Research on the full-load joint regulation strategy of coal-fired generating units and electrolyzed hydrogen production

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Abstract. As the installed capacity of wind power and other renewable energy sources continues to increase, the intermittent and volatility of their output has put tremendous pressure on the safe and stable operation of the power grid. The demand for peak shaving is becoming increasingly urgent. In this paper, the electrolysis hydrogen production system participates in the deep peak shaving of coal-fired generators. Through the participation of load regulation of the electrolysis hydrogen production system, according to the requirements of the power grid on the different loads of the unit, the load of the electrolysis hydrogen production system is adjusted to adjust the load of the unit. In order to realize full-load regulation of coal-fired thermal power plants and improve the power generation efficiency of units.

1. Introduction
In recent years, clean energy such as wind energy has developed rapidly, and it accounts for an increasing proportion of the power grid [1], which also puts forward higher requirements for peak shaving of thermal power units. At the same time, the impact of wind power and other new energy generation on the safe and stable operation of the power grid has become increasingly significant. New energy power generation such as wind power has the characteristics of intermittent, randomness and anti-peak shaving. The development of large-scale new energy has led to increasing peak shaving pressure on the power grid [2], and even abandoning wind and power generation problems [3]. In response to the current series of problems, research institutions and government departments have also carried out a lot of research, such as the configuration of energy storage systems on the power supply side and the grid side [4], the deep peak shaving transformation of thermal power plants [5] and auxiliary Peak shaving market construction [6] and so on.

In addition, with the continuous development of hydrogen energy, the current research on hydrogen energy to alleviate wind curtailment has gradually deepened, but the current research mainly focuses on hydrogen production from wind power. Literature [7] analyzes the control strategies for optimal operation of wind-hydrogen coupled power generation systems through actual cases; Literature [8] analyzes wind power, hydrogen production systems, fuel cells and super capacitors; Literature [9] analyzes wind power generation systems hydrogen capacity configuration is analyzed, but its configuration method is mainly to analyze the abandonment of wind, and there is less economic analysis; the literature [10] analyzes the economics of hydrogen production by wind power. Existing researches on the use of hydrogen energy to reduce wind curtailment and power curtailment mainly focus on the control strategy, capacity configuration and economic analysis of wind-hydrogen coupled power generation. At present, there are few studies on the participation of the electrolysis water hydrogen production system in the deep peak shaving of the thermal power unit side to alleviate the wind curtailment.
This paper studies the capacity configuration optimization strategy of the electrolysis water hydrogen production system participating in the auxiliary peak shaving service of the thermal power unit. By configuring the electrolysis water hydrogen production system on the thermal power side to adjust the load distribution, it will help the thermal power unit to quickly make load adjustment changes. Realize deep peak shaving, improve the stability and economy of coal-fired units; at the same time, it can effectively alleviate the current wind abandonment problem.

2. Combined operation control strategy of coal-fired unit and electrolytic water hydrogen production system

2.1. Model establishment and operation control strategy

As shown in Figure 1, the load regulation control system provides an adaptive method for realizing load regulation within the full load range of coal-fired units. Through the change of external load demand for units, the load regulation control system regulates the load power relationship among coal-fired units, electrolytic hydrogen production system and hydrogen fuel cell power generation device, realize the rapid response of the unit to the change of external load demand within the full load range, and improve the peak shaving capacity and load change response rate of the unit; in the peak period of power consumption, hydrogen fuel cell device can be used for power generation to improve the power supply capacity of the unit.

In addition, the hydrogen produced by the electrolytic water hydrogen production unit is stored through the hydrogen storage unit, and can also be supplied to the hydrogen cooling system of the generator or sold through pipeline transportation, so as to increase the revenue of the unit; the generated oxygen can also supply oxygen for boiler combustion or be sold through pipeline transportation, so as to increase the unit income, realize the functional diversification of coal-fired units, and integrate power generation, hydrogen production and oxygen production, so as to increase the survival and development space of coal-fired units in the future.

Specifically, the load regulation system of the coal-fired generator unit obtains the external peak load regulation and load change command, determines the load reduction / increase of the generator unit by judging the difference between the unit load and the command load, and realizes the variable load operation of the generator unit by sending the load regulation command to the generator unit and
the electrolytic water hydrogen production system. The joint control system aims to provide the efficiency of coal-fired generating units and minimize the system energy consumption.

