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Research on Coordinated Control Strategy of Power Response Rate of Thermal Power Plant with High Temperature Molten Salt Heat Storage

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ABSTRACT

Large-scale intermittent renewable energy grid-connected power generation requires thermal power units with sufficient flexibility to adjust resources, which can achieve deep peak regulation of 35% THA, and respond to load changes when intermittent renewable energy is connected to the grid in real time. In this paper, the flue gas heating molten salt is extracted directly from the process flow of the thermal power unit for heat storage, and the energy utilization efficiency is theoretically about three times that of the electric heat storage peak regulating system. The simulation results show that the coordinated control of flue gas-molten salt heat exchanger, molten salt-water/steam heat exchanger and boiler main control can reduce the depth peak regulation of thermal power units by 10%. The coordinated control method of thermal power unit of coupled molten salt heat storage system can effectively improve the response speed of AGC and primary frequency modulation of thermal power unit, and the output power response speed is increased by 39.12% after stabilization.

1. INTRODUCTION

Our country is striving to achieve the goal of 2030 carbon peak and efforts to achieve carbon neutralization by 2060 years ago, and raises higher requirements for optimizing energy structure and clean and efficient use of coal. It is of great significance to improve the efficiency of electric coal, reduce the consumption of electricity and reduce the consumption of electricity and reduce the energy of the clean energy, and make important measures to promote the carbon peak carbon and target.

With the effect of the nitro and the steady combustion load, the minimum load of the fire power unit is 45 percent, and the heat and heat of the heat and heat system of the coupled molten salt reservoir is controlled by the melting salt reservoir heat and the fire electrical unit, which can be carried out by the strength of the peak and the 10% capacity to meet the capacity of the heat system, and the relevant research of the heat and heat system is the attention of some of the researchers. Zhang et al. [1], the coupling system scheme of heat power unit and molten salt reservoir heat, concrete reservoir heat and subcritical water storage heat reservoir is designed, and the thermal performance and peak performance of each coupled system are analyzed, the thermal coupling system improves the performance of the system and the whole process of the whole process, and the optimal coupling scheme is to heat molten salt with flue gas and heat the feed water with molten salt, and the efficiency increases by 0.6 percent compared to the thermal change. The optimal coupling scheme for the peak performance is to use the molten salt to extract the high pressure cylinder exhaust, the heat of the heat is used to heat the high water and water, and the peak depth of the reservoir is 4.87% and 6.08%. Li and Wang [2] proposed three kinds of high temperature thermal storage and two types of heat release, which can be stored in the heat of the reservoir, and heat the water in the heat release stage, and then release the heat to the system, and the results show that the integrated thermal energy storage plant has a faster response time to load. Richter et al. [3] proposed the transformation scheme of the steam accumulator integrated into the control system of the fire power unit is proposed, and the dymola dynamic software is used to simulate the critical 695MW coal plant. The results show that the steam storage heat scheme can effectively improve the flexibility of load control and increase the capacity of the load depth. In addition, the thermal power units that integrate the energy storage can significantly increase the reserve control capacity of ±2.8%. Piancastelli [4] proposed a patented method to recover heat is obtained from the burned flue gas by exchanging heat with the inlet air of an external heat exchanger. The ventilation system of the unit sends fresh air through the extraction fan. The warm flue gas stores the heat energy in the hot melt salt tank through the flue gas-molten salt heat exchanger, and then raises the temperature of the water supply by the heat of hot melt salt through the molten salt water/water steam heat exchanger. In this way, the feed water temperature into the boiler is higher, but the steam flow increases rapidly, improving the energy utilization efficiency of the whole thermal power unit. Wojcik and Wang [5] proposed the operation plan of 375MW subcritical fuel power plant with integrated thermal storage system, this paper puts forward the reservoir heat and heat release scheme of different locations in the whole plant, and analyzes the advantages and disadvantages of each scheme, and the results show that the integration of thermal energy storage with the power plant cycle is feasible. Zhao et al. [6] based on the analysis of the frequency demand of the power system, the operation strategy of the thermal station of the phase transition heat station is proposed. In the middle of the Middle East of the heat, two typical 300mw and 200mw heating units were used as an example, and the cutting peak of the two units increased by 21% and 14% respectively. Gao et al. [7] is proposed to apply the absorption heat pump and the system of the system to realize the deep peak. This paper adopts the prediction control algorithm of feedforward feedback structure to solve the big delay and inertia problem of boiler side, and the pressure ratio of the first level pressure and the pressure of the high-pressure cylinder is compared with the control of high pressure. The simulation results show that the strategy can meet the demand of the residents' heat load, and ensure the stable operation of the steam turbine in the operation of the unit, and the state of the deep peak. The above research uses different methods to realize the deep peak of the thermal power unit, and most research results have shown that the thermal system of the coupled reservoir is feasible in the depth of the heat control [1, 8].

