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Optimization of Sea Wind Storage Joint Operation Based on Genetic Algorithm

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Abstract: To improve the dissipation capacity of wind and power, based on genetic algorithm, the multi-objective optimal scheduling model of the wind-storage-fire system with the maximum joint benefit and the minimum wind power fluctuation is proposed. The model takes into account wind power characteristics, pumped storage characteristics, and the output force characteristics of thermal power units, and studies the optimal scheduling of power systems including wind power, pumped storage, and thermal power. Results: simulation results show that the multi-objective optimization problem of wind-storage-fire combined operation, which takes into account the maximum joint benefit and the minimum wind power fluctuation, is more consistent with the actual situation of China's power system at this stage. Conclusion: the model can effectively improve the utilization capacity of wind power.
Keywords: Sea wind storage, energy storage scheduling, dependent-chance objective programming, genetic algorithm.

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1. INTRODUCTION

The steady development of society is inseparable from the supply of energy. Therefore, at present, people have put the search for alternative energy sources of fossil fuels into an important position of energy development strategy. Among the various forms of energy, people have researched and explored new energy sources such as wind energy, solar energy, tidal energy, small hydropower, biomass energy, and geothermal energy [1]. Among various new energy sources, wind energy and solar energy have attracted much attention due to their inexhaustible, inexhaustible, pollution-free and widely distributed advantages. In recent years, wind energy and solar energy have been developing at a rapid speed and become the key development field of renewable energy [2].

Wind energy is an ancient energy that has been used by human since ancient times, and wind power generation is undoubtedly the most important form of development and utilization of wind energy. In the strategy of sustainable development, wind energy has become an indispensable part because of its huge scale and unlimited potential. Since 2000, research on wind power generation technology has made continuous breakthroughs, which has led to rapid development of wind power generation and rapid growth of global installed wind power capacity [3]. In 2001, when wind power technology was in its infancy, the world's installed capacity of wind turbines was only 24GW; ten years later, after a leap in development, the world's installed wind power capacity has rocketed to 204GW. During this decade, global installed wind power capacity has maintained an annual growth rate of about 30%. Developed countries, such as Denmark, Germany and the United States, have explored wind power generation earlier. At present, wind power generation has become an important part of total power generation. The research and exploration of wind power generation in China started late, but its development momentum is rapid. At present, China's installed wind power capacity has surpassed many European and American countries and is in the leading position in the world.

2. LITERATURE REVIEW

The oil crisis that occurred in the 1980s prompted scholars from all over the world to begin research the comprehensive utilization of wind energy and solar energy [4]. As early as 1981, Danish scholars have put forward the idea of combining solar energy and wind energy; in the same year, Americans investigated the weather problem of hybrid utilization of wind energy and luminous energy, which laid a foundation for later studies; academics in the former Soviet union assessed the potential for exploitation of wind energy and solar energy. Since then, the utilization and development of new energy have been flourishing all over the world, and more and more universities and research institutions have entered this field [5]. Coforado State University and the National Renewable Energy Laboratory have jointly developed the Hybrid2 application software. The characteristic of the software is that it can change the structure, load, external meteorological conditions and other parameters of the hybrid power generation system, accurately simulate the operation of the hybrid power generation system and obtain the annual simulation operation results, thus providing reference for the actual research [6].

In recent years, people have studied and explored the energy storages of various principles. At present, there are mainly two types of energy storage: one is energy density energy storage that provides a lot of energy at a very small volume; the other is the power density energy storage that can provide a large amount of energy in a short time due to its fast response speed. Energy storage system in the power system is mainly responsible for improving the power quality, providing emergency temporary power supply, improving the performance of micropower, power system peak regulation and frequency modulation and other tasks.

Because energy storage capacity has an impact on power, energy storage needs to be controlled to make better use of limited capacity. In the energy storage control strategy of combined power generation systems for wind energy and solar energy, foreign research has achieved some results, including: Berlin 17MW energy storage system successfully applied energy storage battery; the 10MW/40MWh energy storage system has been successfully applied to California State Chino substation in the United States. These successful applications show that the energy storage system has the characteristics of active regulation ability and fast power throughput. On this basis, Allan Russell et al. of America North Wind Company further studied the system control mode and system scale of wind-solar complementary power generation.

3. METHODOLOGY

In the wind-storage-fire joint optimization scheduling process, it is necessary to preferentially configure the combined output of the wind power and the pumped storage power station, and then configure with the thermal power unit to meet the load demand, as shown in figure 1 below. Due to the uncertainty of wind power, the scheduling of pumped storage power station is mainly to coordinate the fluctuation of wind power. In the case of large wind power generation, it stores wind power that can't be accepted by the power grid in the form of pumping water; in the peak load period, it uses the potential energy of the reservoir stored by the remaining wind power before to generate electricity, so as to relieve the peak pressure in the peak load period. After preferentially configuring the output of wind power and pumped storage, the thermal power unit will be dispatched to arrange the start and stop and output of the unit reasonably.

