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Study on complementary power generation mode of solar thermal and coal-fired power stations under the background of new energy

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Abstract: Under the background of new energy, the complementarity of solar energy and coal-fired power plants can increase power output without increasing the thermal load of boilers and systems, which can significantly improve the operation economy of coal-fired power plants. Based on the established complementary power generation analysis model of solar thermal power station and coal-fired power station, the operation modes of light field and energy storage part of demonstration power station with energy storage system are studied under typical meteorological conditions and load conditions. For 100%THA condition, the heat consumption rate of steam turbine generator set decreased by 4.71%.

1. Introduction

Energy-saving measures in thermal power industry are mainly divided into two categories, namely structural energy saving and technical energy saving. The use of solar energy has not caused damage and pollution to the ecological environment and human life, and will not produce carbon dioxide and sulfur-containing waste gas like traditional fossil energy; As long as the sun can reach the place, you can use solar energy, and there is no geographical limit [1-2]. Under the background of new energy, thermal complementation is more common in fossil energy power generation systems. The diversification of fossil energy power generation modes makes solar thermal complementarity an important auxiliary mode, and its core is to combine solar energy with fossil energy, so as to achieve the purpose of reducing fossil energy consumption and reducing carbon dioxide emissions.

2. Thermal complementarity between solar energy and complementary power generation of coal-fired power stations

Solar energy and other energy sources can be thermally complementary or thermochemically complementary [3]. Photothermal complementary power generation with thermal power unit is to generate electricity by thermal complementary between solar energy and fossil energy such as coal, so that the solar heat absorbed by the concentrated heat collection system of the thermal power plant can participate in the Rankine cycle of conventional thermal power generation. According to different heat requirements, the hot oil flow and temperature can be adjusted to make the boiler feed water temperature reach the design parameters, and the steam or heat will be replaced to continue to do work in the steam turbine, which can increase the power output without increasing the thermal load of the boiler and system, and significantly improve it. However, the existing research ignores the fact that the efficiency of the condenser decreases with the increase of the temperature of the condenser, that is, the existence of the optimal working condition of the condenser [4-5]. Therefore, it is of great significance to study the comprehensive utilization technology of solar energy and traditional thermal power plants under optimized operating conditions.

Compared with the solar thermal power generation system running alone, its complementarity with the thermal power generation system is basically the same as that of the thermal storage subsystem, but the complementary link is added to the thermal energy conversion subsystem, which makes its structure more complex and diverse. Organic matter generally plays two roles in solar thermal cycle. One is to act as working medium and participate in thermal cycle, which is called organic Rankine cycle. The other is used as heat transfer oil to transfer heat energy to working medium, which is mostly used in steam Rankine cycle [6].

In the thermal power plant, in order to reduce the heat transfer temperature difference of the boiler, reduce the heat absorption of the boiler, and thus achieve better energy-saving effect, a regenerative regenerator is installed in the thermal power plant. Based on the above design basis, the hot oil focused by the solar energy collection system can be used as a heat exchange fluid to completely or partially replace the original thermal system for regenerative extraction, which can reduce part of coal consumption while utilizing solar energy. Complementary solar energy and coal-fired power plants can increase power output without increasing the thermal load of boilers and systems, which can significantly improve the operation economy of coal-fired power plants. Fig. 1 is a schematic diagram of the integration scheme of light coal complementary power station.

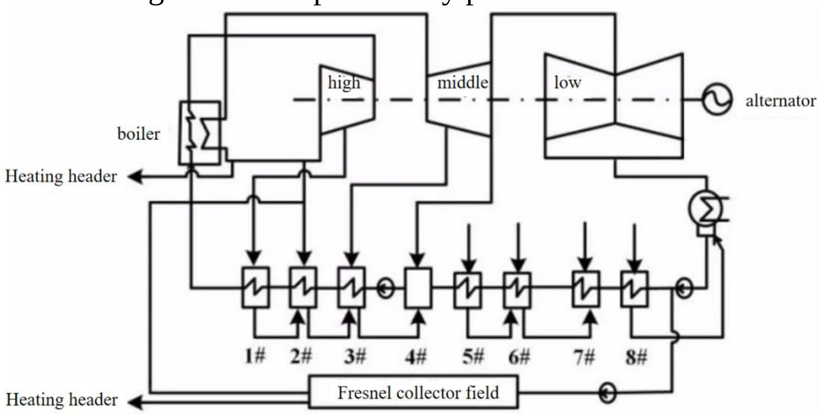

Figure 1: Schematic diagram of integration scheme of light-coal complementary power station

Among them, when the area of the solar heat collection field is large enough to completely replace the high-heating and low-heating regenerative steam extraction except the deaerator, the overall water supply flow is reduced compared with that before the replacement, so the regenerative steam extraction amount of the thermal deaerator changes slightly.

