Electrical Design of a Step-down Substation of the Motor Repair Factory

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ABSTRACT

Electric energy is generated by power plants, which is converted from primary energy in nature, and then converted into other forms of energy for power users. Substation is an important intermediate link between power plant and power user in power system. It is composed of power transformer and distribution device, which can change voltage, exchange and distribute energy. Its operation directly affects the reliable and economic operation of the power system.

This research is mainly aimed at the power supply and distribution design of motor repair plant. Through the combination of the materials provided, the overall design and detailed analysis are carried out. Mainly includes: load calculation and reactive power compensation, determination of substation location, selection of main transformer capacity, selection of transformer in workshop, determination of main wiring scheme, calculation of short-circuit current, selection and verification of primary equipment in substation. Finally, in order to ensure the safety, reliability and economic operation of the primary system, the substation installed relay protection devices, and according to the needs of the substation lightning protection to ensure safe power supply and distribution. The design results can meet the reliability of power supply in factories and ensure the stable operation of electrical equipment in each workshop.

Keywords: Substation, Load Calculation, Main Wiring, Short Circuit Calculation, Equipment Selection

1. Introduction

With the development of science and technology, the electric power industry, as the foundation and pioneer of modern industrial development, has also made great progress. With the increasing demand for electricity, power technology and power industry are further developing towards the direction of high voltage, large generating units and large power grid[1,2]. Because of the emergence of large power grids, the experience of power industry development and operation around the world shows that the larger the power system, the more rational and optimized the dispatching operation, the better the economic benefits, and the stronger the ability to respond to accidents. Therefore, many developed countries'power systems have been united into a unified national power system, or even into a transnational power system[3,4].

Factory power supply system is to reduce the voltage of power system, and then distribute the

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power to each workshop or workshop. Factory power supply system consists of factory step-down substation, high-voltage distribution line, workshop substation, low-voltage distribution line and electrical equipment. The design of plant total step-down substation and distribution system is to solve the problem of safe, reliable, economic and technological distribution of electric energy for each department according to the demand of production process for load quantity and property of each workshop, and load layout, combined with the actual power supply situation of power grid. Its basic content includes the following aspects: the selection of the input voltage, including the electrical design of the substation location, the calculation of short-circuit current and relay protection, the selection of electrical equipment, the selection of substation location and the number and capacity of transformers in workshop, the design of lightning protection grounding device, etc[5,6].

35 kV substation is an important link of power distribution and also a key link of power grid construction. The quality of substation design is directly related to the security, stability, flexibility and economic operation of power system. In order to meet the increasing demand of urban load and improve the reliability and power quality of power supply to users. With the development of national economy and the need for the growth of industrial and agricultural production, it is urgent to increase the power supply capacity. Electrical main wiring is the main link of substation in power plant. The formulation of main electrical wiring is directly related to the selection of electrical equipment, the layout of distribution devices, the determination of relay protection and automatic devices, and is the decisive factor of the investment in the electrical part of substation. With the development and progress of substation integrated automation technology, substation integrated automation system replaces or updates the traditional substation secondary system, and then realizes "unattended" substation has become a new development direction and trend of power system[7,8].

2. Design Requirements and Information

According to the principles, contents and design process that must be followed in the power supply design of the factory, this study designs the substation of the electrical machinery repair plant. The motor repair plant undertakes the repair and manufacture of the motor and transformer in the affiliated factories of the large-scale iron and steel complex. The annual production scale of the motor repair plant is 7 500 motors, with a total capacity of 450,000 kW, a total capacity of 60,000 kW, a maximum capacity of 5000 kW, 500 transformers and 600,000 electrical equipment.The general plan of the motor repair plant is shown in figure 1.