Due to the randomness of wind speed, the output of wind power is uncertain. Assuming that the wind speed follows Welbull distribution, its probability density function is as follows:

$$f_V(v) = \frac{k}{c}\left(\frac{v}{c}\right)^{k-1} \exp\left[-\left(\frac{v}{c}\right)^{k}\right] \tag{1}$$

Where, c and k represent the shape parameter and scale parameter of Weibull distribution respectively, and v is the value of wind speed.

When the wind speed value is greater than the wind turbine's cut-in wind speed v_{ci}, the wind turbine starts to operate; when the wind speed value maintains the rated wind speed v_r, the output of the wind turbine remains unchanged; when the wind speed value is greater than or equal to the cut-out wind speed v_{co}, the wind turbine stops running. The wind power output active power P obeying the wind speed Weibull distribution is as follows:

$$P_{wind} = \begin{cases} 0 & , \quad 0 \le v \le v_{ci}, v >_{co} \\ a \cdot v + b & , \quad v_{ci} \le v < v_r \\ p_r & , \quad v_r \le v < v_{co} \end{cases} \tag{2}$$

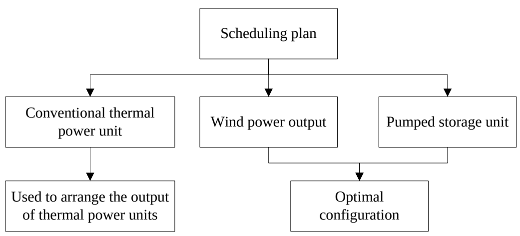

Fig. 1

Power system dispatching model diagram

4. RESULTS AND DISCUSSION

Genetic algorithm is a stochastic global search and optimization method that simulates the evolution mechanism of organisms in nature. It draws on Darwin's theory of evolution and Mendel's genetic theory. Its essence is an efficient, parallel and global search method, which can automatically acquire and accumulate knowledge about search space in the search process, and adaptively control the search process to obtain the optimal solution. It treats the possible solutions in the problem domain as an individual or chromosome of the group, and encodes each individual into a symbolic string form, simulate the biologic evolution process of Darwinian genetic selection and natural selection, and repeat the genetics-based operations on the population (genetic, crossover, and mutation). Each individual is evaluated according to the predetermined target fitness function, and a better group is continuously obtained according to the evolutionary rules of survival of the fittest. At the same time, the global parallel search method is used to search and optimize the optimal individuals in the group to obtain the optimal solution to meet the requirements. Terms used in genetic algorithms include: coding, decoding, genes, individual, population, chromosome, fitness function, selection, crossover, variation. In genetic algorithms, chromosomes are usually represented by one-dimensional string structure data. The numeric string, that is, every binary code in the chromosome, is called the gene. Genetic algorithms process chromosomes or individuals. Each individual is a solution to the problem. A certain number of individuals constitute the optimal solution set of the problem, also known as the group. The number of individuals in a group is called the size of the group. And the degree of adaptation of each individual to the environment is called fitness.

4.1 Model solving idea

Firstly, the wind speed value at 24 hours a day is obtained by using Weibull wind speed with uncertain parameters, so as to obtain the actual output value of wind farm at each period. After determining the output of the wind farm for one day, the on-grid energy of wind power can be determined by judging the output of wind power. When the actual output of the wind farm is less than 300MW, the wind power is fully online; when the actual output of the wind farm is greater than 300MW, the wind power can only be connected to the Internet for 300MW, and the excess wind power is used for pumping water; when the maximum pumping capacity can’t absorb all the wind power that can’t be connected to the Internet, the remaining wind power will be abandoned, so as to obtain the on-grid energy of wind power and the abandoned wind power for each period. Since pumping and generating conditions of pumped storage power station can’t be carried out at the same time, constraint conditions are introduced to deal with the relationship between them, that is, at least one of them is zero at the same time. Under the premise of ensuring that pumping water doesn’t generate electricity and generating electricity doesn’t pump water, the wind power that can’t be accepted by the power grid is used for pumping. That is, the abandoned wind power is stored by pumping water to generate electricity during the peak load period. After the output of the sea wind storage joint operation system in each period is optimized and configured by genetic algorithm, the output of 4 thermal power units in each period is optimized according to the known load value and the climbing slope and start-stop constraints of thermal power units.

4.2 Algorithm solving steps

Genetic algorithm is adopted to solve the joint operation system of wind-storage-fire. The specific algorithm steps are as follows: step 1: randomly generate a set of 24-time wind speed values according to Weibull distribution, and calculate the output of wind power at each time. Step 2: combine the wind power output power, input the parameters of the thermal power unit and the hydropower unit and the load value, solve the optimization model with the joint benefit and the abandoned wind power quantity as the single target respectively, and obtain the maximum and minimum values of each objective function. Step 3: on the basis of the second step, normalize each single target value, and then obtain the fitness function according to the weight relationship of the two objective functions, calculate the fitness value of each generation of the population, and save the relevant variable value corresponding to the maximum fitness value. Step 4: realize population evolution according to the selection, crossover, mutation and other steps of genetic algorithm. According to the optimized value of wind power grid access, reasonably configure the optimal value of pumping and power generation in pumped storage power stations. After preferentially configuring the combined output of the sea wind storage, optimize the optimized values of each unit under the constraint of the characteristics of the thermal power unit. Step 5: repeat steps (1)-(4) according to the set number of Monta Carlo simulations and perform statistical analysis on the results.

