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The optimal dispatch with combination of wind power and photovoltaic power systems

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Abstract

Developing new energy such as wind power and photovoltaic power is the main way to solve our energy problems. However, the volatility of wind power and photovoltaic power will impact the grid. The changes of wind power and photovoltaic power have complementary characteristics. It can effectively reduce the impact to the grid by combining them. This paper studies the optimal dispatch modeling problem with combination of wind power and photovoltaic power systems, establishes the optimal scheduling model of a power system including wind power and photovoltaic power considering the environmental benefits and spare capacity changing, and conducts a simulation calculation to verify the validity of the method.

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Keywords: wind power; photovoltaic power; optimal dispatch; modeling; optimization algorithm

1. Introduction

With the rapid development of China's economy, energy problem has become an important bottleneck restricting China's economic and social development. Development of wind power, photovoltaic and other new energy is the main way to solve the energy problem. However, when connected to the power system, wind power, photovoltaic and other new energy can cause impact on power system, thus affect the safety and stable operation of power system[1-4]. The wind power and photovoltaic complementary grid can effectively reduce the volatility of the new energy. As a large number of wind power and photovoltaic being connected to the grid, it is significant to research on how to conduct optimal operation of wind power, photovoltaic and thermal power unit power reasonably to reduce pollution emissions.

A lot of work has been done on the value of wind power [5-6].The literature [2-3] studies the influence of the wind power accessed to the power system and literature [7] studies an economic dispatch model incorporating wind power. But none of them consider the complementary characteristic of the new energy.

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This paper studies the combination of wind power and photovoltaic power and establishes the optimal scheduling model.

2. The Modeling of Optimal Dispatch of Power System Containing Wind Power and Photovoltaic

In the past power system dispatch, thermal units' pollution costs have not been considered as a apart of generating cost, which is bad for the dispatch of new energy, with high generation costs of wind power and photovoltaic.

The environmental punishing cost is expressed as follows：

$$C_{EPi}=\eta_{EPi}\times S_{Ni} \tag{1}$$

where C_{EPi} is environmental punishing cost; η_{EPi} is environmental punishing cost coefficient, S_{Ni} is pollution emission of thermal unit *i*.

S_{Ni} and generation power P_{Gi} have a quadratic function relationship:

$$S_{Ni}=\alpha_i+\beta_i P_{Gi}+\gamma_i P_{Gi}^2 \tag{2}$$

where α_i , β_i , γ_i are the emission characteristic coefficients of thermal unit *i*.

The cost function of thermal power

The thermal unit cost C_{Gi} is the sum of generation cost C_{BGi} and environmental punishing cost C_{EPi} :

$$C_{Gi}=C_{BGi}+C_{EPi}=a_i+b_iP_{Gi}+c_iP_{Gi}^2+C_{EPi} \tag{3}$$

where a_i, b_i, c_i are the cost coefficients of thermal unit *i*.

The calculation of the spare capacity punishing cost

The connection of wind power and photovoltaic can affect the safety and stable operation of power system and cause the change of spare capacity, which generates spare capacity punishing cost:

$$C_{RWj}=\rho_{RWj}\left[\min(0,P_{Wj}-P_{Wja})\right] \tag{4}$$

$$C_{RPm}=\rho_{RPm}\left[\min(0,P_{Pm}-P_{Pma})\right] \tag{5}$$

where ρ_{RWj} and ρ_{RPm} is the spare capacity punishing coefficient, P_{Wja} and P_{Pma} is the planed generation and P_{Wj} and P_{Pm} is the actual generation of wind turbine *j* and photovoltaic turbine *m*, respectively.

The Cost Function of Wind Power and Photovoltaic

The generation cost of wind power and photovoltaic are as follows：

$$C_{Wj}=C_{BWj}+C_{RWj}=\eta_{Wj}P_{Wj}+C_{RWj} \tag{6}$$

$$C_{Pm}=C_{BPm}+C_{RPm}=\eta_{Pm}P_{Pm}+C_{RPm} \tag{7}$$

where η_{Wj} and η_{Pm} are the cost efficients, respectively.

The total cost of system is:

$$\sum_{t=1}^{T}\sum_{i=1}^{N}U_{it}C_{Gi}+\sum_{t=1}^{T}\sum_{j=1}^{M}K_{jt}C_{wj}+\sum_{t=1}^{T}\sum_{m=1}^{L}J_{Pt}C_{Pm}$$

The objective function

$$\min\ \left(\sum_{t=1}^{T}\sum_{i=1}^{N}U_{it}C_{Gi}+\sum_{t=1}^{T}\sum_{j=1}^{M}K_{jt}C_{wj}+\sum_{t=1}^{T}\sum_{m=1}^{L}J_{mt}C_{Pm}\right) \tag{8}$$

where U_{it} , K_{jt} and J_{mt} are the variables of running or stopping and N,M,L are the number of thermal power units, wind turbines and photovoltaic turbines respectively.

The constraints of the system

The power balance of the system：