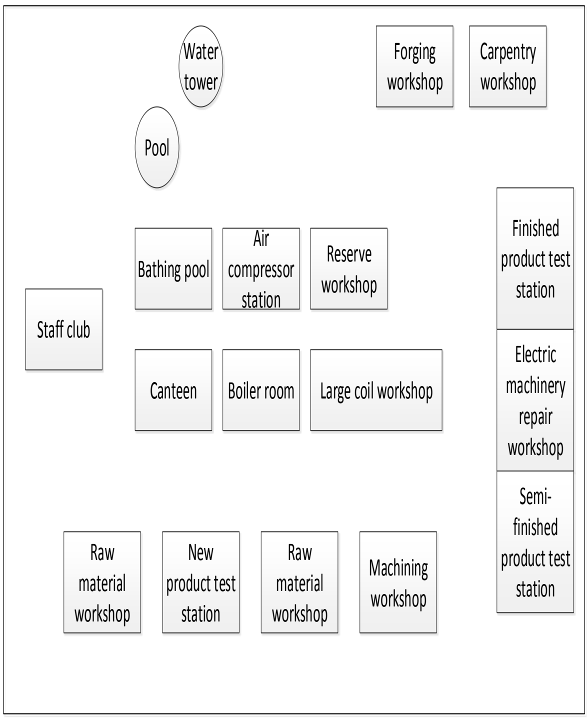

Figure 1: General plan of motor repair plant

The load of each workshop in the factory is shown in table 1.

Table 1 Generator data of the system.

Shop name	Equipment capacity (kW)	K_d	$cos\varphi$	$tan\varphi$
Electric machinery repair workshop	2505	0.24	0.77	0.82
Processing workshop	886	0.18	0.53	1.58
New workshop	634	0.35	0.55	1.51
Raw material workshop	514	0.6	0.86	0.59
Spare parts workshop	562	0.35	0.78	0.79
Forging workshop	150	0.24	0.53	1.61
Boiler room	269	0.73	0.75	0.87
Air compressor station	322	0.56	0.75	0.88
Garage	543	0.57	0.75	0.9
Large Coil Workshop	335	0.56	0.85	0.63
Semi-finished product test station	—	0.63	0.79	0.79
Finished product test station	2290	0.28	0.80	0.75

The 220/35 kV regional substation provided by the local power supply department provides power for the factory, which is 4.5 kilometers south of the factory.Short circuit data of power system are shown in table 2.

Table 2 Short circuit data of power system.

System operation mode	Short circuit data of the system
Maximum operating mode of the system	$S_{k\max}^{(3)} = 600$MVA
Minimum operating mode of the system.	$S_{k\max}^{(3)} = 280$MVA

The power supply system diagram is shown in figure 2.

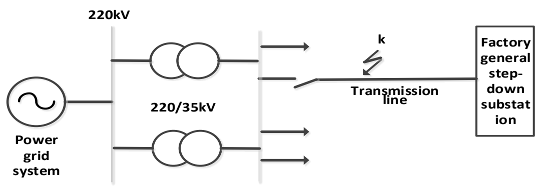

Figure 2: Power supply system diagram

The main technical requirements put forward by the power supply department to the factory are as follows: the setting time of overcurrent protection for 35 kV feeder of regional substation is 1.8 s, the setting time of overcurrent protection for total step-down substation is not more than 1.3 s, and the power factor value should be above 0.9 at the maximum load of the factory.

The annual maximum active load utilization hours of the plant are 2200h. The transformer in the boiler room is used for high-pressure steam for production. Power failure will cause danger to the boiler. Because the factory is far from the city, fire water needs to be supplied by the factory itself. Therefore, high reliability of power supply is required.

3. Load Calculation and Reactive Power Compensation

3.1 Computational Load

Calculating load is the basis for selecting rated parameters and types of user power supply system structure design, power supply lines, transformer number and capacity, electrical equipment, etc. to ensure the normal operation of the system. It is of great significance to reasonably determine the calculated load of user power system at all levels. The calculated load is the maximum imaginary load determined and expected to remain unchanged according to the installed capacity of electrical equipment provided by known factories. In distribution design, the maximum average load of half an hour is usually used as the basis for selecting electrical appliances or conductors according to heating conditions[9].

