be operated jointly by peak load regulating unit, frequency regulating power plant and energy storage system. At this time, the total revenue generated by electric vehicles consists of peak shaving, new energy consumption and economic revenue.

2) The power grid needs electric vehicle group access to provide peak load regulation auxiliary services, but there is no new energy access. Compared with scenario A, the grid will not be affected by new energy access, and the factors affecting the grid stability will be reduced. If the power grid wants to restore stable state as soon as possible, it needs the cooperation of peak load regulation unit and frequency regulation power plant, at the same time, the economic impact should be considered. At this time, the total revenue generated by electric vehicles is composed of peak shaving and economic revenue.

3) The power grid is in the period of flat or low power consumption, the power grid is in a stable state, and there is no new energy access. The power grid does not need peak load regulation and other auxiliary services, nor does it need to absorb new energy. Compared with scenarios A and B, the power grid is more stable, and the demand for electric vehicle group discharge is not high. At this time, the total income generated by vehicle network interaction is only composed of economic income.

5. **Conclusion**

Electric vehicle energy storage participating in auxiliary services, including peak shaving, frequency modulation, standby, etc., should be selected, priced and compensated by the service provider in the way of market. Through the above cost-benefit analysis, it can be concluded that the participation of electric vehicle energy storage system in auxiliary services also needs the promotion of electric power market to realize and quantify its potential return and value, to discover the price in the way of market, to reflect the supply and demand of auxiliary services, to promote the entry of more auxiliary services
resources, and to ensure the adequacy of the medium and long-term supply of auxiliary services; in addition, electricity. It still needs some incentive policies to participate in auxiliary service of energy storage technology of motor vehicles. The text of your paper should be formatted as follows:

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