Design of clean energy dispatching system for wind and solar storage

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Abstract. In order to optimize the capacity dispatch of energy storage system in grid-connected wind-solar hybrid power generation system, a method for optimizing the capacity of hybrid energy storage system composed of supercapacitors and batteries in grid-connected wind-solar hybrid power generation system is proposed by utilizing the generation data of wind power and photovoltaic and the dispatch data of power grid. Based on the method of Particle Swarm Optimizer (PSO), it was simulated that wind-solar hybrid power joined into the dispatch according to the rules of dispatch system. The best power dispatch was achieved by multi-objective particle swarm optimization (MPSO). The results show that the accuracy of capacity optimization of energy storage system can be improved by considering both the total continuous power loss and the instantaneous power loss. The hybrid energy storage system composed of supercapacitors and batteries can improve the overall security and economy of the power grid.

1. Introduction

Green energy, energy saving and emission reduction, circular economy and sustainable development have become the focus of international attention. The adjustment of national energy policy and the strengthening of environmental supervision put forward higher requirements for power market and network. Facing the increasingly severe pressure of resources, environment and policies, the power grid must adjust its energy structure on a large scale, to improve its operational capacity, to innovate its energy management system. Smart grid will become the inevitable trend of the development of modern power industry.

In order to ensure the real-time trading of the market and the interconnection and interaction among the members of the power grid, improve the efficiency and reliability of power utilization, satisfy environmental protection constraints, ensure power quality, and adapt to the development of power market. Now the smart grid mostly adopts integrated automatic control system, through widely used distributed sensors, intelligent and broadband communication network to complete all kinds of functions. Smart grid should have high-quality characteristics and performance, such as self-healing, interactive, compatible, strong, economic, cleaner, integration.

Self-healing refers to the smart grid without or only a small amount of human intervention when a grid accident occurs. It can detect, analyze and respond, modify, or formulate the start-up plan according to the actual situation, maintain its stable operation, and minimize the impact on the normal system.
Compatibility refers to the open compatibility between power generation networks. Smart grid should be able to support the centralized access of large power sources, distributed generation mode and large-scale application of renewable energy, such as wind power and solar power, promote standardization and achieve plug-and-play. Interaction refers to information exchange and demand interaction between grid enterprises and grid users in smart grid network. It includes interaction with changing business structures and new energy sources flexibly accessed in distribution networks. Two-way interactive information communication can improve the real and effective information transmission, and make the function of DSM more perfect.

2. Current situation and trend of wind power generation

Wind energy is typical clean energy, which has the characteristics of large reserves and pollution-free. Its total installed capacity has increased from tens of kilowatts in the early 1980s to 282 million kilowatts in 2012. In just 30 years, more than 30 countries around the world have built large-scale wind farms. Its development speed is so fast that it is incomparable with any other energy. Wind power generation is becoming one of the key parts of renewable energy development.

According to the survey data, it is predicted that from 2019 to 2023, the total installed wind power in the world will be nearly 317 GW and CAGR will be 2.7%. Among them, 145 GW, 63 GW, 63 GW and 7 GW will be installed in Asia-Pacific, Europe, North America, Latin America and Africa respectively. As shown in Figure 1.

2019-2023 China has always been the largest wind power market in the world. GWEC data show that in 2018, 41% of the world is in China for new wind power capacity, and till 2023, 36% of the world will be in China new wind power capacity, China is always the largest wind power market around the world.

![Figure 1. Global Wind Power Year New Installation Capacity Prediction (GW)](image)

3. Current situation and trend of photovoltaic power generation

As the environmental and energy issues continue to stand out, countries all over the world have made tremendous progress in photovoltaic technology research. China has a vast territory, in which more than 60% of the total annual solar radiation is more than 4000MJ per square meter, and the average annual sunshine duration is more than 2100 hours. Particularly in the northwest of China, photovoltaic power generation has great potential for development. Solar power generation in China began in 1958. Until the end of the 1980s, the photovoltaic technology industry was basically formed in China and entered the stage of sustainable development. By the end of 2014, the total installed capacity of photovoltaic in China has exceeded 28GW [Data Source: Public Data Sorting]. Figure 2 shows the total installed capacity of global photovoltaic power generation from 2008 to 2016.

![Figure 2. Global Photovoltaic Power Year New Installation Capacity Prediction (GW)](image)
4. Energy storage and super capacitance
As a mature energy storage device, the battery has the advantages of high energy density, but it also has the disadvantages of low power density, short cycle life and low charging and discharging efficiency. As a new type of energy storage equipment, supercapacitor has the advantages of high power density, long life and fast charge-discharge rate. However, compared with storage battery, the energy density of supercapacitor is low, generally only 20% of that of storage battery. Therefore, the combination of supercapacitors and batteries can combine their advantages. Through appropriate control strategies, supercapacitors can prolong the life of batteries. The hybrid energy storage device of supercapacitor and battery can better meet the power and energy requirements of power grid in wind-solar hybrid power generation system.