The electrical machinery repair workshop and boiler room are primary loads in the important electrical equipment of the plant. Because the primary load is an important load, if the power supply is interrupted, the consequences are very serious, so two power supply is required. The test station, the mechanical processing workshop and the new product trial production workshop are secondary loads. Secondary load is also an important load, which requires power supply from two loops[10]. There should also be two transformers for power supply. The other three loads have no special requirements for power supply.

The commonly used methods to determine the calculation load include the need coefficient method, the binomial coefficient method, the use coefficient method and the unit product power consumption method, etc[11]. According to the location of workshop substation and its calculation load in the known plant plan, some workshops are merged appropriately. Finally, it is merged into six factories. The substations in No. 1 and No. 2 are located in each workshop, the substations in No. 3 are located in the mechanical processing workshop, the substations in No. 4 are located in the new product test station, the substations in No. 5 are located in the spare parts workshop, and the substations in No. 6 are located in the finished product test station.

(1) The determination of calculating load for single set of electrical equipment.

Active power calculation load is:

$$P_{30} = K_d P_e \tag{1}$$

In the above formula, P_e is the capacity of the device.

The reactive power calculation load is:

$$Q_{30} = P_{30} \tan\varphi \tag{2}$$

In the above formula, φ is the power factor angle.

Considering the calculation load as:

$$S_{30} = \sqrt{P_{30}^2 + Q_{30}^2} \tag{3}$$

The calculated current is:

$$I_{30} = \frac{S_{30}}{\sqrt{3}U_N} \tag{4}$$

(2) The determination of the calculation load of multiple sets of electrical equipment.

Active power calculation load is:

$$P_{30} = K\sum P_{30i} \tag{5}$$

The reactive power calculation load is:

$$Q_{30} = K\sum Q_{30i} \tag{6}$$

In the above formula, K is generally 0.85 - 0.95.

Considering the calculation load as:

$$S_{30} = \sqrt{P_{30}^2 + Q_{30}^2} \tag{7}$$

According to the above formulas, the calculation of variable load in each plant area is summarized as shown in table 3 below.

Table 3 Computational load summary for each workshop of the factory. (K =0.9)

Shop name	$\cos\varphi$	Equipment capacity (kW)	P_{30} (kW)	Q_{30} (kvar)	S_{30} (kWA)	I_{30} (A)
Electric machinery repair workshop	0.77	2505	609	500	788	1197
Semi-finished product test station	0.79	—	365	287	464	705
Machining workshop	0.73	886	163	258	305	884
Raw material workshop		514	310	183	360	
Subtotal		1400	426	397	582	
New product trial workshop	0.64	634	222	336	403	955
Boiler room		269	197	172	262	
Garage		543	30	27	40	
Subtotal		1446	404	482	628.6	
Air compressor station	0.79	322	181	159	241	972
Large coil workshop		335	187	118	221	
Spare parts workshop		562	199	158	254	
Subtotal		1219	506	3912	639.6	
Finished	0.78	2290	640	480	800	1181

product test station						
Forging workshop		105	36	58	68	
Subtotal		2395	608	484	777.6	
Total	0.75	8965	2918	2541	3870	5880

3.2 Reactive Power Compensation

In the industrial power supply system, most of the electrical equipment is inductive load. They not only need to absorb the active power of the system, but also absorb the reactive power of the system. Therefore, in the case of transmitting a certain amount of active power, the increase of reactive power will lead to the increase of power loss, affect the voltage quality and increase the cost of power generation. In order to save electric energy, improve the utilization of transformer and distribution equipment and improve power quality, it is necessary to reduce the adverse effects of reactive power[12]. Therefore, it is necessary to install reactive power compensation equipment. Because the power factor of the low voltage side of the total step-down substation is 0.75, and the power supply department requires that the power factor should not be less than 0.9, it is necessary to compensate the reactive power of the system so as to improve the power factor of the factory. There are mainly two kinds of artificial compensation devices for reactive power: synchronous compensator and shunt capacitor. Because shunt capacitor has the advantages of simple installation, convenient operation and maintenance, small active power loss, flexible assembly and convenient expansion, shunt capacitor is chosen[13].

