Research on Optimal Operation of Energy Storage Configuration in Regional Distribution Network Based on Particle Swarm Optimization Algorithm

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Abstract: In the actual management, it can be found that the power distribution scheme of energy storage power station will often have a certain impact on its scheduling cost in the use process. In this paper, the energy storage configuration of the regional distribution network based on particle swarm optimization algorithm will be analyzed to help relevant personnel grasp the power distribution direction of the energy storage power station and realize the optimization of power distribution of the energy storage power station.

1. Introduction

At present, the application of energy storage power stations has become more and more extensive, and their status in the power system is also higher. This is mainly because its application can effectively improve the quality of power and is conducive to the optimal distribution and utilization of power. Therefore, it is necessary to optimize the energy storage configuration of its own regional distribution network based on particle swarm optimization algorithm, so as to ensure the reliability and economy of energy storage power station operation.

2. Energy Storage Configuration of Regional Distribution Network Based on Particle Swarm Optimization Algorithm

2.1 Energy storage power station

In the process of practical application, the energy storage power station includes a power dispatching center and a plurality of battery systems. In the process of use, the energy storage power dispatching center and other functions carried by the energy storage power dispatching center can realize the distribution of dispatching tasks to the superior power grid and complete corresponding tasks by its own subordinate battery systems. An independent battery system usually includes an energy storage converter (PCS), a battery management system (BMS) and a plurality of battery packs (BP). In general, in the process of practical application, the battery pack needs to undertake the storage task of electric energy and charge and discharge the batteries in the battery pack according to the scheduling task. At the same time, its own application can not only improve the quality of electric energy, but also play the role of "peak cutting and valley filling", peak shaving and new energy absorption according to the change of electric load, which is helpful for the optimal distribution and utilization of electric energy [1]. But also enables the power grid to carry out charging and discharging processes according to corresponding requirements after dispatching tasks to the energy storage power station. In this process, the operation and maintenance costs, loss costs and construction costs can be collectively referred to as the dispatching costs of energy storage power stations, and in order to optimize them, it is necessary to analyze them based on particle swarm optimization.

2.2 Objective function

When optimizing the energy storage configuration based on particle swarm optimization algorithm, the analysis content needs to be simplified through reasonable assumptions, i.e. the internal battery systems, SOC, SOH and other contents, and the consistency of efficiency in the process of developing tasks such as charging and discharging needs to be ensured. Moreover, the battery system parameters should be regarded as unchanged during the period, and the scheduling tasks assigned by the superior power grid should also be kept within the acceptance range of the energy storage station. In addition, the objective function should be constructed by ignoring the self-discharging phenomenon of the battery. However, when constructing the objective function, the operation and maintenance cost of the energy storage power station should be taken into account, and the calculation of the dispatching cost should be completed by combining the loss cost and the fixed cost. These costs are calculated as follows:

1) Operational costs. When the energy storage power station is put into practical operation, in order to ensure its normal application, regular maintenance and monitoring are required to realize the normal operation of the energy storage power station. Therefore, its cost formula should be $C_{\mathrm{fix}} = T\sum_{i=1}^{n} K_i^f P_i$,where t is the time of a scheduling cycle, and $K_{\mathrm{f}}^{\mathrm{i}}$ is the operation and maintenance cost coefficient of the i battery system, p_i is its corresponding scheduling power, and n is the specific number of battery systems.

2) Cost of loss. After the equipment is put into actual operation, the loss problem is inevitable, and when calculating it, the loss generated in the charging and discharging processes need to be considered separately. K_{i}^{1} in which the coefficient of power loss is represented, $\eta_{\mathrm{i}}^{\mathrm{c}}$ and $\eta_{\mathrm{i}}^{\mathrm{d}}$ respectively represent the charging efficiency and discharging efficiency of the corresponding system.The formula is $C_{\mathrm{loss}} = \begin{cases} T\sum_{i=1}^{\mathrm{n}} K_i^1 \left(1-\eta_i^c\right) P_i \\ T\sum_{i=1}^{n} K_i^1 \left(\dfrac{1}{\eta_i^d} - 1\right) P_i \end{cases}$.