Based on matlab software, this paper establishes the coordination control model of the thermal power unit of the coupled molten salt reservoir, and is based on the heating and heat modulation of the flue gas in the fire power plant. Operation of 45% turbine heat acceptance operating condition of the thermal power unit. The research satisfaction can reduce the depth of the heat control unit by 10%, the gas of the molten salt heat exchanger, the smoke quantity/speed control, the water temperature/speed control and the coordinated control strategy of the boiler main control. Verify the effectiveness of the coordinated control method of the coupled fused salt reservoir, and the quantitative calculation can improve the AGC and the speed of the frequency modulation response.

2. UNIT PROFILE AND SYSTEM MODELING

2.1 Unit profile

This paper studies the supercritical coal-fired units of 660MW grade of a power plant in China. The turbine type is: supercritical, one middle reheat, single axis, three-cylinder two lines of steam, indirect air cold, reactionary steam type. The whole flow of the steam turbine consists of three cylinders, namely a high pressure cylinder, a double flow middle cylinder and a double flow low pressure cylinder. The boiler system adopts single furnace, once reheat, balanced ventilation, tight closed, solid slag, all-steel frame, full suspension structure boiler. The boiler launch system is equipped with the circulating pump and the atmospheric hydrothermal expansion device, which can be used in the 30%~100% load. The water supply of two 50% boiler maximum continuous rating capacity is used to operate the water pump. There is a 30% boiler maximum continuous rating capacity electric speed feed pump, which is used only for the unit to start and not to do hot standby. The boiler export steam parameter is 25.4MPa(a)/571℃/569℃, and the boiler maximum continuous rating of 2250t/h [9, 10].

2.2 The model of system

The heat modulation and heat modulation system of the heat of fire power plant is shown in Figure 1.

In this paper, matlab software is used to analyze the coordination control strategy of the thermal depth modulation system of heat and heat reservoir in fire power plant, as shown in Figure 2.

In the operation of the 45% THA operating condition of the fire power unit, the demand for the depth of the 35% THA depth of the fire power unit is met. The amount of smoke extracted by the flue gas of molten salt heat exchanger can reduce the unit by 10% THA. In the same way, when it is required to release the corresponding heat in the molten salt and water steam heat exchanger, the corresponding heat disturbance is caused by the boiler, and the actual condition of the operation unit is combined, and the heat capacity of the molten salt is set 80MWh in the model.

In order to verify the correctness of the simulation of matlab software, the production process of the heat ignition unit, which is coupled with the coupling reservoir, select the 45% THA condition of the unit and 35% THA condition for the model benchmark. The model calculation data of these two conditions is compared with the design parameters, and the power validation of the motor side output is sent by the unit of 45% THA and 35% THA. In table 1, the results show that the design parameters of the unit are compared with the design parameters of the unit in 45% THA and 35% THA, and the design parameters of the unit are derived from the heat balance of the steam turbine in the deformation of the unit [11, 12].

