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Primary design and protection of 110kV substation

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Primary design and protection of 110kV substation

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Abstract. This paper designs a 110KV substation. Through the analysis of transformer load, the capacity and number of main transformers are selected, and the main connection modes of 110kV, 35kV and 10kV are determined. By calculating the short-circuit current, it can be used to select the main electrical equipment to complete the design of transformer protection and the selection of distribution devices, and draw the main wiring diagram and the plane layout. Finally, we design a simple relay protection, and complete the design of the primary electrical part of 110kV substation.

1. Introduction

Usually, the classification of substation design is divided into three ways: substation layout, distribution device type and substation scale.

According to the layout of substations, 110kV substations are divided into four types: outdoor substation, indoor substation, semi-underground substation and underground substation.

According to the type of power distribution equipment, 110kv power distribution equipment can be further divided into two types: conventional open switch equipment and fully enclosed combined electrical equipment.

According to the scale of substation (such as outdoor AIS substation): 110kv power distribution equipment can be divided into three types: terminal substation, intermediate substation and hub substation according to different scales such as the number of outgoing circuits and the number and capacity of main transformers with the highest voltage level.

2. Design principles of main electrical wiring in substations

2.1 Wiring mode

For substation electrical wiring, when it can meet the operation requirements, its high-voltage side wiring should be as little as possible with or without circuit breakers. If it can meet the requirements of relay protection, branch wiring [1] can also be used.

In 110-220kV distribution equipment:

- When the outgoing line is 2 rounds, bridge connection is generally used.
- When the outgoing line is no more than 4 rounds, single bus connection is generally used.
- When 110-220kV outgoing line is 4 rounds or more, double bus connection is generally used in hub substation.



2.2 Circuit breaker settings

According to the electrical wiring mode, each circuit should be equipped with a corresponding number of circuit breakers to complete the task of switching and closing the circuit.

2.3 Load parameter setting

- The minimum load is 60-70% of the maximum load.
- The load simultaneous rate is 0.85-0.9, when the feeder is below three cycles and there are extra heavy loads, it can be 0.95-1.
- The power factor is generally 0.8.
- The average line loss is 5%.

3. Raw data and plan selection

A 110kV step-down substation is to be built in the suburbs. The system parameters of the substation to be built [2] are as follows:

- The substation needs to provide three voltage levels: 110kV, 35kV and 10kV to meet the electricity demand of nearby factories and residents.

- Maximum operation mode: S1 capacity is 200MV·A, S2 capacity is 400 MV·A..

- Minimum operation mode: S1 capacity is 180MW·A, S2 capacity is 300 MV·A.

Load circuit number is as follows:

- High voltage side: feeder 4 times, 2 times standby.
- Medium voltage side: feeder 6 times, 2 times standby.
- Low-voltage side: feeder 12 times, 4 times of standby.

The main electrical wiring of this design is shown in figure 1, 110kV side adopts double bus connection mode, 35kV side adopts single bus section with bypass bus connection mode, and 10kV side adopts single bus section connection mode.