4.3 Analysis of result

It not only considers the optimization of wind-storage joint dispatch, but also considers the characteristics of thermal power units. The output of thermal power unit is analyzed, and the combined output of wind-storage-fire is considered comprehensively to meet the load requirements of the system. In the dispatching process, in order to maximize the absorption of wind energy, the power grid should make the best use of wind power on-grid energy to power the load. At the moment of large wind power generation, the output of the thermal power unit is reduced, and the pumped storage power station cooperates with the output of wind power to carry out pumping power generation.

Figure 2 shows the comparison between the actual output of the wind farm and the actual on-grid energy of wind power. It can be concluded from the figure that the maximum amount of wind power that can be connected to the grid is 300MW. When the actual output value of the wind farm is greater than 300MW, the power grid has to discard excess wind power, resulting in waste of wind power resources. However, in this study, the abandoned wind power is used to pump water, which reduces wind curtailment. Figure 3 shows the joint benefit curve after the optimization of the wind-storage-fire system.

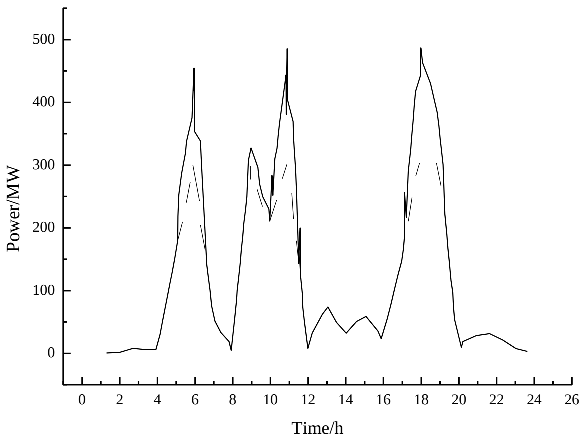

Fig. 2 Comparison of wind farm output and actual power consumption

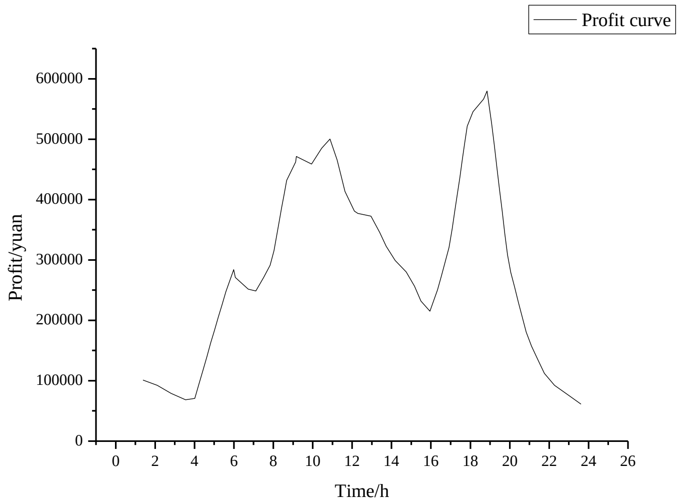

Fig. 3 Profit curve of joint operation system

In order to better compare the results of multi-objective optimization and single-objective optimization, under the same wind power output, the corresponding single-objective optimization results and multi-objective optimization results are the sum of the scheduling cycle optimization values. The above analysis results are all optimized values under the condition that the multi-objective weight is 0.5. In order to study the influence of different weights on the output of each unit, the optimized values under different weights are compared and analyzed, and the corresponding output statistical results are obtained through 100 Montocarlo stochastic simulations. It can be concluded from the simulation results that as the weight of the joint benefit gas increases, the sum of the joint benefits at each moment will increase, and the total output of each conventional thermal power unit, the total power of hydropower network and the total power of water pump show an irregular change.

5. CONCLUSION

The good peak regulation performance of pumped storage power station is utilized and jointly configured with wind farm to establish a multi-objective optimization model of combined operation of sea wind storage station with maximum economic benefit and minimum fluctuation of wind power. The optimization model is solved by genetic algorithm, and the optimal values of wind power output, actual online power of wind power, pumping power of water pump, generating power of hydropower unit, and output of thermal power unit in the dispatching period are obtained. The model comprehensively considers the operating characteristics of wind power, hydropower and thermal power, analyzes the influence of the optimization model on the output of thermal power units, and obtains the corresponding probability and statistics results through Monte Carlo random simulation. Finally, an example is given to verify the built model, and the results show the correctness of optimization model.

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