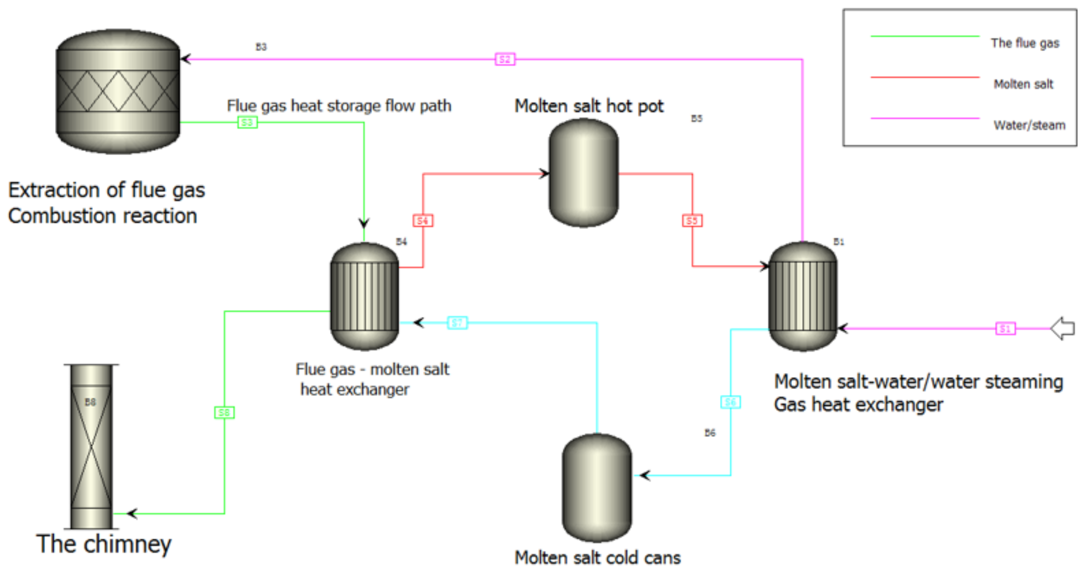

Figure 1. The system of thermal power plant flue gas heating melting salt reservoir heat peak

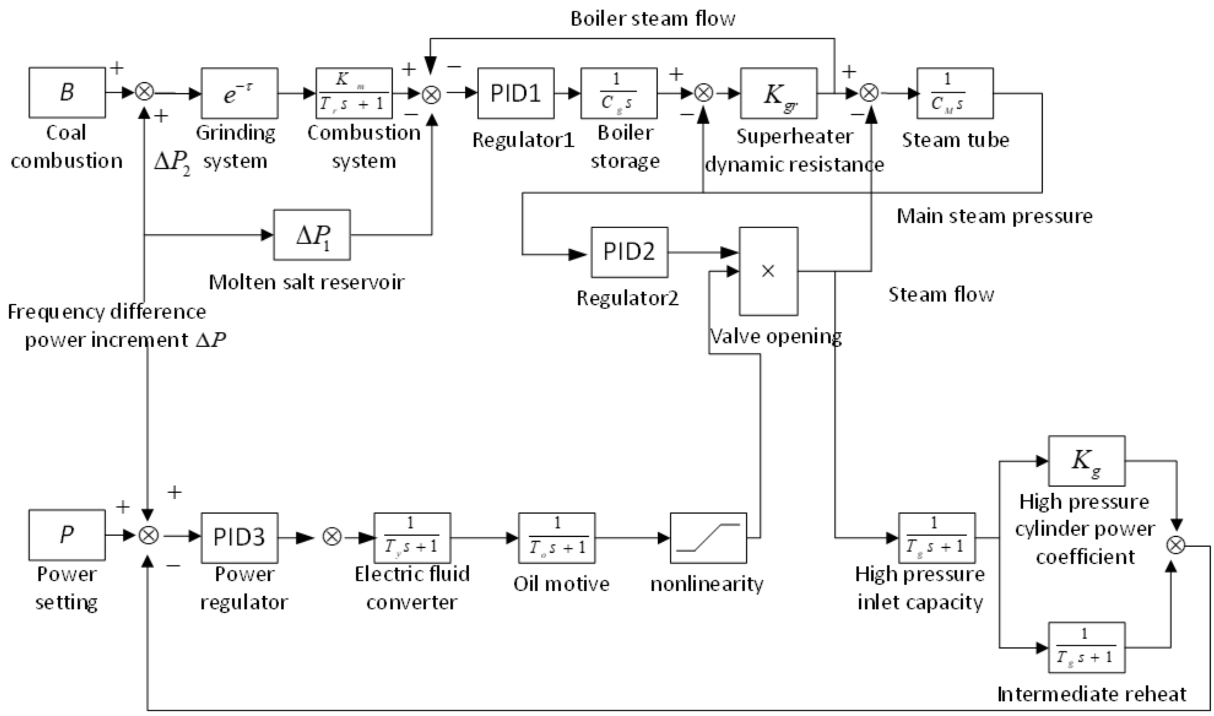

Figure 2. Control model of heat modulation and heat modulation system of thermal gas heating and melting of fire power plant

