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Market-oriented Trading Optimization Model and Value Evaluation Standard Mechanism of Energy Storage System

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Abstract

In view of the increasingly wide application of large-scale energy storage, a comprehensive optimization model of energy storage system planning and operation is proposed, and the complexity analysis and solution method of the model is given. Based on the two-tier decision-making problems, the model combines the problems of planning and running two different time scales to solve them, while considering the interaction between the planning and operation of energy storage system. The research shows that the comprehensive optimization model can realize the comprehensive optimization application of energy storage system for improving wind power access ability, suitable for various different types of energy storage system and various application scenarios, and lay the foundation for the application of large-scale energy storage system in power system.

Keywords

Energy storage system; Optimization model; Evaluation criteria.

1. Introduction

Energy shortage, environmental pollution and other issues are becoming more and more prominent, the development and utilization of new energy, improve the energy structure has become the consensus of all countries in the world. As the main form of clean energy utilization, wind power generation and photovoltaic power generation have the potential to compete with traditional power supply, and have been developed rapidly. However, wind power and photovoltaic power generation show strong volatility and randomness, affecting the security and stability of power grid operation. This makes it difficult to dispatch the power grid, adversely affects the continuity and reliability of power supply, and limits its own development [1].

In the process of grid-connected new energy, by installing energy storage device on the export side, we can calm the fluctuation of output power, to a certain extent, the new energy power supply can be converted into a dispatchable power supply, which can help reduce the impact on the power system, improve the operational stability of the power system, in addition to providing voltage support and improving the quality of electricity. Therefore, energy storage technology is considered to be a feasible solution to the problems of the continuous increase of new energy penetration rate in the current and future power grid [2].

This paper first briefly summarizes the current situation of various energy storage technologies and their applications, makes a detailed analysis of the research progress in the solution of new energy grid-connected problems in energy storage systems, and then focuses on the optimization and allocation methods of energy storage systems, and summarizes the control strategies of the energy storage system in different health conditions, and finally, the research direction and application prospects of energy storage technology [3].

2. The Classification and Application Status of Energy Storage System

Electrical energy can be converted into mechanical energy, chemical energy, electromagnetic energy and other forms of storage, according to the different ways can be divided into mechanical energy storage, electrochemical energy storage, electromagnetic energy storage and phase-change energy storage four types [4]. Among them, mechanical energy storage includes pumped storage, compressed air storage and flywheel energy storage, electrochemical energy storage includes lead acid, nickel isolation, lithium ion, sodium sulfur, liquid flow and other battery storage, electromagnetic energy storage includes superconducting, supercapacitor and high energy density capacitors Energy storage, etc. ; phase-change storage can be achieved by phase change of heat storage material and then absorbed or released latent heat, both in summer heat storage or in winter cooling, the main applications include cooling air-conditioning system, thermoelectric phase-change heat storage device and building energy-saving [5]. Table 1 is a classification of common energy storage systems.

Table 1. Common Energy Storage System Classification

Classification	How to implement
Mechanical energy storage	Pumped storage, compressed air storage, flywheel storage
Chemical energy storage	Electric gas power plants, power liquid systems, electric chemical plants
Electrochemical energy storage	Classic battery energy storage, redox storage
Electrical energy storage	Superconductive magnetic energy storage, supercapacitors
Heat storage	Sensitive heat storage, thermochemical energy storage, latent heat storage

At present, the capacity configuration and optimization methods of energy storage system are the difference compensation method, the fluctuation and suppression analysis method, the economic characteristic optimization method, etc. The differential compensation method compensates for the difference between the actual output of wind farms or photovoltaics and the difference in the power level stoain such as load, forecast or scheduling plan, without taking into account the dynamic changes in power and capacity during actual operation, and the configuration capacity is not accurate enough. Volatility leveling analysis method is mainly based on the energy storage system for the energy storage power of the suppression of the optimal configuration of the capacity of the energy storage system, the volatility does not exceed a certain confidence interval or not more than a certain value, but there is no direct correspondence between the compensation band, the amount of compensation and the volatility [6]. The economic characteristic optimization method is mainly to solve the optimization of the capacity of the energy storage system as the optimization variable by establishing the target function and constraint condition, and there is no standard unified target function and solution algorithm, and it is necessary to establish a variety of constraints, and the calculation process is complex. In this paper, in order to meet the new energy grid-connected fluctuation technical indicators as a prerequisite, the spectrum analysis and low-pass filtering combined, through the spectrum analysis of the typical output power data of new energy, according to the spectrum analysis results, in the frequency fluctuation range to determine the best first-order low-pass filter cut-off frequency, and consider charge and discharge loss and continuous operation, to obtain optimized grid-connected target power, energy storage power rating and capacity. After the storage energy configuration is completed, the low-pass filter parameters can be adjusted in the typical frequency fluctuation range, and the storage energy charge and discharge power can be satisfied with the smooth fluctuation operation control requirement, and can be kept within the configured rated power [7].