The selection and calculation of shunt capacitors are carried out according to the active power calculation load and the required power factor. The power factor of low voltage side compensation is selected as 0.92 in this study. The types of shunt capacitors selected are BWF6.3-25-1. The formula for calculating reactive power compensation capacity is as follows:

$$Q_C = P_{30}\left(\tan\varphi_1 - \tan\varphi_2\right) \tag{8}$$

In the above formula, P_{30} is the factory active power calculation load; $\tan\varphi_1$ corresponds to the tangent of the power factor $\cos\varphi_1$ before compensation; $\tan\varphi_2$ corresponds to the tangent of the power factor $\cos\varphi_2$ after compensation.

Taking workshop No. 1 as an example, Q_{30}=245.2kvar can be obtained from the same calculation process in other workshops. The number of shunt capacitors $n = Q_C / qC = 245.2/25 = 11.9$. Since the capacitor is single-phase, it should be multiplied by 3, and take 12 just right. The actual compensation capacity is 250 kvar, and the calculated load after compensation is $P_{30} = 609\text{kW}$, $Q_{30} = 250\text{kvar}$, $S_{30} = 658\text{kVA}$.

The reactive power compensation and the load calculation after compensation are shown in Table 4.

Table 4 Load calculation after reactive power compensation.

Category	$\cos\varphi$	Active load（kW）	Reactive load（kvar）	Apparent load（kWA）
380V side compensates the preload	0.75	2918	2540	3870
380V side compensation afterload	0.94	2918	1415	3248
380V side transformer power loss	—	$0.015S_{30}$ =48.7	$0.06S_{30}$ =197	—
Total load of 10kV side	0.93	2966.7	1612	3376.3
Power loss of 10kV side transformer	—	$0.015S_{30}$ =44.5	$0.06S_{30}$ =96.72	—
35kV side	0.91	2922.2	1515.28	3291

It can be seen that the power factor after compensation is 0.91 > 0.9, which meets the requirements of power supply.

4. Selection of Substation Location and Transformer Capacity

4.1 Selection of Substation Location

The substation should be located as close as possible to the plant's load center. The load center of the factory can be determined by the method of load power moment. On the lower and left sides of the plan of the factory, the X and Y axes of the rectangular coordinate table are made respectively, and then the coordinate positions of the load points in each workshop and dormitory area are measured.

The plant's load center is assumed to be P(x, y), where $P = P_1 + P_2 + P_3 + ... = P_i$. Among them:

$$x = \frac{p_1 y_1 + p_2 y_2 + p_3 y_3 + \dots}{p_1 + p_2 + p_3 + \dots} = \frac{\sum (p_i y_i)}{\sum p_i} \tag{9}$$

$$y = \frac{p_1 x_1 + p_2 x_2 + p_3 x_3 + \dots}{p_1 + p_2 + p_3 + \dots} = \frac{\sum (p_i x_i)}{\sum p_i} \tag{10}$$

The coordinate position of each workshop load area can be measured by the plan of the motor repair plant as follows.

$$\begin{aligned} &p_1(x_1,y_1)=(11,5.5) \\ &p_2(x_2,y_2)=(11,3) \\ &p_3(x_3,y_3)=(9.5,3.5) \\ &p_4(x_4,y_4)=(6,3.5) \\ &p_5(x_5,y_5)=(6.5,4.5) \\ &p_6(x_6,y_6)=(11,7.5) \end{aligned} \tag{14}$$

By substituting the above data into formulas 9 and 10, we can get x = 9.4 and y = 5.7.The factory's load center is almost certainly near the finished product test station.