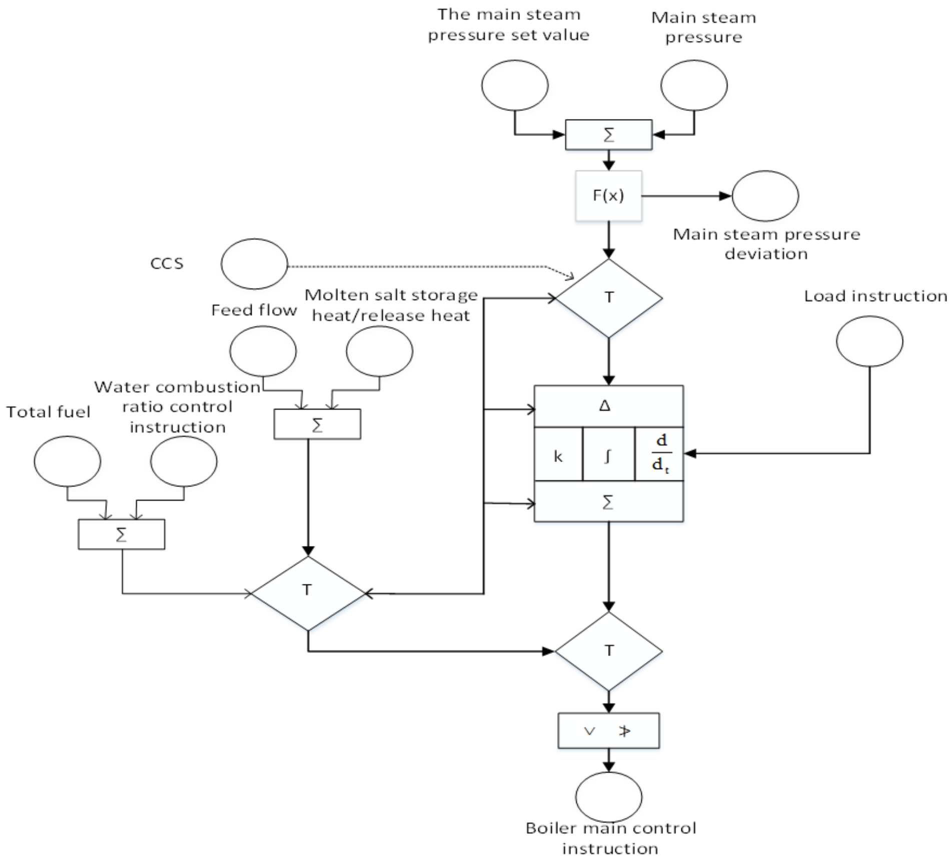

Figure 3. The coordinated control diagram of the main control and the molten salt reservoir

Table 1. Comparison of simulated parameters of the modified condition of the 660MW

Project	45% THA design value	Analog value	error	35% THA design value	Analog value	Error
Main steam pressure (kPa)	1012.5	1031.33	0.38%	787.5	790.42	0.37%
Smoke flow (m^3/h)	57.04	57.32	0.49%	73.34	73.69	0.48%
Coal consumption (t/h)	154.81	155.60	0.51%	120.41	120.96	0.46%
Generator power (MW)	297	298.28	0.43%	231	231.67	0.29%

