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Research on Configuration Strategy of Optical Storage Charging Station

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Abstract*—Energy storage charging pile participating in the joint operation of power grid can not only reduce the cost of power grid expansion, but also obtain the benefit of participating in the auxiliary management service of power grid demand side response, so as to reduce operation cost. In this paper, energy storage charging pile is used to participate in the joint operation optimization of grid demand side response, and a model of optimal allocation of container energy storage in distribution network is proposed. Based on operation strategy of Optical storage charging station vehicle, the model aims to maximize investor's income in investment cycle, considering the income of participating in the voltage regulation, the subsidy income of delaying upgrading of distribution network, its investment and operation cost, and considering the constraints of voltage regulation of distribution network, the conversion of access nodes, energy conservation, etc., so as to optimize the number and rated capacity of Optical storage charging station vehicle. Finally, the case study of ieee33 node system is carried out. The results show that optimal configuration model can make investors of optical storage charging station gain profits and improve the economy of optical storage charging station.

Keywords-Distribution Network; Container Energy Storage; Optimal Configuration; Voltage Control

I. INTRODUCTION

Container energy storage technology has the ability to smooth intermittent electric vehicle charging power fluctuation, enhance power grid frequency modulation and peak load regulation ability, reduce the load peak valley difference, and improve system efficiency and equipment utilization. The configuration of distributed Optical storage charging station for charging pile can increase reserve capacity, reduce requirements for power supply, so that it is not limited by grid capacity. By configuring different energy storage capacity, it can meet the charging requirements of different electric vehicles, and reduce electrical input for charging pile. The energy storage equipment can suppress charging harmonic injection, improve safety and stability of the power grid and improve the quality of energy supply. Therefore, it has great practical and economic benefits to optimize operation of the energy storage charging pile and power grid. Aiming at operation optimization of energy storage system coordination and charging pile, some researches mainly focus on how to use energy storage system to reduce the charging fluctuation of electric vehicle. The main methods include: low-pass filtering, asynchronous control algorithm design, power electronic design, model optimization, etc. In addition, research of charging harmonic suppression guarantees the stability of distribution network operation. However, with a large number of electric vehicles connected to power grid without regulation and control, it may lead to peak superposition of distribution network load curve, further expansion of peak valley difference, increase the risk of line transformer load, and the research of charging harmonic suppression has no significant effect and economy on optimal operation of energy storage charging pile and power grid.

Flexible control and dispatching of controllable units in distribution network is an effective way to eliminate the growing (Distributed Generator, DG) of distributed power supply [1]. However, the fluctuation of DG itself and the problem of voltage exceeding the limit caused by the change of distribution mode in traditional distribution network have become one of the biggest challenges faced by large-scale absorption of DG in distribution network [2].

Combined with the existing research on optimal allocation of energy storage and based on operation strategy in Optical storage charging station, low storage but high arbitrage in Optical storage charging station, interest gained from the pressure regulation, benefits from delaying distribution subsidy along with investment and operating cost is comprehensively considered in this paper. Besides it, combined with regulation of distribution network, access node conversion and energy conservation constraints, Optical storage charging station optimization configuration model with the largest return of Optical storage charging station investors is established during investment period, which aims at the maximum return of Optical storage charging station for investors during the investment period.

II. Operation Strategy on Optical Storage Charging Station

The operation strategy of optical storage charging station vehicle is affected by the operation status of distribution network. Network loss is an important index to assess the operation status of power grid enterprises, so distribution network operates with the goal of minimizing network loss in the dispatching period. The specific operation strategy is: when distribution network voltage is normal, optical storage charging station vehicle arbitrage between low storage and high storage; when the distribution network voltage exceeds the limit, the optical storage charging station vehicle access to the node with the most serious voltage exceeding the limit [3-4]; the operation strategy objective function of optical storage charging station vehicle can be expressed as

$$\min F = \sum_{i\in N}\sum_{j\in N} G_{ij}\left(V_i^2 + V_j^2 - 2V_iV_j\cos\theta_{ij}\right)\Delta t \tag{1}$$

N is the node set of distribution network; G_{ij} is the conductance between nodes i and j. V_i, V_j is the voltage amplitude of nodes i and j respectively; θ_{ij} is the voltage phase angle difference of nodes i and j; Δt is simulation step, and this paper takes 15 minutes as an example.