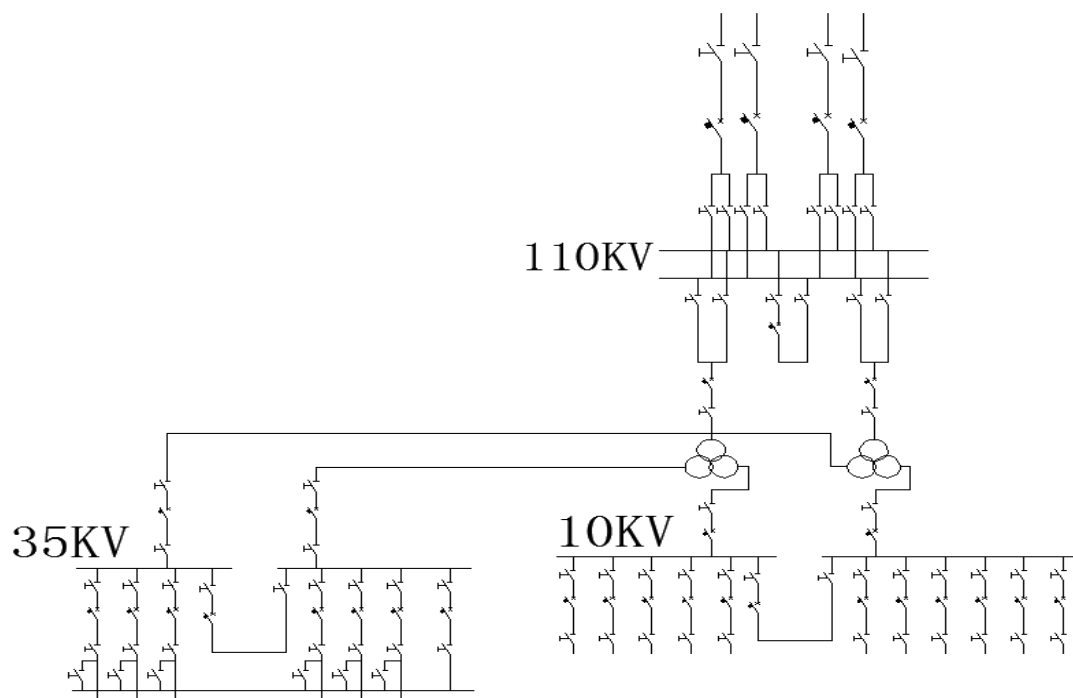


Figure 1. Electrical main wiring diagram

4. Load calculation and main transformer capacity determination

When the substation is equipped with two main transformers, two conditions [3] must be met: when any one main transformer is shut down, the other main transformer must meet 60% ~ 70% of the maximum load, and at the same time it must meet the needs of all primary and secondary loads.

Maximum load calculation formula(1):

$$S_{max} = K_t (\sum_{i=1}^n \frac{P_{imax}}{\cos\varphi}) (1 + \alpha\%) \quad (1)$$

According to the load data of each voltage level given by the original data, the above formula is substituted. At this time, the synchronization coefficient is 0.85, and the network loss rate is 5%, and the total load of each voltage level can be calculated.

- 35kV load calculation:

$$S_{35max} = 0.85 \times (2 + 2 + 2.5 + 2.5) \div 0.9 \times (1 + 5\%) = 8.925 \text{ MW} \cdot \text{A}$$

- 10kV load calculation:

$$S_{10max} = 0.85 \times (2 \times 4 + 2.5 + 2.5 + 1.5 + 2.2) \div 0.9 \times (1 + 5\%) \\ = 15.561 \text{ MW} \cdot \text{A}$$

- Station lighting and power equipment load:

$$S_{\text{light}} = 0.85 \times 82 \div 0.85 \times (1 + 5\%) = 86.1 \text{ KW} \cdot \text{A} = 0.0861 \text{ MW} \cdot \text{A}$$

5. Short circuit current calculation

The formula(2) for calculating the short-circuit inrush current is:

$$i_{sh} = \sqrt{2} I_p \left(1 + e^{\frac{-0.01\omega}{Ta}} \right) = \sqrt{2} K_{sh} I_p \quad (2)$$

According to formula (2), the short circuit of each voltage level is calculated. The calculation results are given in Table 1.

Table 1. Short-circuit current calculation results

Short circuit point	Voltage reference U_n (kV)	Reference current I_B (kA)	Equivalent impedance	Short circuit current I_p (kA)	Short circuit inrush current i_{sh} (kA)	Short circuit current is most effective Value I_{sh} (kA)	Short circuit capacity S_k (MV·A)
f_1	115	0.502	0.203	2.473	6.31	3.76	492.59
f_2	37	1.56	0.467	3.34	8.518	5.077	214.05
f_3	10.5	5.499	0.642	8.565	21.842	13.02	155.75

6. Capacity selection of parallel capacitors

Most shunt capacitors are connected by star connection, triangle connection, double star connection and double triangle connection. As far as the current situation is concerned, triangular wiring is seldom used in high voltage field. When any capacitor is short-circuited, the fault short-circuiting current is very large. If it cannot be cut off in time, the capacitor may burn or even explode. The star connection can cut off the fault capacitance by fusing the protective fuse.

For 110kV substation, the power factor in the high voltage side of the substation should be higher than 0.95 at the maximum load of the main transformer voltage. Power factor should be controlled from 0.92 to 0.95 in low valley load.

As far as the normal situation is concerned, the general substation generally selects the medium voltage side or the low voltage side for its reactive power compensation, and the substation selects the 10kV side compensation.

$$P_{ml} = S_{35max} \times \cos\varphi = 15.561 \times 0.85 = 13.23 \text{ MW}$$

The formula(3) for calculating the maximum capacitive reactive power required by load is as follows:

$$\begin{aligned}
 Q_{cm} &= P_{m.l}(|\tan \varphi_1| - |\tan \varphi_2|) \\
 &= P_{m.l}(\sqrt{\frac{1}{\cos^2 \varphi_1}} - 1 - \sqrt{\frac{1}{\cos^2 \varphi_2}} - 1) \\
 &= 13230 \times |0.62 - 0.42| \\
 &= 2646 \text{ (kvar)}
 \end{aligned} \tag{3}$$

According to the above analysis and calculation, it can be selected in the following capacitor bank. The specific parameters are shown in table 2.