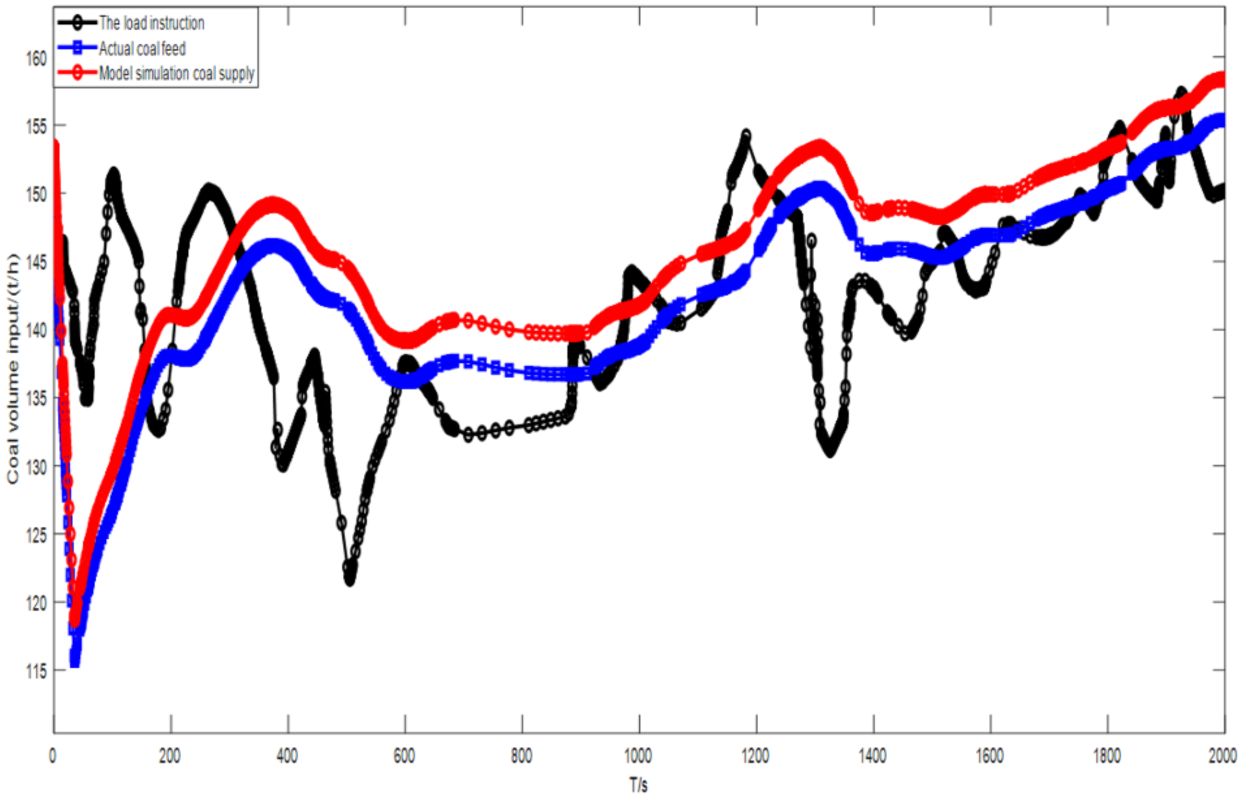

Figure 4. The simulation value and actual value of the coal quantity based on the actual coal instruction