According to the situation of power supply, considering that the location of substation should be close to the load center, in order to meet the convenience of inbound and outbound lines, transportation equipment, comprehensive calculation results and the selection principle of load center, it is finally determined that the load center of the factory is on the west side of the finished product test room, and the load center is on the east side of the accumulated water areas such as water towers and pools. At the same time, the load center is located in the south side of the plant, which is supplied by a regional substation 4.5 kilometers from the south side of the plant, which meets the principle of convenient access. At the same time, the load center basically meets the general principle of substation location selection. Therefore, the total step-down substation is located on the southeast side of the finished product test station. Therefore, the location of the substation of the selected motor repair plant is shown in figure 3 below. The location of the selected plant substation is indicated in the figure.

According to the load situation of each workshop, we plan to set up six workshop substations, and two transformers are installed in each workshop substation. According to the workshop distribution and load situation provided by the layout plan of the plant area, the location of the substation is determined in combination with other selection principles and other related aspects. The location of the substation is also marked in figure 3.

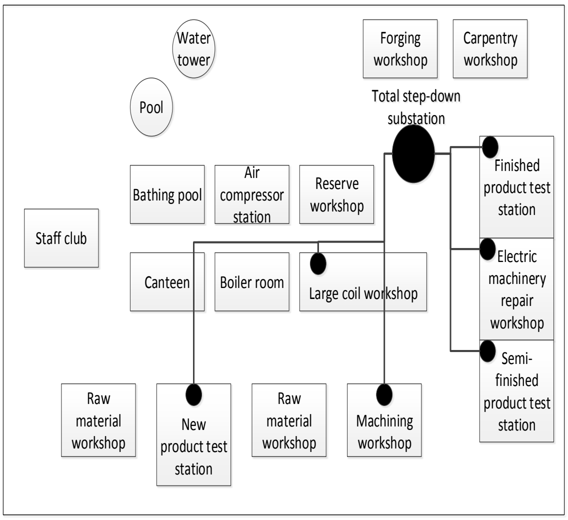

Figure 3: Location of substations in motor repair plant

35kV substation is divided into indoor and outdoor type, which is easy to operate and maintain and occupies less space, so we adopt indoor type. According to the specific geographical environment of the factory, the 10kV substation can choose the indoor operation and maintenance conveniently and occupy less space according to local conditions.

4.2 Selection of Transformer Capacity in Total Step-down Substation

Factory power supply is introduced from 220/35 kV substation of electrical system to 35 kV double circuit overhead line. The plant has a large number of secondary loads and a small number of primary loads. In order to ensure the reliability of power supply, two main transformers should be adopted so that when one transformer fails, another transformer can continue to supply power for these important loads[14].

For substations equipped with two main transformers, the capacity of each transformer should satisfy the following conditions at the same time: when any transformer runs alone, $S_{NT} \geqslant (0.6 \sim 0.7) S_{30}$; when any transformer runs alone, $S_{NT} \geqslant S_{30(I+II)}$. Based on the above conditions and the design of the main wiring scheme of the substation, two main transformers of 2500 kVA are selected, and the SCB10 series 35 kV power transformers of Schneider Electric Company are selected as the models. The connection groups are all Dyn11. The series belongs to resin cast dry-type transformers with low loss and low noise.

Table 5 Technical parameters of SCB10 series 35kV transformer.

Rated capacity (kVA)	Connection group	No-load Loss (W)	U_k%	I_0%
2500	Dyn11	4460	6	0.5

4.3 Selection of Transformer Capacity in Workshop Substation

According to the calculation load of each workshop calculated before, two transformers with 630 kVA capacity are selected in workshop 1 and 6, two transformers with 400 kVA capacity are selected in workshop 2, 3 and 4, and two transformers with 500 kVA capacity are selected in workshop 5. SCBH15 series are selected in workshop transformers. The technical parameters are listed in table 6 below. Dyn11 is used in connection group.

Table 6 Technical parameters of SCBH15 series 10 kV distribution transformer.