Distribution network operation constraints are power flow related constraints and distributed power output constraints. When the distribution network operates in the optimal target mode, due to the fluctuation of distributed power and possible mismatch between its output and distribution network load sequence, distribution network may have voltage overrun. When the distribution network voltage overruns, the distribution network operators dispatch optical storage charging station for voltage regulation, and need to optimize objective function of power required for voltage regulation to minimize voltage threshold crossing of each node after the optical storage charging station is connected to distribution network[5].

$$\min q = \left|V_{most}\left(t_{DSO}\right) - V_{allow}\right| \tag{2}$$

In the formula (2), t_{DSO} refers to the time when the voltage of distribution network exceeds the limit value; $V_{most}\left(t_{DSO}\right)$ refers to the maximum value of voltage exceeding the limit value; V_{allow} refers to the allowable value of the voltage; it reaches the minimum value in case of under voltage and the maximum value in case of over voltage.

If the optimal access points of the two adjacent time steps of optical storage charging station are inconsistent, the optical storage charging station needs to be converted between two points, during which it is impossible to charge and discharge, so frequent conversion of the access points will affect the economy of optical storage charging station. Therefore, the access nodes of optical storage charging station should be reduced as much as possible. This Optical storage charging station operation strategy will convert the access nodes according to the following principles[6]: ① If the interval between the two voltage regulation periods is less than the interval time, the charging and discharging nodes will be changed, otherwise the charging and discharging nodes will not change; ② When the state of charge of optical storage charging station is about to exceed the limit, the charging and discharging will be carried out by changing the charging and discharging nodes.

To sum up, the flow of optical storage charging station operation strategy determination in the scheduling cycle is shown in Figure 1.

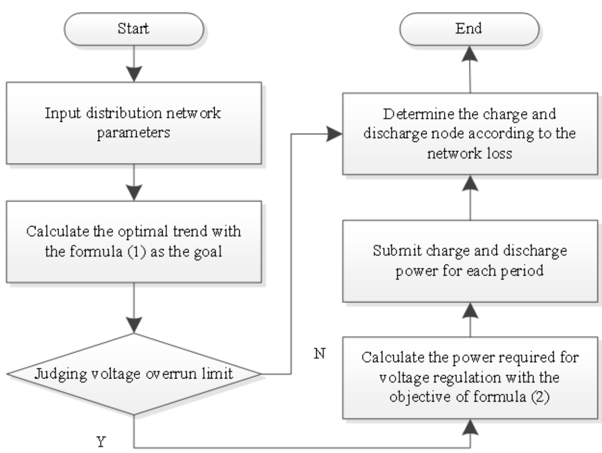

Figure 1. Process of movable storage operation strategy

III. CONFIGURATION MODEL OF OPTICAL STORAGE CHARGING STATION

According to operation strategy of optical storage charging station in this paper, only one optical storage charging station vehicle with enough capacity can meet the demand of distribution network voltage regulation in theory, but this is not in line with the interests of investors. At present, the cost of energy storage battery and its supporting equipment is still relatively high.

Dynamic energy storage operation strategy determination investor's point of view. Increasing capacity of optical storage charging station vehicle will increase the income and cost significantly. On the other hand, participation of optical storage charging station vehicle in the voltage regulation will affect its normal low storage and high discharge, so the energy storage investor hopes to complete voltage regulation of distribution network at a small cost. Therefore, through the cooperation of multiple optical storage charging station vehicles with appropriate capacity, the capacity can be arranged more reasonably for voltage regulation, so the impact of voltage regulation on its revenue can be reduced, and the economy of optical storage charging station can be improved.

Therefore, on the basis of strategy described in Section 2, the station can be optimized. The purpose of optical storage charging station optimization is to maximize the interests of investors by selecting the optimal number and capacity of optical storage charging station vehicles.

The objective function of Optical storage charging station allocation is that the station investor has the largest income within planning period, which can be expressed as

$$\min f = f_1 + f_2 + f_3 - f_4 - f_5 \tag{3}$$

In the formula, f_1 is peak valley arbitrage of optical storage charging station; f_2 is voltage regulation subsidy obtained by optical storage charging station; f_3 is income subsidy obtained from the delayed construction of power grid obtained by the station; f_4 is investment cost; and f_5 is operation cost.

The income from low storage and high development of optical storage charging station vehicles can be expressed as follows:

$$f_1 = \sum_{y=1}^{Y} D g_1 \left(\frac{1+r_i}{1+r_d} \right)^y \tag{4}$$

$$g_1 = \sum_{m=1}^{n} \sum_{t=1}^{96} \left[P_{dis}^m(t) - P_{char}^m(t) \right] C(t) \Delta t \tag{5}$$

Where, y is the using year of station; Y is investment period; D is the days of use of optical storage charging station in a year; r_i is inflation rate; r_d is discount rate; n is the number of vehicles; $P_{dis}^{m}(t), P_{char}^{m}(t)$ respectively is the discharge and charging power of M vehicles in t period; and $C(t)$ is the electricity price in t period.