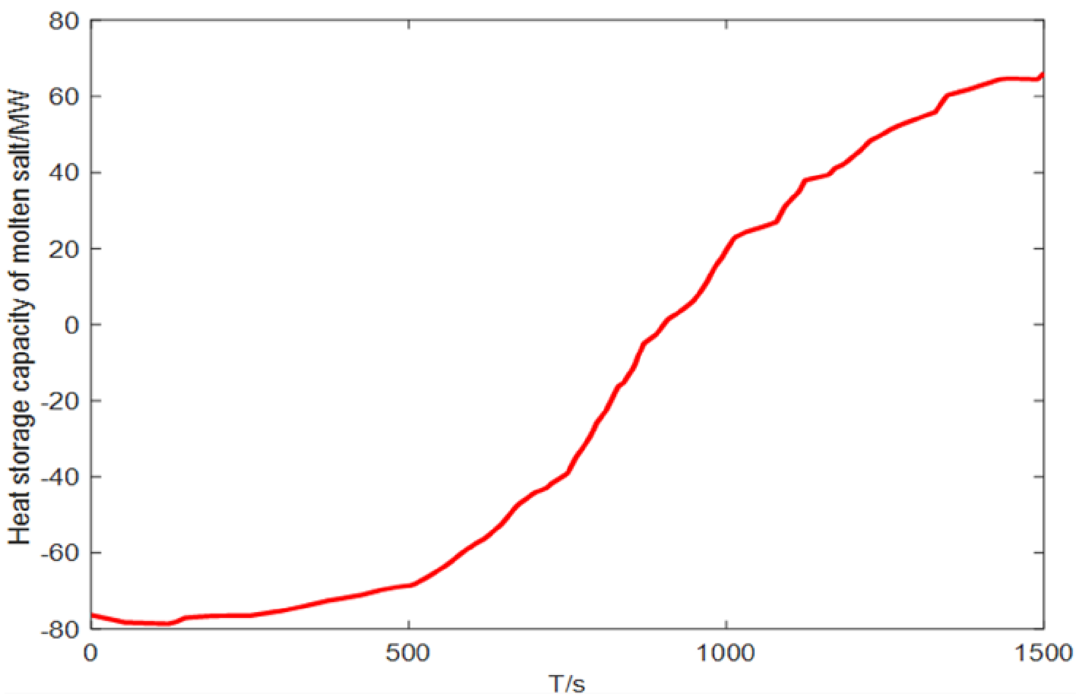

Figure 5. Molten salt storage capacity

From Table 1, the calculation of the model of matlab software is basically the same as the design value parameters of the actual running unit. The unit was given a power of 297MW and 231MW in 45% THA and 35% THA 2 operating conditions. The main steam flow, the export temperature of the main steam, the export pressure of the main steam, and the design value of the design of the thermodynamic calculation are consistent. The relative error of the simulation is about 5%, and the majority of the error is less than 1%, so the model of this class is of high accuracy.

3. THE GAS HEATING AND MELTING SALT RESERVOIR AND THE HIGH VELOCITY SYSTEM COORDINATION CONTROL STRATEGY

The coordinated control of the main control and the melting salt storage system SAMA in Figure 3 [13].

In the process of melting salt heat, the smoke valve of the flue gas - molten salt exchanger is activated, which mainly affects the boiler air smoke system, and the flue system is the basic system that guarantees the combustion of the burning pot.

The air smoke system provides a certain amount of wind to the boiler furnace to make the coal powder fully burned in the furnace, and the wind quantity is used to maintain the pressure of the furnace to maintain the pressure of the furnace. After the combustion of the combustion of the furnace, the combustion product of the furnace is used to heat the heat of the molten salt heat exchanger, and then it will be discharged into the atmosphere after the process of removal of niting, dust removal and desulfurization [14, 15].

In the process of melting salt, the high plus by-road molten salt-water/water-steam heat exchanger and the regenerative high voltage heater are parallel, When the main steam flow is constant, the water supply of the high-pressure heater is exchanged for energy exchange with the molten salt-water steam heat exchanger and hot temperature melting salt, and the water temperature is raised, and the molten salt after the heat is stored in the cryogenic salt tank. The water supply of the heating water is mixed with the high pressure heater main water supply and the boiler continues to heat up as a high temperature superheated steam [16]. Due to the introduction of the high pressure and the water steam heat exchanger, the steam flow of the high pressure cylinder, middle cylinder and low pressure cylinder is increased, and the rapid increase of the power generation of the steam turbine is realized [17, 18].

4. THE EFFECT OF THE THERMAL DEPTH OF THE HEAT AND HEAT RESERVOIR OF THE THERMAL ELECTRIC UNIT IS COORDINATED WITH THE CONTROL OF THE AGC AND THE FREQUENCY MODULATION

In case of the operation unit of a power plant in Mongolia, this paper analyzes the coordination and control characteristics of the thermal power unit of the coupled molten salt reservoir based on the actual coal instruction and the melting salt reservoir heat/release heat capacity. In this paper, the response of the AGC and the frequency modulation of the molten salt reservoir is analyzed, and the difference between the actual output power of the molten salt reservoir is compared [19, 20].

4.1 The gas heating and melting salt reservoir heat depth modulation system coordinate the input characteristics

The simulation value and the actual value of the coal load based on the actual coal instruction are shown in Figure 4. The limit of the amount of coal to coal is 120.41(t/h) to 154.81(t/h), and the instruction for coal quantity is ahead of actual amount of coal.

The heat/release capacity of molten salt is shown in Figure 5, considering a certain heat loss, the actual molten salt is the highest heat storage heat of 72.49MWh, the lowest storage heat is 78.54 MWh.

4.2 The analysis of the influence of the hot depth peak system on AGC and the frequency modulation

Based on the actual power given and the simulation power response is shown in Figure 6. As seen from the figure, at 104.41s the time power value and the simulation power response error maximum is 13.30MW and the rest of the time is consistent. The main reason is that the response power needs a certain reaction time when the power mutation is given.

As shown in Figure 7 of the coupling molten reservoir heat, the steam turbine valve is opened quickly when the output power increases, and the melting heat system improves the power by increasing the temperature release of the water supply temperature. At the same time, the pressure of the main steam is gradually increased, so that the steam turbine output power 80s can meet the requirement of the instruction.

