4 x 200MW Thermal Power Plant Electrical Design and Protection

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Abstract. This paper includes the main wiring design of 4 x 200MW thermal power plant, the calculation of short-circuit current, the selection of some electrical equipment, and the transformer longitudinal differential protection. Finally, the lightning protection is set up.

Introduction

The power system is a whole consisting of power generation, power supply and electricity. Since most power plants and load centers are located in different areas and cannot store large amounts of electricity, the production of electricity must always be balanced with consumption. The design includes: main wiring design, short circuit calculation, part of the electrical equipment selection and transformer differential protection.

Power plant site overview: The plant is a pit-mouth power plant, and all fuel is directly supplied by the coal mine. In addition to the electrical energy produced by the power plant, all 220kV lines are sent to the peripheral system. There is a large river near the site, which is rich in water. The maximum wind speed is 20m/s. The annual average temperature is +12 °C, the highest temperature is +41 °C, the lowest temperature is -2 °C, and the soil resistivity is >500.

Units with single capacity of 100-125 MW should be directly boosted into 220 kV power network when system stability is required. Units with single capacity of 500 MW and above should be directly boosted into 500 kV power network.

220 kV Voltage Level Connection Mode

Electrical main wiring is the main part of the electrical part of power plant and substation[1], which reflects the function of each equipment, the connection mode and the relationship between the circuit. It is directly related to the selection of electrical equipment, distribution arrangement, relay protection, automatic device, control mode and so on. There are two possible main wiring schemes.

Design Scheme 1. The double bus section connection method is adopted, and the double loops are connected to different bus sections respectively, so as to reduce the influence range of bus faults. See figure 1 for the main connection form.

Design Scheme 2. The double bus connection is adopted, and the circuit breaker adopts high-reliability circuit breaker. See figure 2 for the main wiring form.

Scheme 2 can be operated by switching two groups of bus dis-connectors, and one group of buses can be overhauled in turn without interrupting power supply[2]. When overhauling any circuit breaker, the circuit shall be cut off for a short time. The circuit breaker adopts a circuit breaker, so that the maintenance period is long, frequent maintenance is not required, and the probability of power failure during maintenance of the circuit breaker is reduced. Through comparison, it can be seen that the feasibility of scheme 1 is slightly higher than scheme 2 in terms of reliability.

Although the reliability of scheme 2 is slightly lower than that of scheme 1, the SF6 circuit breaker is used in the circuit breaker, which has a long overhaul cycle and does not need regular overhaul. In this way, the probability of power failure in circuit breaker maintenance can be reduced. In terms of economy, scheme 2 is obviously higher than scheme 1, so the choice of scheme 2 is considered comprehensively.
The reliability of the three sections of double bus is very high. If a section of bus suddenly fails, the relay protection will act immediately, cutting off the connection between the failed section of bus and the power supply, and connecting the normal working power supply to the standby bus, so that the failed bus can be cut off to resume power supply. In this design, double bus three-section connection is adopted to directly connect with the generator, and then circuit breaker and isolating switch specially matched with the generator are used to enhance the reliability of the system, as shown in figure 3.

According to the original material, the selected generator capacity is 200 MW. Therefore, SF10-240 is selected, which has excellent performance. In this design, transformers are all unit wiring. The transformer capacity shall be determined with a margin of 10% after deducting the unit's service load from the generator's quota capacity. The rated capacity of the generator is 200MW, after deducting the auxiliary power, the capacity of the transformer is as follows:
$$S_N = \frac{1.1P_{NC}(1 - K_p)}{\cos \Phi_g} = \frac{1.1 \times 200(1 - 0.08)}{0.85} = 238.12 \text{MVA}$$

**Direct Grounding of Transformer Neutral Point**

In this design, the transformer neutral point will be directly grounded. This connection method is very suitable for power plants above 110kV voltage level, which is very suitable for the design requirements of this thermal power plant. If a short-circuit fault occurs, the short-circuit current will be very large, and the line equipment needs to be cut off immediately. The large short-circuit current can immediately make the relay protection device operate and disconnect the fault circuit, which can ensure the safety of the system. This connection method can greatly reduce the insulation level of the system, reduce the construction cost of the thermal power plant, and meet the economic requirements.

