Distributed Energy Storage Scheduling Optimization of Micro Grid Based on Particle Swarm Optimization Algorithm

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Abstract. Distributed generation is a new type of environment-friendly energy, which has a good development prospect. However, due to its inherent defects, it is still difficult to be widely used in large-scale access points and loads. As a new type of distributed power supply, Micro grid is decentralized and intermittent in power supply. In order to make rational use of power grid resources, it is necessary to optimize the distributed energy storage scheduling. The particle swarm optimization algorithm proposed in this paper is also to improve the data processing capacity of the scheduling system. This paper mainly uses the experimental comparison method and particle swarm optimization algorithm to study the micro grid distributed energy storage scheduling optimization. The experimental results show that the FCPSO algorithm takes the least time, only 7s, and has the lowest cost. Therefore, this algorithm can be used for in-depth analysis of micro grid scheduling.

1. Introduction

Micro grid is one of the emerging system engineering projects. This paper will study and analyze the impact of micro grid and its related technical characteristics on the energy storage scheduling scheme. Micro grid will generate a lot of harmonics and excess energy in operation, which will cause great harm to the system, so it is necessary to reasonably arrange distributed power supply. Energy storage is an integral part of the normal operation of the Micro grid unit. This paper mainly focuses on solving the required energy storage based on particle swarm optimization.

There are many theoretical achievements in the research of particle swarm optimization algorithm in micro grid distributed energy storage scheduling. For example, some scholars take the micro grid optimal dispatching as the research object, and establish the micro grid optimal dispatching model. The improved particle swarm optimization algorithm is used to solve the model, and a convenient micro network platform is established to design and implement the search results [1-2]. In view of the poor absorption capacity of existing microarrays for photovoltaic and wind energy, other scientists proposed a multi-objective optimization method for microarrays based on improved particle swarm optimization algorithm [3-4]. Other experts believe that micro grid is a medium and low voltage grid, which combines various small distributed power sources and energy storage to provide power for local consumers. This is the main working mode of distributed power supply in the future [5-6]. Therefore, this paper will start with the particle swarm optimization algorithm to improve the efficiency of the system.

In this paper, we first study the particle swarm optimization algorithm, and describe its particle position. Secondly, the role of energy storage in Micro grid is described and analyzed in detail. Then the reactive power optimization and dispatching control strategy of micro grid based on distributed generation are studied. Finally, through the simulation of Micro grid operation considering energy consumption, relevant conclusions are drawn.

2. Micro grid Distributed Energy Storage Scheduling Optimization Based on Particle Swarm Optimization Algorithm

2.1 Particle Swarm Optimization Algorithm

Compared with genetic algorithm, the whole process of particle swarm optimization is more clear, convenient and intelligent. At present, the particle swarm optimization algorithm has been combined with other algorithms. To a large extent, it has strong computing power for the analysis of complex nonlinear mathematical models, and the method is simple, universal and robust. Particle swarm optimization (pso) is a calculation method based on the idea of population, similar to genetic algorithm. The starting point of calculation is a group of randomly generated solutions, and the optimal value is determined through iterative calculation. Due to the rapid development of pso method and the introduction of other advanced algorithms, it is

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widely used in fuzzy control, neural network model training and optimization, model classification optimization and other fields [7-8]. The formula for calculating particle velocity in each evolution process is as follows:

$$V_{ic}^{a+1} = q * V_{ic}^{a} + d_1 s_1 (u_{best\_ic}^{a} - m_{ic}^{a}) + d_2 s_2 (u_{best\_c}^{a} - m_{hc}^{a}) \quad (1)$$

The formula for calculating particle position is as follows:

$$m_{ic}^{a+1} = m_{ic}^{a} + V_{ic}^{a+1} \quad (2)$$

Where, $i = 1,2,3,\cdots,X$, X is the population size, $c = 1,2,3,\cdots,C$, a is the number of iterations, and q is the inertia weight.