3. Operation mode of complementary power generation of solar thermal and coal-fired power stations

Affected by weather, seasons and other natural conditions, the solar radiation intensity is quite unstable. In order to ensure the stable operation of the solar light-coal complementary power station and avoid the situation that the collected solar energy cannot be effectively utilized, heat storage measures can be taken [7-8]. In order to maximize the solar energy utilization rate of the composite power generation system, it is necessary to combine the trough solar collector with the conventional thermal power generation system according to the principle of "temperature matching and energy cascade utilization". After being pressurized by water pump, circulating water enters the solar collector for heating and vaporization, which converts solar energy into latent heat of water vapor, enters the steam turbine after being overheated by superheater, and finally converts it into electric energy.

Solar thermal power generation system is usually composed of solar collector and heat engine, and its power generation efficiency is usually:

$$\eta = \eta_s \eta_c \tag{1}$$

Where η_s is the collector efficiency and η_c is the heat engine efficiency.

Because of the different input energy of solar field, the boiler working conditions in the solar economizer cooperative coal-fired system will change correspondingly under steady-state working conditions, which will lead to the change of boiler thermal efficiency. This section calculates and compares the boiler thermal efficiency under different steady-state conditions, so as to find the law of boiler thermal efficiency changing with the increase of solar field input energy.

As a large-scale power generation system, coal-fired power station includes many subsystems and equipment: boiler, steam turbine, reheat system, regenerative system, etc., and its operating mechanism is complex [9]. When solar heat is coordinated with coal-fired power stations, there will be coupling problems between them, which will make the whole coordinated power generation system more complicated. With the gradual increase of input energy of solar field, the temperature of boiler material before desuperheating water adjustment gradually rises, which may exceed the safe temperature range and then be in a dangerous state.

The thermal efficiency of boiler is defined as the ratio of the total heat absorbed by steam-water working medium in boiler to the total calorific value of pulverized coal combustion. Its expression is as follows:

$$\eta = \frac{Q_{water}}{Q_{coal}} \tag{2}$$

Where Q_{water} is the effective heat utilization of the boiler; Q_{coal} is the total heat input to the boiler.

The total calorific value of pulverized coal combustion can be obtained from the low calorific value of pulverized coal and its corresponding mass flow:

$$Q_{coal} = M_{coal} Q_{net} \tag{3}$$

Where M_{coal} is the total mass flow of pulverized coal entering the boiler; Q_{net} is the low calorific value of pulverized coal.

4. Complementary power generation characteristics of solar thermal and coal-fired power stations

Because the optimal working temperature of trough solar collector determines the interface between trough solar collector and conventional coal-fired power generation system, it is necessary to determine the optimal working temperature of the collector first [10]. After the solar energy is concentrated, it is directly converted into sensible heat of high-pressure air, which enters the combustion chamber and turbine and is converted into output work together with the high-temperature heat released by fuel. This system not only improves the photothermal conversion efficiency because solar energy is directly converted into internal energy of high-pressure air, but also converts solar energy into mechanical work with high efficiency by means of Brayton cycle, which increases the output work of the system [11].

Taking the 300MW coal-fired generator set as an example, this paper studies the integration scheme of the hybrid power generation system of 300 MW solar energy and coal-fired generator set. The trough solar light field of the light-coal complementary power station selected in this paper is a light-gathering and heat-collecting system loop composed of four groups of light concentrators. Each concentrator consists of one identical module, with a total length of about 130 m, an opening length of 5.7 m and a collector spacing of 1 m.

The site of the light-coal complementary power station is located in a typical Chinese mainland desert, and the solar irradiation intensity parameter of a certain day in summer is selected as a typical day, and the variation trend of its irradiation intensity with time is shown in Figure 2.