**Transformer Longitudinal Differential Protection**

This design mainly sets the current setting value of transformer longitudinal differential protection [3,4]. The transformer current setting value is set according to the secondary current value, which obtained from each side of the transformer through the current transformer. According to the selected current transformer, calculate the secondary side current, as shown in table 1 and table 2.

| Transformer | 220kV Inside Side | 110kV Inside Side | 10kV Inside Side |
|-------------|-------------------|-------------------|-----------------|
| Primary Side Calculation Current of Transformer(A) | 826.28 | 1653.36 | 7936.06 |
| Transformation Ratio | 2×600/5=240 | 2×1000/5=400 | 12000/5=2400 |
| Secondary Side Current(A) | 57.26 | 4.13 | 19.84 |

| Location | 220kV External Side | 110kV External Side | 10kV External Side |
|----------|---------------------|---------------------|-------------------|
| External Fault Current(A) | 115850 | 6190 | 13230 |
| Transformation Ratio | 2×600/5=240 | 2×1000/5=400 | 12000/5=2400 |
| Secondary Side Current(A) | 482.7 | 15.475 | 5.512 |

Single-phase diagram of differential protection wiring, as shown in figure 4.

![Single-phase diagram of differential protection wiring](image)

**Figure 4. Single-phase diagram of longitudinal differential protection wiring.**
Main Wiring Equivalent Circuit Diagram

In this design, the short-circuit current will be calculated according to the maximum operation mode to ensure the accuracy of short-circuit calculation and ensure the stability of the system[5]. Three short-circuit points d1, d2 and d3 are set up in this calculation. Figure 5 illustrates the equivalent circuit diagram of point d1.

![Equivalent circuit diagram of point d1.](image)

Installation of Lightning Rod

Lightning rod plays an important role in protecting power plant[6]. Lightning rods are generally made of different diameters of steel pipe welding, the tip of the round steel, generally to prevent rust and plated with a layer of zinc.

A lightning rod is the lowest point of protection width. In this design, the distance between the two lightning rods D=40m, the protection height is 15m, and the lightning rod setting height h=25m.

Magneto-blow lightning rod has discharge gap. It uses magnetic field to extinguish arc. It has strong ability to extinguish arc and can cut off the continuous current with large power frequency. This design chooses FCZ with very high performance, as shown in table 3.

| Location                        | Model   |
|---------------------------------|---------|
| 220kV Bus                       | FCZ-154J|
| 110kV Bus                       | FCZ-70  |
| 10kV Bus                        | FCZ-8   |
| Transformer High Voltage Side   | FCZ-110J|
| Generator Side                  | HY5W-25/45|

Lightning Protection Setting Diagram

The designed factory covers an area of 240*200 square meters, with 6 lightning rods on the long side and 5 lightning rods on the short side. There are 30 lightning rods in total. The distance between the two lightning rods is 40 meters, and the height of the lightning rods is 25 meters, as shown in figure 6.
Design of Distribution Device

Distribution devices can be divided into indoor and outdoor distribution devices according to the installation location of electrical equipment; according to the assembly mode, they can be divided into assembly type and complete set type. Generally speaking, in large and medium-sized power plants and substations, indoor distribution devices under 35kV should be adopted, of which 3-10kV mostly adopts complete distribution devices, and 110kV and above mostly outdoor distribution devices.

The 220kV distribution device is arranged by split-phase medium-sized pipe buses, which can save land, simplify the structure, minimize construction workload, shortest construction period, clear layout, convenient operation and save three materials.

Medium-sized distribution devices can be divided into two types: ordinary medium-sized and phase-separated medium-sized. Common medium-sized bus can be arranged in two ways: single-row and double-row. Bus can be flexible conductors and aluminum tubes. Bus-bar dis-connector are directly arranged under each phase buses in phase-splitting medium-sized system, and only one group of Bus-bar dis-connector are arranged in phase-splitting mode. The dis-connector can be GW4 double-column type, GW7 three-column type or GW6 single-column type bus-bar can be flexible or tubular bus-bar. This arrangement can save land, simplify the structure and save three materials, so it has basically replaced the ordinary medium-sized configuration.

Summary

Generally speaking, the main electrical wiring used in this design has the characteristics of reliable power supply, flexible dispatch, convenient operation and maintenance, and economic and expansion.

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