The iteration of particles in the search space in the particle swarm optimization algorithm is shown in Figure 1:

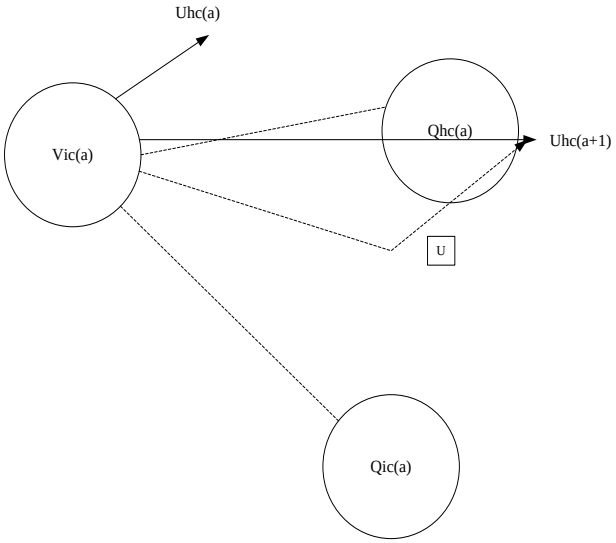

Figure 1. Particle Swarm Algorithm Particle Update

Particles update their optimization effects by using a portion of their previous generation velocity. By learning the particle's best value, particles can further optimize their velocity values and find a better solution in this area. Understanding these two learning factors is also important for particle swarm optimization. No matter which algorithm is lacking, it is impossible to quickly find the optimal solution of the objective function in the search area. When selecting the particle swarm size, it is necessary to ensure the diversity of the population, reduce the overall running time of the algorithm, improve the optimization efficiency, and optimize the algorithm performance according to the objective function of the specific problem. Particle velocity represents the direction and extent to which particles are close to the optimal particle position. The selection of the maximum velocity has a great influence on the convergence time, solubility and accuracy of PSO. If the maximum particle velocity is too large, the velocity value may be close to infinity, causing the particles to fly directly above the search range of the optimal solution, which makes the particle swarm optimization algorithm unable to obtain the optimal solution with many irreplaceable advantages. At present, it has been widely used in many projects, but there are some problems in practical application, such as slow local search speed, simple prior knowledge, etc. Some algorithms have good local search ability, and some heuristic optimization algorithms have high search efficiency [9-10].

2.2 Role of Energy Storage in Micro grid

In micro grids, the process of information interaction is slightly different from other micro grids: when micro grids communicate, they do not have very strict requirements on many performance indicators, which are relatively broad. In the process of information interaction, micro network represents a high degree of integration, especially the integration of technology and economy. Large power grid construction strength is strong, but micro grid is relatively weak, which requires micro grid to quickly handle problems and quickly restore the original capacity in case of failure. In order to enable the communication process to conduct bidirectional and real-time communication efficiently and accurately, the communication process based on microarray must be based on recognized communication technology standards. It is very important that micro networks operate on the basis of communication systems. Predict network reliability and events that may have negative impact accordingly [11-12].

Due to the randomness and intermittency of renewable energy generation, the normal operation of micro grid is facing new challenges. To solve this problem, we usually install batteries. They can absorb the surplus output in the peak period, compensate for the energy shortage in the peak load demand period, and compensate for the changes in net energy in the short term. Battery energy storage is a fast reaction device based on electric energy. Therefore, if the energy storage device is inserted into the island microscope, the imbalance of active power can be minimized.

There are two working modes of microarray, namely island mode and network mode. During normal operation, the Micro grid and Micro grid are connected to the grid. In case of operation failure or other problems during operation, the Micro grid will immediately disconnect from the Micro grid and switch to island operation. In the conversion process of the two modes, micro grid often shows some performance differences. Only by installing energy storage devices with certain energy in the corresponding power system, can the stability and smooth transition of the system be guaranteed. Energy storage system used for power compensation is an effective method to suppress wind power fluctuations. After the accumulator is installed in the wind power system, the total output power of wind power is the output power of the original fan plus the output power of the energy storage system. The function of the energy storage system is to stabilize the wind power load [13].

Since the micro current sources in the Micro grid are usually distributed, the load requirements of the Micro

grid are not constant and fluctuate with the changes of some external factors. If the maximum load can be reduced, the capacity increase of the equipment will be delayed to improve the utilization of the equipment and save some costs. Users on the load side can obtain economic benefits through the peak valley price difference. Large battery energy storage system has unique advantages in reducing peak valley and charging. The battery energy storage system is controlled by a constant charging and discharging scheme, which is convenient for peak and high charging and real-time control.