Rated capacity (kVA)	400	500	630
Connection group	Dyn11	Dyn11	Dyn11
No-load Loss (W)	310	360	410
U_k%	4	4	6
I_0%	0.6	0.6	0.5

5. Design of Electrical Connection for Total Step-down Substation

The main wiring of the total buck substation consists of various power equipment such as transformers, arresters, circuit breakers, transformers, disconnecting switches and their connecting wires. The selection of main wiring is closely related to the equipment selection, normal operation of the substation, relay protection and control mode. It is an important part of the power supply design. According to the comprehensive factor analysis, it is also necessary to meet the requirements of safety, reliability, flexibility and economy.

For 35 kV power supply plant, it is necessary to first pass through the total step-down substation to reduce the high voltage distribution voltage to 10 kV, and then through the workshop substation to reduce the 380 V voltage required for general low voltage equipment. The main transformer of the total step-down substation is connected with the primary side of 35 kV, and the secondary side is connected by a single bus section[15,16].

In order to facilitate maintenance, operation, control and management, high-voltage circuit breakers are installed at the high-voltage side of transformers. Because 10 kV lines are not allowed to be put into operation at ordinary times, the standby 10 kV power supply circuit breakers must be disconnected in normal operation. The secondary side of transformer is equipped with a few oil circuit breakers, and an automatic switching device of standby power supply is composed of a 10 kV standby power supply circuit breaker. When the working power supply loses its working voltage, the standby power supply is put into operation automatically immediately. The main transformer's secondary side 10 kV bus is connected by single busbar, the transformer's secondary side 10 kV bus is connected by main busbar, the 10 kV standby power supply is connected by the second busbar, the bus section breaker closes in normal operation, and the important load can be connected to the second busbar, so that the power supply of the important load will not be affected when the power supply stops. According to the load situation of each workshop, the 10kV side outgoing line goes through the cable to each factory area, and there are two GG-1A-J cabinets and two GG-1A-(F) cabinets, which have higher power supply stability.The following figure shows the main wiring scheme of 35 kV total step-down substation.

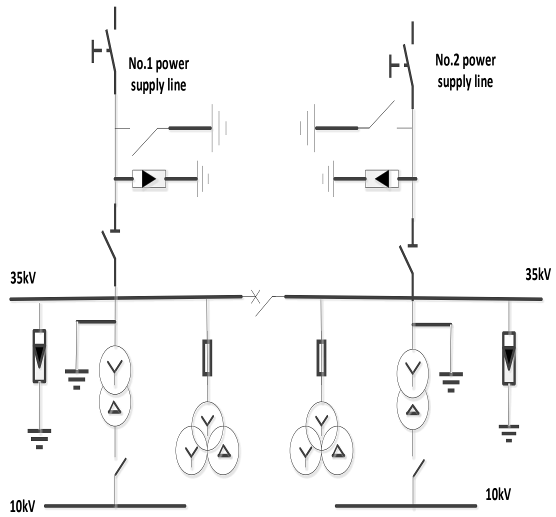

Figure 4: Main wiring scheme of 35kV total step-down substation

6. Calculation of Short Circuit Current

Short-circuit is one of the most serious and common faults in power system. The consequences caused by short-circuit are often destructive. It will not only affect the normal operation of electrical equipment, cause equipment damage, but also cause large-scale blackouts. The results of short-circuit calculation must be taken as the basis for the design and operation of power system, so short-circuit calculation is very important[17].

For general factories, the direction of power supply can be regarded as an infinite capacity power system, whose basic characteristic is that bus voltage can be considered to remain unchanged[18]. There are many short-circuit calculation methods for infinite capacity system. Taking the first workshop as an example, the equivalent circuit for calculating short-circuit current is shown in figure 5.