3. Energy Storage System Market-Oriented Trading Optimization Model Establishment

3.1. Outer Optimization Issues

The two-tier decision problem is a system optimization problem with two-layer step structure, and both the outer optimization problem and the inner optimization problem have their own target function and constraint, the target function and constraint condition of the outer optimization problem are not only related to the decision variable of the outer optimization problem, but also depend on the optimal solution of the inner optimization problem, and the optimal solution of the inner optimization problem is affected by the decision variable of the outer optimization problem. In the application of power system, the internal and outer optimization problems are convex continuous, the optimal condition sq. , the optimal solution exists. However, the resolution of the two-layer optimization problem is difficult to obtain, only through numerical solution to iterative approximation, to meet a certain convergence conditions, that is, it is considered to be the best. The mathematical model of the two-tier decision problem is as follows [8]:

In the two-tier decision model proposed in this paper, the outer optimization model is responsible for solving the planning problems of energy storage system, including the layout and capacity configuration of energy storage. The inner optimization model is responsible for solving the operation problems of the energy storage system, including the operation of the energy storage system and the conventional unit when considering the wind power. Here are the following. The decision variables of the outer optimization are the configuration location, configuration capacity and maximum input and output power of the energy storage system, the target function is the cost of the whole system, including the investment cost of energy storage and the operating cost of the system, such as power generation cost, network loss cost, etc. , and the constraint is the safety constraint of the system, including the flow equation constraint, node voltage and line trend safety constraint. In order to simplify the calculation, the capacity of the energy storage system can be characterized by the number of energy storage devices, so that the continuous energy storage capacity variable can be converted into discrete energy storage unit variables, thus unifying the capacity and layout into integer planning problems [9].

1) The impact of external layer optimization problems inthe application scenario.

After analysis, the scene leading to wind abandonment mainly has 2 points: First, the power peak, that is, under natural conditions, the evening load level is very low wind, the system can not accept more electricity to lead to wind abandonment; The first scene has no effect on the external layer optimization; the power blocking scenario tends to distribute the energy storage system at the wind farm nodes that are limited by the grid structure [10].

2) Exterior optimization complexity analysis.

The decision variables of outer optimization include integer variables and continuous variables, which belong to mixed integer planning, and are difficult to solve by conventional optimization algorithms, such as inner point method and gradient descent method. To solve this problem, this paper uses an intelligent algorithm based on a genetic algorithm, the detailed algorithm steps will be described in Section 2. 3. The actual results show that the intelligent algorithm based on the genetic algorithm proposed in this paper can solve the problem of hybrid integer planning well. The constraints of outer optimization include nonlinear trend calculation, especially when the system involved is large, the trend calculation will consume a larger part of the calculation time, this paper uses the most commonly used fast decomposition method at the same time to deal with the trend calculation.

In summary, the use of intelligent algorithms has largely solved the problem of hybrid integer planning that is difficult to solve by conventional algorithms, and the most complex part of the outer optimization lies in the nonlinear trend calculation and network loss calculation. The complexity of trend computing is related to the dimension of the decision variables optimized by the outer layer, in particular to the number of nodes contained in the system under study. The larger the number of system nodes, the higher the dimension of trend calculation, and the more complex the calculation. Because the energy storage system must be connected to the whole system rather than independent existence, so the increase and decrease of the number of energy storage system, or the capacity and power change of each energy storage system, affect the power and capacity range of each node in the system to participate in the trend calculation, but these will not affect the total number of nodes contained in the system, nor will it affect the complexity of the outer optimization, which is not the same as the internal optimization to be discussed below.

3.2. Inner Optimization Issues

As mentioned above, the outer layer optimization determines the layout and capacity of energy storage, on which the inner layer optimization considers the operation of energy storage. In general, the adjustment period of the energy storage system is less than or equal to one hour, and the total capacity is limited, which will not affect the start-stop plan of the conventional unit. Therefore, the essence of inner layer optimization is a simplified unit combination that considers the energy storage only in the power distribution stage. The decision variables of inner optimization are the operation of energy storage system and generator on the typical day of wind power, the target function is the running cost of the whole system, including the system power generation cost and wind exhaust cost, and the constraint stake is the operation constraint of the system, including power balance constraint, system safety constraint, power capacity constraint of energy storage system, etc.