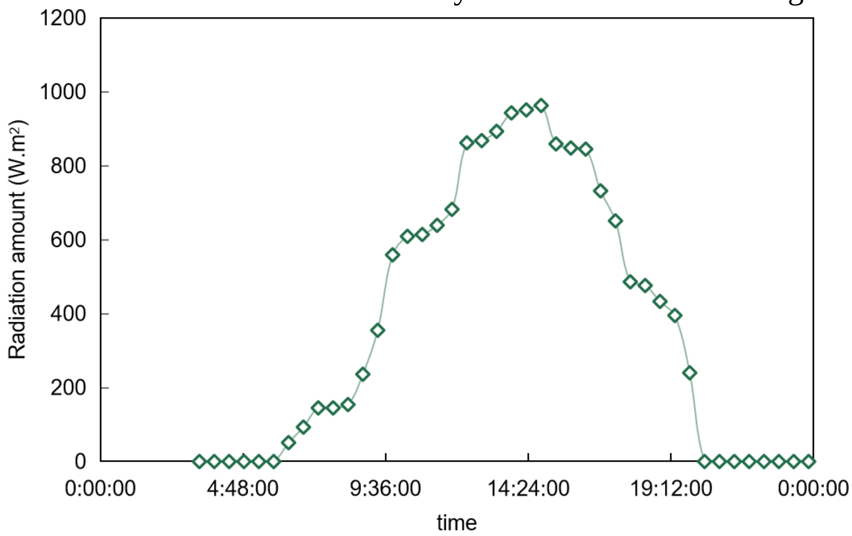

Figure 2: Variation trend of irradiation intensity with time

It can be seen that the sun rises after 6:20:00, and the solar irradiation intensity continues to increase, reaching the maximum at 14:50:00. Subsequently, the radiation intensity decreased rapidly, and the sun set at 20:20:00 in the evening.

When solar energy is used to replace the first stage extraction of HP heater, the outlet feed water of oil-water heat exchanger directly enters the boiler, and the hydrophobic flow of regenerative extraction steam fed into deaerator in the thermal system of coal-fired unit is reduced due to the removal of the first stage extraction of HP heater. At the same time, the exhaust steam of HP rainbow of steam turbine is increased when the replaced steam is not extracted, which leads to the increase of the heat load of reheater and condenser in the boiler under the condition of unchanged setting parameters. However, the possible influence of increased power on the safety of steam turbine units must be considered when operating under the condition of power change.

In traditional coal-fired generating units, besides primary intermediate reheating and regenerative heating, secondary intermediate reheating of steam can further improve the power generation efficiency of coal-fired generating units [12]. Fig. 3 shows the calculation results of thermal performance of steam turbine-generator set under 100%THA, 65%THA and 50%THA in constant flow operation mode.

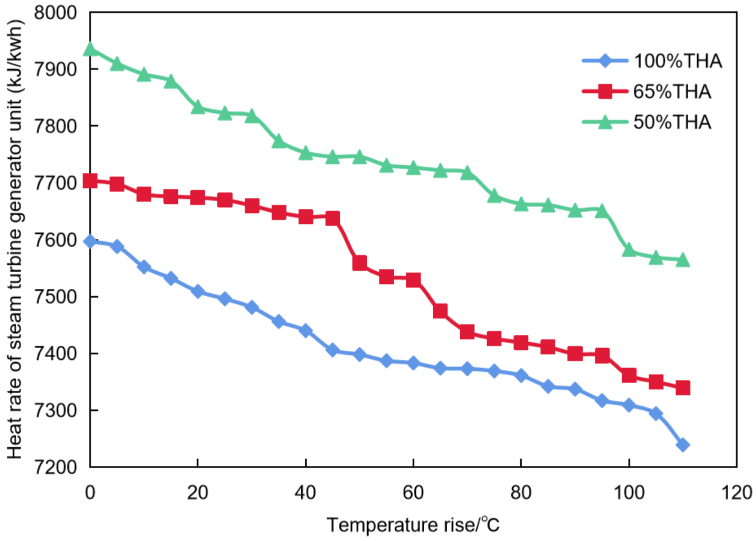

Figure 3: Calculation results of thermal performance of turbo-generator set

Under the constant power operation mode, with the increase of the temperature of secondary reheating, the heat consumption rate of steam turbine generator set under each working condition decreased. For 100%THA working condition, the heat consumption rate of steam turbine generator set decreased from 7597kJ/kwh to 7239kJ/kwh, a decrease of 4.71%.

For the solar field in the cooperative system, with the increase of the cooperative secondary reheating temperature, the direct radiation solar energy, solar energy received by the heat collection field and solar power generation power increase, while the solar thermoelectric conversion efficiency and photoelectric conversion efficiency increase, while the solar photothermal conversion efficiency decreases.

5. Conclusions

Compared with the solar thermal power generation system running alone, its complementarity with the thermal power generation system is basically the same as that of the thermal storage subsystem, but the complementary link is added to the thermal energy conversion subsystem, which makes its structure more complex and diverse. In conventional thermal power generating units, the efficiency of thermal power generating units can be further improved by introducing secondary medium temperature on the basis of primary medium temperature and secondary medium temperature. Under the condition of THA100% operation, the energy consumption of the unit decreased from 7597 KJ/kwh to 7239 KJ/kwh, a decrease of 4.71%. In the cooperative system, the higher the secondary reheating temperature of the cooperative system, the more direct radiation energy, solar energy absorbed by the heat collection system and solar energy generated. At the same time, the higher the light and heat conversion efficiency of the cooperative system, the lower the light and heat conversion efficiency of the cooperative system.

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