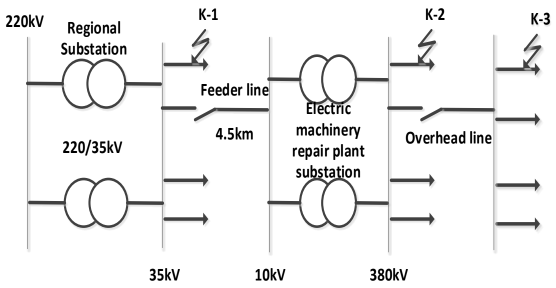

Figure 5: The equivalent circuit for calculating short circuit current

Select the reference capacity $S_d = 100\text{MVA}$, reference voltage $U_{d1} = 37\text{kV}$, $U_{d2} = 10.5\text{kV}$, $U_{d3} = 0.4\text{kV}$. The reference current is derived from the formula:

$$I_{d_i} = \frac{S_d}{\sqrt{3}U_{di}} \tag{15}$$

Calculate the reactance of the power system:

$$S_{k\ \max} = 600\text{MVA}$$
$$X_{L\min} = \frac{S_d}{S_{k\ \max}} = \frac{100}{600} \approx 0.17 \tag{16}$$

$$S_{k\ \min} = 280\text{MVA}$$
$$X_{L\max} = \frac{S_d}{S_{k\ \min}} = \frac{100}{600} \approx 0.17 \tag{17}$$

According to $X_0 = 0.4\Omega/\text{km}$, the reactance of each overhead line is calculated.Then, the three-phase short-circuit current and the three-phase short-circuit capacity under k-1, k-2 and k-3 short-circuit conditions are calculated according to the equivalent circuit under the maximum operation mode and the minimum operation mode respectively. The results are shown in table 7.

Table 7 Calculation results of k-1, k-2 and k-3 point short circuit.

Short circuit calculation point	System operation mode	Three-phase short circuit current (kA)					Three-phase short circuit capacity (MVA)
		$I_k^{(3)}$	$I''^{(3)}$	$I_\infty^{(3)}$	$i_{sh}^{(3)}$	$I_{sh}^{(3)}$	
k-1	Maximum	5.18	5.18	5.18	13.21	7.82	332.2
	Minimum	3.18	3.18	3.18	8.11	4.8	203.67
k-2	Maximum	5.0	5.0	5.0	9.2	5.45	90.83
	Minimum	4.26	4.26	4.26	7.84	4.63	77.46
k-3	Maximum	20.32	20.32	20.32	37.39	22.51	14.08
	Minimum	19.79	19.79	19.79	36.41	21.57	13.72

7. Selection and Verification of Primary Equipment

In order to ensure the safe and reliable operation of primary equipment, it is necessary to select and verify the primary equipment according to the following conditions:

(1)According to the normal working conditions of the voltage, current, frequency and breaking current selection.

(2)According to the short circuit condition, including dynamic stability and thermal stability, the test is carried out.

(3) Consider the environmental conditions such as temperature, moderation, altitude, height, dust-proof, anti-corrosion, fire-proof, explosion -proof and so on.

7.1 ChooseAccording to Normal Working Conditions

According to the normal working conditions, it refers to the selection of conductors and electrical equipment according to the installation location, use conditions, convenience of maintenance, operation safety and environmental conditions[19,20].

(1)Selection according to working voltage: The rated voltage of equipment should not be less than the rated voltage of the system.

(2)Selection according to working current: The rated switching current of the equipment should not be less than the calculated current of the circuit in which it is located.

(3) Selection according to breaking capacity: The rated breaking current or breaking capacity of the equipment should not be less than the maximum effective value of short circuit current or short circuit capacity that it may break.

7.2 Check According to Short Circuit Condition

Short-circuit condition checking is to check the dynamic and thermal stability of electrical appliances and conductors during short-circuit.

(1)Short-circuit stability check of disconnector, load switch and circuit breaker.

Dynamic stability check conditions:

$$I_{\max} \geq I_{sh}^{(3)} \qquad (18)$$

In the above formula, $I_{\max}$ is the effective value of the current through which the limit of the switch passes. $I_{sh}^{(3)}$ is the effective value of three-phase short-circuit impulse current at the switch.