When the Micro grid is connected to a large network, it must meet the requirements of power factor, current harmonic distortion, voltage flicker, voltage asymmetry and other parameters. In addition, the Micro grid must ensure that the power supply voltage and frequency of the Micro grid are within an appropriate range. Energy storage system is an important link to ensure the power quality of micro grid. The battery and the super capacitor are combined to form a hybrid energy storage device. By using solar energy at night and wind energy under windless conditions, the energy storage system can play the role of conversion and damping. The stored energy mainly depends on the load demand .

2.3 Micro grid Reactive Power Optimization and Dispatching Control Strategy of Distributed Generation

Micro grid is a complex network composed of relay protection devices, various instruments, control units and many other electrical components. To ensure the normal power supply of the system, all power supply components must work together. Reactive power optimization is divided into two aspects: the optimal location of reactive power compensation points and the reasonable determination of reactive power compensation capacity. In order to solve these two problems, it is necessary to improve the power factor of power load. In order to improve the load power factor, synchronous motors can be used instead of asynchronous motors at the required connections. The synchronous generator provides reactive power to the system under overexcited conditions, which can not only reduce reactive power consumption, but also increase reactive power, thus greatly improving the total power factor of the load.

Reasonable adjustment of operation mode is an effective way to reduce power loss of power system. The basic objective of reactive power optimization in micro grid is that the reactive power compensation device adopts the principle of hierarchical distribution and local equalization to compensate the reactive power shortage. Minimize the reactive power flow of the power grid, reduce the transmission loss, and improve the system voltage level and equipment utilization. In the micro-grid dispatching, the restriction on the interactive power between the large power grid and the micro-grid is in line with the actual situation and the actual demand, which can be expressed by formula (3):

$$-G_{\mathrm{ex}\max} \le G_{ex}(s) \le G_{ex\max} \tag{3}$$

When the interactive power transmission is too large during a certain scheduling period, the frequency deviation of one of the systems will be too large. Unlike other distributed power sources, energy storage devices also have their own capacity constraints. Unreasonable reactive power flow in the power grid will have a negative impact on the voltage level of the system nodes, and will also lead to increased power loss of the Micro grid. Therefore, it is necessary to minimize the reactive power flow in the system, especially to avoid its long-distance flow in the Micro grid. Therefore, the compensation principle of the reactive power compensation device of the micro grid should be layered and locally balanced to reduce the reactive power flow and make up for the lack of reactive power. In order to reasonably select the location of reactive power compensation equipment and optimize the selection of reactive power compensation capacity, the following four aspects must be carried out: comprehensive compensation and local compensation exist at the same time, and the compensation effect of medium and low voltage micro grid is the best. Other compensation schemes shall be supplemented, the power supply department shall operate, and the user shall voluntarily merge the schemes, so as to reduce the loss preferentially and consider the voltage control at the same time.

At present, the compensation system is widely used in the power system of our country, because the management and maintenance of the substation reactive power compensation device is convenient, but the compensation form is firm, lacks flexibility, and there are some problems. In particular, the compensation can effectively improve the load power factor, but can not meet the requirements of the system to reduce network loss. The basic purpose of reactive power compensation is to ensure the stability of system power supply voltage, minimize energy loss, save costs, and improve the economy of system operation. Therefore, we will deeply study how to reduce the system loss from the aspects of system design and selection of appropriate operation mode.

The optimal configuration of the Micro grid mainly includes three aspects: first, to meet the power demand of various loads of Micro grid users. The second is to coordinate the production cooperation of micro energy such as wind turbines, photovoltaic cells and micro gas turbines. Finally, it is necessary to consider the power transaction between Micro grids and Micro grids. Based on this, the optimization strategy of micro grid configuration control mainly focuses on the current control operation in the micro grid and the electrical connection between the micro grid and the grid. In this paper, fuel cost, Micro grid maintenance cost and gas pollutant emission cost are taken as the objective functions of Micro grid optimization. Quantum particle swarm optimization (QPSO) algorithm is used to calculate the output power of micro power supply at any time to reduce fuel costs, maintenance costs and emissions of gas pollutants.