5. Brief introduction of grid-connected wind-solar hybrid power generation system
The grid-connected hybrid wind-solar storage power generation system is integrated into the grid as a distributed power source, which includes wind farm, photovoltaic power station and energy storage power station. Due to the different types of wind turbines used in wind farms, the grid-connected mode of wind turbines is also different, including direct grid-connected and grid-connected through power electronic inverters. The output of photovoltaic array and energy storage system is direct current, which can be connected to the grid only after the inverters are converted. Therefore, the basic structure of the wind-solar storage hybrid power generation system is shown in Fig. 3, regardless of the type of fan.
6. Particle swarm optimization

Particle Swarm Optimizer (PSO) uses efficient clustering to search non-inferior solutions in parallel, and multiple non-inferior solutions can be generated in each iteration process. At the same time, particle swarm optimization (PSO) has memory function. Particles search by tracking their own historical optimal solution and the global optimal solution of the population, which makes the PSO have good convergence and global search ability in the process of optimization. Therefore, particle swarm optimization can be used to solve the multi-objective optimization problem of energy storage system.

In order to solve the problem that the particles exceed the feasible region in the multi-objective particle swarm optimization (MPSO), the particle exceeding the feasible region is modified by adjusting the inertia weight and random coefficient. Finally, the improved multi-objective particle swarm optimization algorithm is used to solve the model.

**Formula 1.** The renewal equation of velocity and position is expressed as:

\[ v_{id}^{k+1} = \omega v_{id}^{k} + C_1 \xi (p_{id}^{k} - x_{id}^{k}) + C_2 \eta (g_{id}^{k} - x_{id}^{k}) \]

\[ x_{id}^{k+1} = x_{id}^{k} + \gamma v_{id}^{k+1} \]

The historical optimum value \( p_i = (p_{i1}, p_{i2}, ..., p_{iQ}) \), \( i = 1, 2, 3, ..., n \), which each particle searches for itself. The optimal value of \( g_i = (g_{i1}, g_{i2}, ..., g_{iQ}) \) is found for all particles. Note that there is only one \( g_i \) here.

\( \omega \): The coefficient that keeps the original velocity, it called inertia weight.

\( C_1 \) It is the weight coefficient of the particle tracking its historical optimum value. It represents the understanding of the particle itself, so it is called "cognition".

\( C_2 \) It is the weight coefficient of the optimal value of the particle tracking group. It represents the particle knowledge of the whole group, so it is called "social knowledge", often called "society".

\( \xi \eta \) It is a random number with uniform distribution in \([0, 1]\) interval.

\( \gamma \) When updating the position, we add a coefficient in front of the velocity, which we call the constraint factor.
The process of capacity optimization based on particle swarm optimization is as follows:

1. **Initialize particle swarm optimization.** Within the range of energy storage capacity, each particle is randomly selected as well as the initialization of individual optimum and global optimum.

2. **Formula 2.** The number of supercapacitors and batteries in each particle is changed:

   \[
   \text{Formula 2, } \bigcap_{i,d}^t + 1 = \bigcap_{i,d}^t + \sqrt{t + 1}
   \]

3. Each particle calculates the power generated by the energy storage device and the corresponding energy storage output, whether it meets the power demand of the grid and the power demand of the grid, and if it meets, calculates the objective function.

   \[\text{F (nt + 1, nt + 1)}, \text{and compared with the individual and global optimum of the particle, replace the optimal value, turn (4); if not satisfied, turn (2).}\]

4. **Judging the objective function**

   \[|\text{MinF (nt + 1, nt + 1)} - \text{MinF (nt, nt)}| = \epsilon\]

   is satisfied or not, the calculation ends when satisfied, and turns if not satisfied (2).

Because of the low energy density and the low power density of the supercapacitors, the cost of the supercapacitors for energy storage alone is much higher than that of the hybrid energy storage system composed of them when they meet the maximum power shortage and the maximum instantaneous power loss simultaneously. In hybrid energy storage system, supercapacitors play the role of instantaneous high-power replenishment, while batteries play the role of continuous power generation. Therefore, the hybrid energy storage system composed of supercapacitors and batteries can improve economic benefits.

7. **Conclusion**

When wind-solar hybrid power generation system is connected to the grid, it is required to meet the needs of grid dispatching, so the energy storage system should smooth the fluctuation of wind-solar energy output as much as possible. This paper studies the capacity optimization of hybrid energy storage system in hybrid power generation system, and draws the following conclusions:
By optimizing the system algorithm and considering the capacity of energy storage and power output of energy storage system, the accuracy of optimal allocation of energy storage system capacity can be improved, and the security of power grid dispatching and operation can be increased.

Using the complementary advantages of battery and supercapacitor, the hybrid system of battery and supercapacitor can improve the economic benefit of the system.

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