3) Fixed cost. During the operation of the power storage station itself, the battery system equipped by the power storage station itself can complete the charging and discharging of relevant work contents according to its own power scheduling. However, after the battery is charged and discharged, its SOH will enter the process of gradual attenuation. Finally, after it enters $SOH_i^{\min}$, the system will determine that it has entered a state where tasks cannot be scheduled and needs to be replaced. The input and construction cost of the battery system is a fixed cost, and the cost will be evenly distributed throughout the attenuation process of SOH to form a fixed cost loss. In the process of calculating the fixed, the expression is $C_{\mathrm{f}} = \sum_{\mathrm{i}=1}^{\mathrm{n}} \dfrac{\Delta SOH_{\mathrm{i}}}{1 - SOH_{\mathrm{i}}^{\min}} f_i^B$, and the expression of SOH is $SOH = \dfrac{C_{bat}}{C_{bat,0}} = 1 - \dfrac{C_1}{C_{bat,0}}$. The SOH variation corresponding to the battery system is indicated ΔSOH_i, and the SOH lower limit value of the battery system is indicated $SOH_i^{\min}$.

2.3 Constraints

Constraints, in the process of operation research, it can be found that in the actual process of receiving scheduling tasks, the charging and discharging power of each battery system in the energy storage power station will normally remain the same as the scheduling tasks, thus realizing the balance of scheduling power. Moreover, for each battery system, its internal scheduling power often has certain upper and lower limits, and in the process of assigning tasks, power will be assigned based on its acceptable range. Moreover, the optimization can be adjusted according to its characteristics, so as to keep the absolute value of the rated discharge power and the rated charge power of the battery system at an equal amount.

3. Distribution Network Configuration Optimization Direction Based on Particle Swarm Optimization Algorithm

3.1 Algorithm Process Optimization

In the process of optimal operation of energy storage power station, it is necessary to design corresponding scheduling cost measures according to its different power allocation schemes, so as to realize optimal processing of scheduling task scheme allocation based on the optimal operation scheme of energy storage power station. At the same time, PSO-based optimal allocation scheme has obvious advantages over traditional equal proportion power allocation scheme. Therefore, it is necessary to explore the optimal power allocation scheme based on PSO algorithm. In the process of optimizing its algorithm flow, firstly, its basic idea is to design multiple groups of random solutions, i.e. different power allocation schemes, starting from the power allocation scheme, and to calculate the scheduling cost in combination with the existing schemes, from which the scheme that is most beneficial to cost optimization is selected. However, the remaining power allocation schemes are also based on the application of transformation calculation, and gradually close to the currently designed optimization scheme for iteration. Finally, from these schemes, the one with the lowest scheduling cost is selected as the final optimization scheme, that is, the global optimal power allocation scheme.

3.2 Fitness function

The fitness function refers to the selected objective function in the process of optimizing the configuration of the power storage station, and since the purpose of optimizing the configuration based on particle swarm optimization is to minimize the scheduling cost, it is necessary to ensure that the corresponding allocation scheme is brought into the fitness function to obtain the minimum value in the process of optimization, so as to ensure that it has good fitness.

3.3 Implementation of Constraints

In the actual configuration optimization, combining with the relevant working conditions, the optimization conditions of particle swarm optimization algorithm can be summarized into $\begin{cases} P_{total} = \sum_{i=1}^{n} p_i \\ -\hat{P}_{dis,i} \le P_i \le \hat{P}_{chg,i} \\ SOC_i^{\min} \le SOC_i \le SOC_i^{\max} \end{cases}$ and need to be incorporated into the algorithm, thus forming a complete optimization algorithm. For example, in the process of applying this algorithm, the manager of a power storage station can control its constraint conditions within the SOC allowable range of the battery system according to its corresponding constraint conditions, and the maximum dispatching power it can accept and the sum of battery system power can remain the same as the tasks issued by the dispatching center [2]. At the same time, according to the battery system power and its own maximum SOC obtained in the actual application process, the calculation of the maximum dispatching power that the storage station can accept is completed, and at the same time, the constraint that the total power of each battery system is equal to the total dispatching power can be satisfied.

4. Conclusion

To sum up, the optimization of its own power distribution can be realized by adopting the optimal energy storage configuration of regional distribution network based on particle swarm optimization algorithm. Therefore, it is necessary to optimize the algorithm flow, fitness function and constraints according to the composition of the energy storage power station, its corresponding objective function and constraints, so as to ensure the reliability and economy of the operation of the energy storage power station.

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References

[1] Wang Deshun, Xue Jinhua, Ye Jilei, et al. Optimal Economic Dispatch Strategy of Energy Storage Power Station Based on Particle Swarm Optimization [J]. Renewable Energy, 2019, 37(05):714-719.

[2] Wang Chunmei, Xiong Binyu. Two-stage optimization method for balancing unbalanced power in microgrid based on energy storage dispatching mode [J]. Smart Power, 2019, 47(02):22-28+55.