3. Micro grid Operation Simulation Considering Energy Consumption

3.1 Actual Operation of Micro Grid Power Users

Select the required parameters from the established model to reflect the running state of mechanical equipment. In the calculation process, these parameters replace the original model in order to obtain a feasible microarray optimization plan in the calculation example. The load determines the power and generation priority of decentralized generation in the Micro grid. First, the typical daily load distribution is specified. Different from the traditional large-scale grid planning, the daily Micro grid planning must consider the natural conditions. Therefore, wind speed, solar radiation intensity and temperature must also be considered. The parameters of each distributed power supply shall be specified to provide the data required for programming simulation. Finally, the peak and high load are adjusted by time-sharing power measurement.

3.2 Parameters of Distributed Power Supply Equipment

The parameters of decentralized production determine the economy and environment of Micro grid planning. Therefore, the parameters are classified according to ecological and economic characteristics. It is worth noting that in this paper, the interaction power is considered to be the power generated by a special battery, but there is no capacity limit for this battery. When calculating environmental costs, two factors must be considered. First of all, in the operation process of each distributed energy, what kind of harmful gases to the environment will be produced, and whether greenhouse gases such as carbon dioxide will be produced. Second, the cost of treating these gases needs quantitative analysis.

3.3 Simulation Scheme

The analysis of simulation results is mainly based on comparison. The simulation results are taken as the main line before and after the time-sharing power consumption measurement. The simulation content can be divided into three parts. The first part is the comparison of load curve before and after time-sharing energy consumption measurement. The second part is the current situation of decentralized power generation. The total economic and environmental costs of the optimal planning are pointed out and compared with the planning considering only economic costs. The third part is to generate decentralized generators in isolated Micro grids. The overall economic and environmental costs of the optimal planning are shown and compared with the planning conditions that only consider the economic costs.

4. Analysis of Experimental Results

4.1 Convergence Comparison of Three Algorithms

Under the conditions of meeting load demand, grid connected power constraint, battery charge limit, upper and lower limits of controllable micro source output and ramp rate, the optimal scheme for grid connected power and battery charging and discharging of micro grid is solved for standard PSO algorithm, CPSO algorithm and FCPSO algorithm. See Table 1 for details:

Table 1. Convergence Comparison of the Three Algorithms

	PSO	CPSO	FCPSO
Maintenance costs	10.7	10.4	9.95
Environmental costs	0.38	0.42	0.4
Total cost	11.08	10.82	10.35
Solve the time	39	9	7

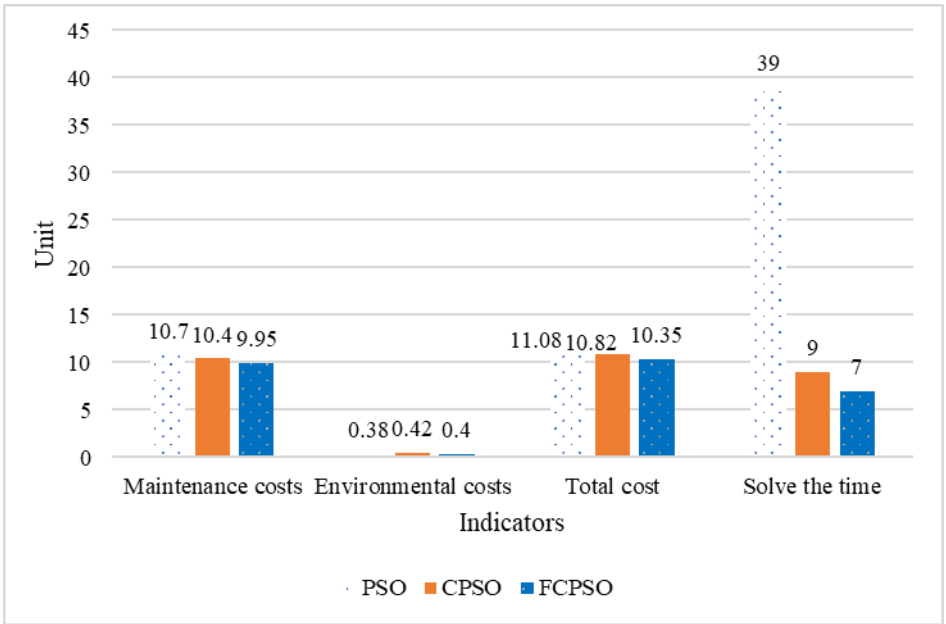

Figure 2. Convergence Comparison of the Three Algorithms

As shown in Figure 2, we can see that compared with the standard PSO algorithm, the CPSO algorithm gives priority to optimizing the operation and maintenance cost, making its total cost lower. Because FCPSO algorithm uses fuzzy membership degree to evaluate the two objective functions, it further optimizes the operation and maintenance cost under the condition of ensuring relatively low environmental cost, and finally minimizes its total cost.