1) The effect ofthe energy storage category on the internal optimization problem.

The energy storage category primarily has an impact on constraint c for internal optimization. Energy storage systems can be divided into power type and energy type. Power-based energy storage systems, such as supercapacitors, do not provide a smooth, continuous power output for a long time, so the time interval t considered for operational problems Δ t should not be too large, otherwise the average power output does not correctly represent the output characteristics of such energy storage systems. However, if the interval t is too small, the calculation speed of the optimization problem is difficult to guarantee, and there Δ t is no problem with the energy storage system. Therefore, for power-based energy storage systems, it makes sense for the interval Δ t to take 15min, and for energy storage systems, it is reasonable to take Δ t 1h at the interval.

2) Inner-layer optimization complexity analysis.

The objective function of inner optimization is a secondary form, the constraint condition is linear, and the difficulty is reflected in the scale of the decision variable. When more power supplies and smaller time intervals are involved, the dimensions of the inner optimization decision variables increase exponentially

4. Simulation analysis

In order to verify the validity and adaptability of the model proposed in this paper, pumped storage and battery storage are used for power peaking scene and power blocking scene respectively, and the planning and operation of energy storage system under different application scenarios and different optimization objectives are discussed. Among them, the pumping data comes from a pumping power station in the north, with a installed capacity range of 50 to 400MW, and a maximum operating depth of 45mofreservoir, with a total capacity of 2400MWforcontinuous power · hgeneration. Battery data from a Dalian energy storage technology development company, battery modular assembly, can provide 5 to 50MW power output, storage capacity of up to 500MW · h, a minimum of 50MW · h. Table two is a study scenario.

The simulation system topology uses the IEEE Standard 10 machine 39-node system, where the generator F is replaced by a standard fan (field)) with an output power of a typical daily output of wind power from a wind farm in Inner (Mongolia. The remaining conventional generator output is consistent with the standard model, with all power based on 100MVA and the calibration processed to participate in the calculation. Detailed generator parameters and fan output can be found in Appendix A. The study scenario is shown in Table 1. The simulation environment is the Matlab and PSAT toolkit. In a power blocking scenario, set the transmission capacity limit between node 35 and node 22 to 450MW.

Table 2. Study Scenario

Scene	Types of energy storage	Number of energy storage	Scenarios	Optimising goals
1	Pumped storage	1	Power peaking	Minimum total cost
2	Pumped storage	1	Power peaking	Minimum operating cost
3	Pumped storage	1	Power blocking	Minimum total cost
4	Pumped storage	1	Power blocking	Minimum operating cost
5	Battery storage	2	Power peaking	Minimum total cost
6	Battery storage	2	Power peaking	Minimum operating cost
7	Battery storage	2	Power blocking	Minimum total cost
8	Battery storage	2	Power blocking	Minimum operating cost

The simulation results for each study scenario are statistically shown in Table 3. The individual calculation time is defined as the total calculation time divided by the total number of individuals, which is used to measure the calculation speed of the algorithm. Defining the system net = load the original load storage energy output can be – counted in the power peak ingress scenario.

Table 3. The simulation results for each study scenario

Scene	Layout	Capacity	Power	Individual calculation time
1	30	24	0. 5	0. 6819
2	30	24	3. 6	0. 6023
3	35	24	0. 5	0. 6213
4	35	24	3. 8	0. 6842
5	14/30	0. 5/0. 5	0. 05/0. 05	0. 6321
6	30/36	3. 7/3. 8	0. 46/0. 48	0. 6894
7	30/32	0. 5/0. 5	0. 05/0. 05	0. 6812
8	30/35	1. 8/ 5. 0	0. 5/0. 5	0. 6312

5. Conclusion

With the research and development of large-scale energy storage system, it is possible to apply energy storage system in power system. Based on the decision-making problems of the two-tier edict, this paper puts forward a comprehensive optimization model for the planning and operation of wind power access, and discusses the calculation method of the energy storage system. The validity of the proposed model is verified in the improved IEEE10 machine 39 node system and the simulation results in a provincial power grid, and the empirical method of energy storage layout is proposed according to the simulation results. First of all, the energy storage system investment cost is high, the appropriate amount of wind can make the system total cost optimal, and do not need to blindly pursue the least wind discard, will greatly increase the system cost.

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