Table 2 BFM11/ $\sqrt{3}$ -200-1W capacitor technical parameters

Rated voltage (kV)	Rated capacity(kvar)	Rated capacitance (μ F)	Phase number	Outline size width,depth and height (mm)
$11/\sqrt{3}$	200	15.79	1	440×180×696

$$N = \frac{Q}{q} = 2646 \div 200 = 13.23$$

Therefore, the reactive power compensation in this design is finally decided to be compensated at the side of 10kV, and the capacitor of model BFM11/ $\sqrt{3}$ -200-1W is selected and set as 14 groups.

7. Transformer protection configuration

For transformer, its main protection can adopt the most common longitudinal differential protection and gas protection. The combination of these two protection modes can achieve complementary advantages. In this design, the longitudinal differential protection is used as the main protection of transformer, and the gas protection is mainly used to protect the internal faults of transformer.

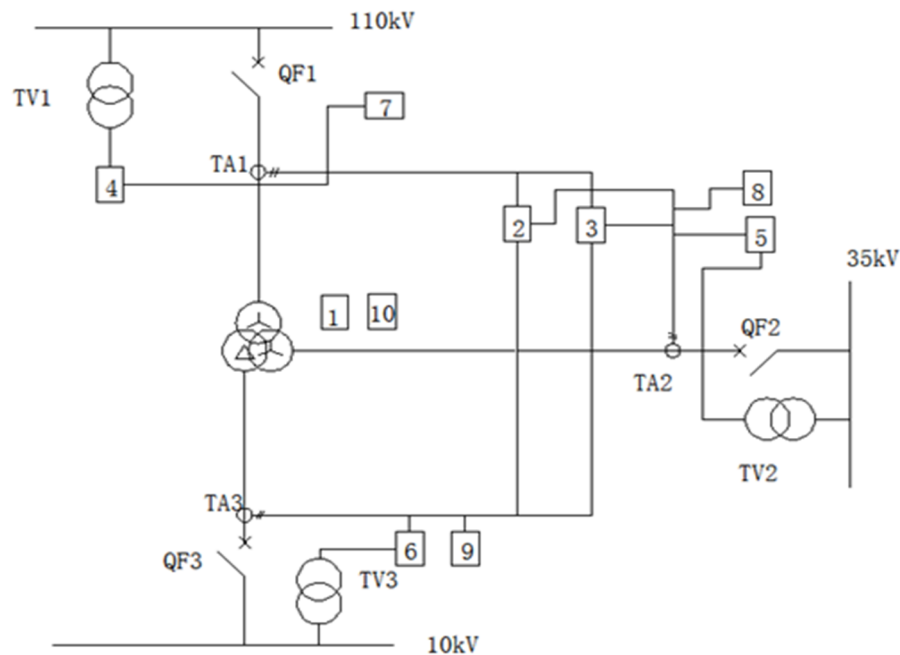


Figure 2 Transformer protection configuration

The transformer protections designed in this paper are as follows: gas protection, overload protection, longitudinal differential protection, over-current protection and some other non-electrical protection devices, as shown in figure 2., which relevant symbols are described as follows:

TA1, TA2, TA3-----Current transformers for high, medium and low voltage sides, respectively;
 TV1, TV2, TV3-----Voltage transformers for high, medium and low voltage sides, respectively;
 1-----Gas Protection;
 2,3----- Longitudinal Differential Protection;
 4, 5, 6----- Over-current Protection;
 7, 8, 9-----Overload Protection;
 10-----Non-electrical Protection;

8. Conclusion

Substation plays the role of transforming and distributing energy, which requires that the primary design part of substation should be economical and reasonable, and the secondary design part should be safe and reliable. The operation and capacity of substations directly affect the power supply of lower loads, and then affect industrial production and people's daily life. Various protection devices are installed in the high-voltage distribution room, transformer room, low-voltage distribution room and other parts of the 110KV step-down substation. In case of failure, the system can automatically make judgment and start corresponding protection, and the automatic re-closing device in the system will quickly switch on to restore power supply.

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