4.2 Elastic Coefficient of Peak-Valley Flat Phase

In order to ensure the initiative and authenticity of the experimental data in this paper, this paper selects the energy consumption calculation in different periods, and takes it as one of the means to adjust the load. Among them, the most important data set is the energy consumption measurement and elasticity coefficient of each time period. The details are shown in Table 2:

Table 2. Elastic Coefficient and Energy Consumption Measurement in Peak, Ordinary and Valley Level Phase

	Peak time	Ordinary times	Valley time	Buy electricity	Sell electricity
Peak time	-0.08	0.015	0.011	0.82	0.64
Ordinary times	0.015	-0.08	0.09	0.5	0.38
Valley time	0.011	0.09	-0.08	0.16	0.12

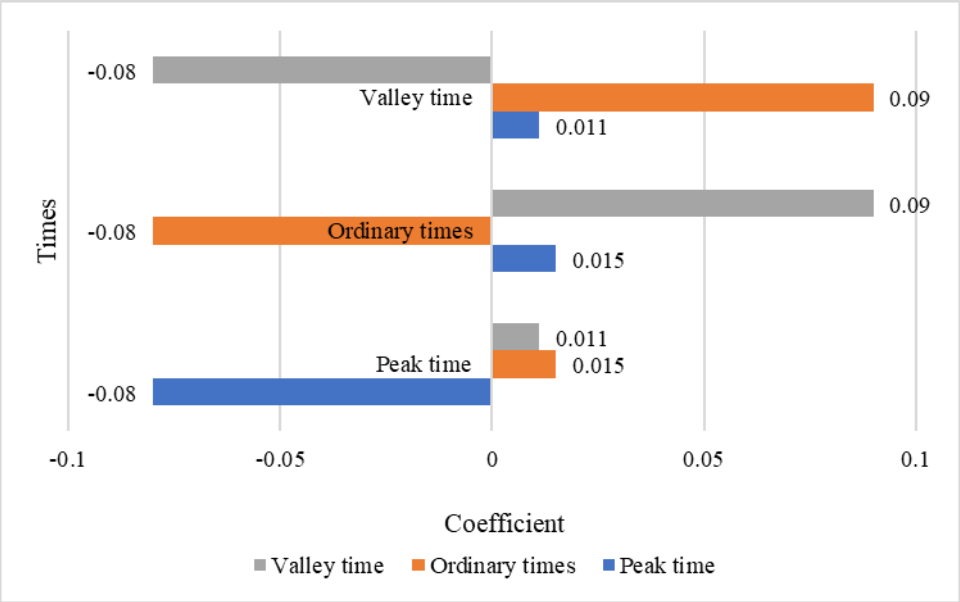

Figure 3. Elastic Coefficient in Peak, Ordinary and Valley Level Phase

As shown in Figure 3, we can find that the elasticity coefficient of the peak period is negative, while the elasticity coefficient of the normal period and the valley period is positive. In addition, we can know from the data diagram that the variation range of the elasticity coefficient ranges from-0.1 to 0.02, and the variation is relatively small, so the users of the microgrid system are relatively stable.

5. Conclusion

Through the analysis of the operation mechanism and system structure of the micro grid. This paper builds a distributed generation model based on particle swarm optimization algorithm to design and calculate the distributed generation model with energy storage scheduling as the goal, and consider the constraints of unit reserve capacity and voltage fluctuations. The research shows that this method has a high theoretical level. But in practical applications, we found its limitations: first, the local search ability is limited and can not make good use of existing energy. This paper studies the characteristics of Micro grid and its distributed generation, analyzes the mathematical model based on particle swarm optimization algorithm, which takes energy storage scheduling as the objective function, and simulates it on the MATLAB software platform.

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