In order to meet the voltage regulation instruction of distribution network, the optical storage charging station vehicle needs to reserve a part of capacity for voltage regulation, which will affect normal operation income of optical storage charging station. Therefore, the distribution network needs to subsidize the investor for its reserved capacity. The voltage regulation subsidy can be expressed as:

$$f_2 = \sum_{y=1}^{Y} Dg_2 \left(\frac{1+r_i}{1+r_d} \right)^y \tag{6}$$

$$g_2 = \sum P_{\min}(t_{DSO}) b_1 \Delta t \tag{7}$$

In the formula, $P_{\min}(t_{DSO})$ is the power required by the voltage regulation of the distribution network; b_1 reserves unit capacity subsidy price for the station. The optical storage charging station can release electric energy during peak load period, reduce peak load of distribution network, and delay the demand for upgrading of the distribution network. Therefore, by introducing optical storage charging station, the distribution network operators have obtained the income of delay construction, that is, the time value of the funds needed for the upgrading of the delayed lines. Because distribution power grid operators and optical storage charging station investors are different stakeholders, and distribution network operators should subsidize the income from delayed construction to investors in a certain proportion.

IV. CASE ANALYSIS

In this case, distribution network adopts improved ieee33 node feeder system, as shown in Figure 2 .The rated voltage of system bus is 10kV, and the standard deviation of distribution network voltage is ± 7%. The peak load of typical daily distribution network is (2.981 + j1.780) MV ·a. Nodes 5, 16 and 27 are respectively connected with distributed photo-voltaic with capacity of 1.65mw, 2.43mw and 3.68mw, and the typical daily output curve of node 16 photo-voltaic is shown in Figure 3. The initial SOC of optical storage charging station is 0.3, the upper and lower limits of SOC are 0.8 and 0.1, the maximum charge discharge ratio is 2c, investment cycle is 8 years, inflation rate is 1.6%, discount rate is 7%, annual interest rate is 9%, battery of optical storage charging station comes from the power battery echelon utilization, cost is 490000 yuan / (MW ·h), cost of power transformation unit is 1.7 million yuan / MW, and the annual cost of operation and maintenance is 70000 yuan/ (MW · H / a), the cost of expanding unit power equipment is 2.5 million yuan / MW, subsidy for voltage regulating capacity is 400 yuan / (MW ·h), and the subsidy ratio for delayed construction of distribution network is 21%. The case price adopts seasonal peak price implemented in 2015 in a province, and is divided into four stages. The typical daily price is shown in Table 1.

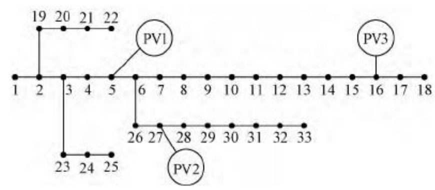

Figure 2. Modified IEEE 33 nodes distribution network

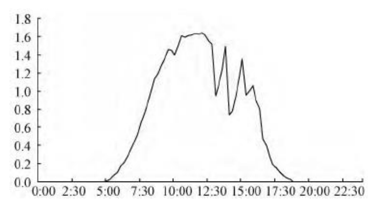

Figure 3. Distributed photo-voltaic power

TABLE I. TYPICAL DAILY POWER PRICE

Time period	**Power price (Yuan/MW.h)**	**Time period**	**Power price (Yuan/MW.h)**
0:00-8:00	372.4	14:00-15:00	1455.2
8:00-10:00	1357.3	15:00-19:00	815.0
10:00-11:00	1455.2	19:00-22:00	1357.3
11:00-12:00	1357.3	22:00-24:00	815.0
12:00-14:00	815.0		

V. Conclusion

In this paper, optimal allocation model of mobile energy storage in the distribution network is established to maximize the interests of investors of optical storage charging station. The conclusion is as follows: through optimal allocation model of optical storage charging station proposed in this paper, the problem of voltage exceeding the limit of distribution network can be solved, and the investors' income of optical storage charging station can be improved. The charging and discharging strategies of multiple optical storage charging stations are different, but there will be no one charging and discharging, and the voltage regulation can be completed by reasonable scheduling in the period when voltage exceeds limit value. With further improvement of power market system, optical storage and charging station can participate in multiple services, further improve its economy, and achieve win-win results for different stakeholders.

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