According to the operation status of coal-fired generating units under different loads and the variation law of coal consumption for power generation, the full load peak shaving regulation process of the unit is controlled in sections. The logic of the section regulation control process is shown in Figure 2. The full load of coal-fired generating units is divided into four stages: low load stable operation stage of coal-fired generating units (DC stage), coordinated operation stage of variable load operation and electrolytic water hydrogen production of coal-fired generating units (CB stage), variable load operation stage of coal-fired generating units (BA stage) and rated load stable operation stage of coal-fired generating units (AE stage).

In AB stage, the unit increases its own regulating load, in BC stage, the thermal power unit and the hydrogen production system participate in the load regulation together. In CD stage, the unit load remains unchanged, and the hydrogen production system participates in the load regulation. In AE stage, if the rated load of the unit exceeds, the hydrogen prepared by partial hydrolytic water consumed by the fuel cell supplies power to the power grid.

2.2 specific implementation plan
Specifically, take the regional microgrid total installed capacity of 900MW as an example, including thermal power 600 MW and wind power 300 MW. Take the 24 h operation of the microgrid in this area as an example, and take 1h as the time interval to analyze the operation of the system according to the above-mentioned operation control strategy. The operating conditions of each load are shown in Figure 3:
According to the load curve of wind energy resources, the distribution of wind energy resources is low during the day and high at night. When the load is in a low state at night, the load reduction pressure of coal-fired units will increase. At this time, the electrolyzed water hydrogen production device combined with coal-fired units will be put into operation for consumption, reducing the load regulation of coal-fired units. In the case of wind curtailment, when the load regulation pressure of the coal-fired unit is low, the hydrogen production device will not be put into operation. Compared with the previous non-electrolyzed water hydrogen production system, the power supply of the system to the grid can be maintained to meet the external demand, but it runs under a higher load condition than before, reducing the impact of deep peak shaving on the unit. The hydrogen produced at the same time can make up for the coal consumption cost of coal-fired units due to the increase in load, and can also be used for hydrogen cooling of unit engine devices, etc, providing better economic benefits for the system.

As shown in Figure 3, due to the instability of wind power generation, which affects the stable operation of the power grid, in order to adapt to the gap instability of wind power generation, the load of coal-fired generator sets is required to participate in the adjustment, which makes the load adjustment fluctuations of the unit larger, which will affect the unit load. Cause many adverse effects. In the case of the electrolysis-free hydrogen production system, the coal-fired power generation unit has to reduce the load of the unit during the peak wind power generation; and when the electrolysis water hydrogen production system is involved, the load of the thermal power generation unit is increased due to the participation of the electrolysis water hydrogen production system in load regulation. High-efficiency operation can effectively improve the efficiency of the unit, reduce the coal consumption of the unit for power generation, and improve the operating economy of the unit. Participating in the load regulation of coal-fired units through the combined electrolysis of water hydrogen production system can not only increase the operating load of coal-fired units, enable the units to operate with higher efficiency, reduce the coal consumption of the units for power generation, improving the operating economy of the unit can also effectively realize the effective use of wind power.

3. Conclusion
In view of the current difficulties in the consumption of new energy, the pressure of coal-fired generating units has increased in deep peak shaving, and the efficiency and economy of the unit itself
will be affected to a certain extent during the peak shaving process. Participate in the daily load regulation of coal-fired units with the electrolyzed water hydrogen production system, and propose a model based on the electrolyzed hydrogen production system participating in the deep peak shaving of thermal power units and the operation control strategy of the electrolyzed hydrogen production system, taking into account the comprehensive load of the power grid affected by wind power fluctuations based on the principle of giving priority to the development of new energy power generation, and considering the high-efficiency and economic operation of the combined thermal power and electrolyzed hydrogen production system, the optimal load configuration operation plan is obtained. The proposed combined operation control strategy of the electrolyzed water hydrogen system and coal-fired generating units can not only effectively realize the full-load peak shaving of coal-fired generating units, but also improve the economic efficiency of unit operation. At the same time, it also alleviates the impact of new energy access on the security and stability of the grid.

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