The impact of the thermal system on output power is shown in Figure 8. After the fusion of the molten salt reservoir, the power response ability of the thermal power unit can be improved significantly, and the power response speed of the stable after the stable is increased by 39.12%.

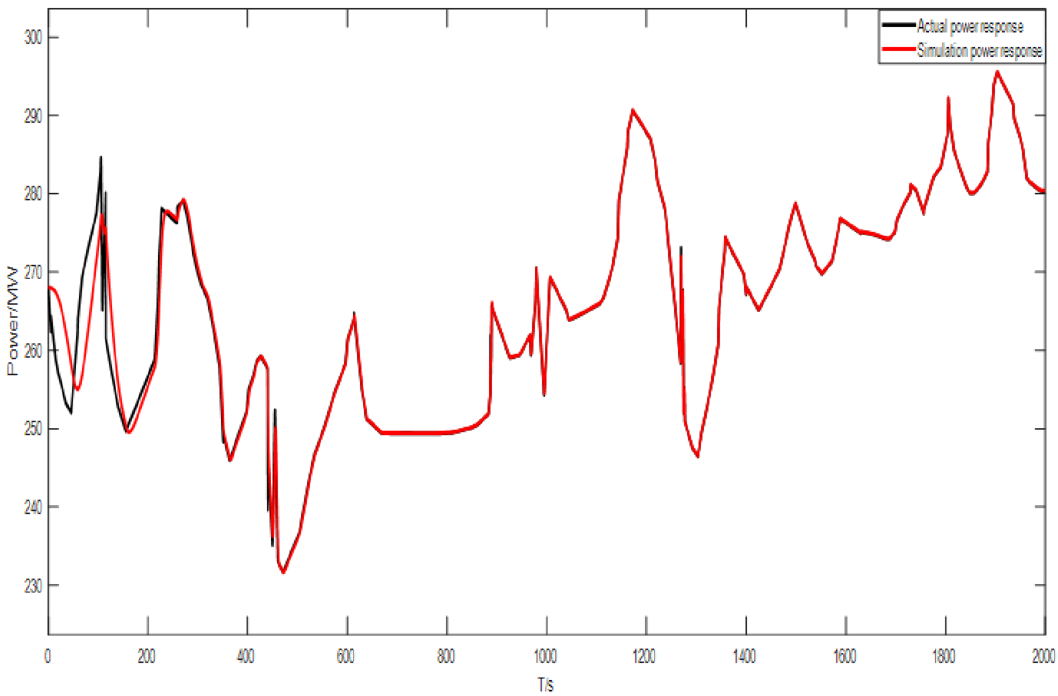

Figure 6. The actual value and simulation value of the unit power

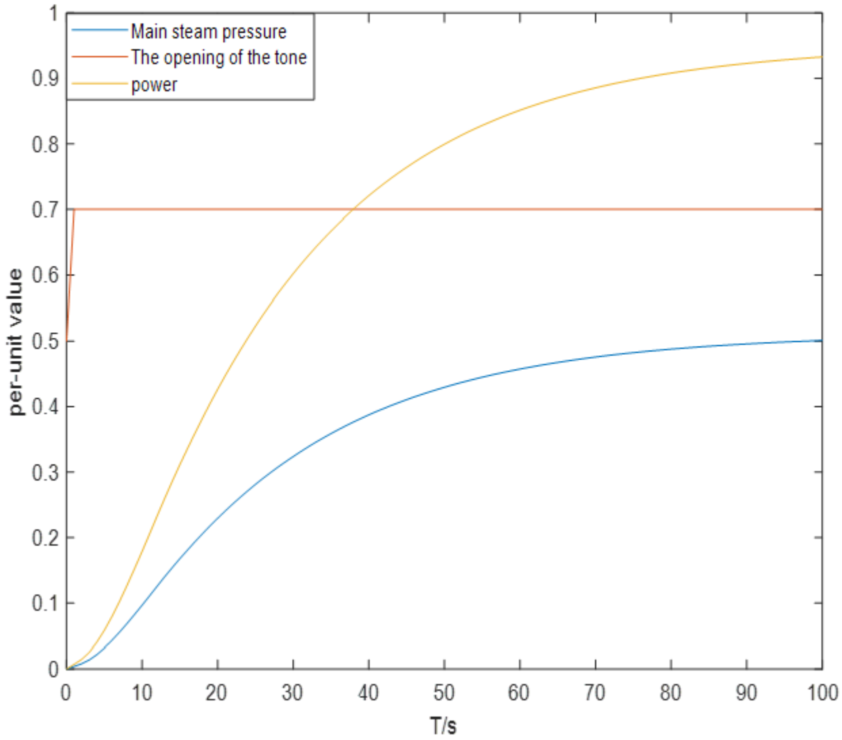

Figure 7. Frequency modulation simulation curve of coupled molten salt reservoir

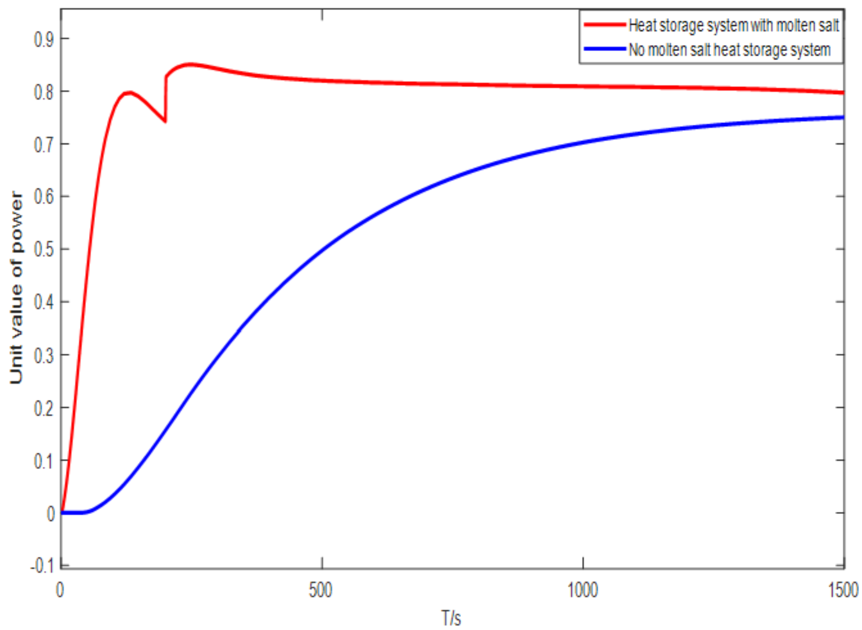

Figure 8. The effect of the output power on the output power of or without the molten salt reservoir

4.3 Data analysis

In the process of the actual frequency modulation, the lifting load is not only the increase of the valve opening degree, the increase of the capacity of the unit, but also the effect of the main steam pressure. Therefore, in order to measure the amount of the unit's frequency modulation process can lift the load, the concept of using a frequency modulation ability is quantified, which is the maximum power value that can be promoted in a certain time [21]. As time changes, the process of the unit is gradually changed, and the power plant is concerned about the ability of the frequency modulation ability of several time nodes at (15s and 60s). The response data of the heat ignition unit for the heat of the coupled molten salt reservoir are shown in Table 2 [22, 23].

Table 2. Frequency response of the heat generator of the coupled molten salt reservoir

Response time/s	Output power/MW	Main steam pressure/kPa	Valve opening/%
10	59.09	98.02	70
15	102.78	169.98	70
30	198.84	328	70
60	281.01	463.15	70

As shown in Table 2, when the output power increases from 231MW to 297MW, the power of 15s is 102.78 MW the power of 34.60%, and 60s is 281.01 MW, which can achieve the target power of 94.62%. We know that the hot salt reservoir can improve the speed of the next frequency modulation response.

5. CONCLUSIONS

Based on the matlab software simulation platform, this paper establishes the coordinated control simulation model of the thermal power unit of coupled molten salt reservoir. The control strategy of the thermal depth modulation system of the heat and heat reservoir of fire power plant was developed, and the control ability and the influence of the AGC and the frequency modulation were verified. The results show that: (1) the modeling model can accurately analyze the control system of the heat and heat reservoir of the heat and heat. (2) the coordinated control strategy of the flue gas - molten salt heat exchanger, molten salt - water steam heat exchanger and boiler main control can reduce the depth of the fire power unit by 10% THA. (3) the coordinated control method of the thermal system of coupled fused salt reservoir is used to improve the AGC and the speed of the frequency modulation response of the fire power unit, and the output power response speed of the stable output is raised by 39.12%.

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