Calibration conditions for thermal stability:

$$I_t^2 t \geqslant I_{\infty}^{(3)^2} t_{ima} \qquad (19)$$

Among them, I_t is the effective value of the thermal stability current of the switch; t is the thermal stability test time of the switch; $I_{\infty}^{(3)}$ is the three-phase short-circuit steady-state current of the switch; t_{ima} is the hypothetical short-circuit heating time.

(2)Short-circuit stability check of current transformer.

Dynamic stability check conditions:

$$i_{\max} \geqslant i_{sh}^{(3)} \qquad (20)$$

Calibration conditions for thermal stability:

$$(K_t I_t)^2 t \geqslant I_{\infty}^{(3)^2} t_{ima} \qquad (21)$$

Among them, I_t is the effective value of the thermal stability current of the current transformer; t is the thermal stability test time of the current transformer; and K_t is the dynamic stability current multiple of the current transformer.

(3) Short-circuit stability check of busbar.

Dynamic stability check conditions:

$$\sigma_{a1} \geqslant \sigma_c \qquad (22)$$

Among them, σ_{a1} is the maximum allowable stress of bus material and σ_c is the maximum computational stress when bus passes through $I_{sh}^{(3)}$.

Calibration conditions for thermal stability:

$$A \geqslant A_{\min} = I_{\infty}^{(3)} \frac{\sqrt{t_{ima}}}{C} \qquad (23)$$

Among them, A is the bus cross-section area; $A_{\min}$ is the minimum cross-section area to meet the short-circuit thermal stability condition; C is the bus material thermal stability factor; $I_{\infty}^{(3)}$ is the bus through three-phase short-circuit steady-state current.

8. Design of Relay Protection and Lightning Protection in Substation

8.1 Relay Protection of Substation

Due to the natural environment, operation and maintenance level and other reasons, various electrical components in the system may have various faults and abnormal operation status, so special technology is needed to establish a security guarantee system[21]. The fault protection device operates during the action and will not malfunction when the action should not be taken. For this reason, the relay protection device should be simple and reliable, use fewer components and contacts, make the connection stress simple, and operate and maintain conveniently. When the fault occurs, the protection device of the fault element itself is used to remove the fault. When the protection of the fault element itself refuses to move, the fault should be removed by the protection of the adjacent elements. According to the need, relay protection devices are installed under the total step-down substation: main transformer protection, 10 kV feeder line protection, standby power supply line protection and 35 kV bus protection.

8.2 Lightning Protection of Substation

(1)Lightning rods should be installed in substations and their outdoor distribution devices to protect against direct lightning strikes. A lightning rod or lightning belt is installed on the roof of the substation, and two grounding wires are connected with the common grounding device of the substation. The lightning rod is made of galvanized round steel with a diameter of 20 mm and the lightning belt is made of galvanized flat steel with a diameter of 25 mm×4 mm. Because it is the first type of lightning protection building, the grid size of the overhead lightning protection network should not be greater than 5 m×5 m or 6 m×4 m.

(2)YH5WZ-54/134 valve arrester is installed on the terminal pole of high-voltage overhead line, and the arrester installed at the terminal of overhead line should be connected with the metal skin at the cable head and grounded together because the factory needs a section of lead-in cable. Its lead line is made of 25 mm×4 mm galvanized flat steel, which is connected to the public grounding grid below and bolted to the grounding end of the arrester above.

(3) Valve arresters shall be installed on each set of high voltage buses. All valve arresters in substations shall be connected to the main grounding grid of distribution devices with the shortest grounding wire. The substation adopts metal oxide valve arrester of power station type. DNF7-40.5-56 high-voltage switchgear installed in 35 kV high-voltage distribution room is equipped with YH5WZ-54/134 lightning arrester near the main transformer. The main transformer mainly relies on this lightning arrester to protect against the harm of lightning intrusion wave. Hy5WZ2-17/45Q lightning arrester is used in KGN16-12-10 high voltage switchgear installed in 6kV high voltage distribution room.

(4)On the 380V low-voltage overhead outlet pole, protective clearance is installed or the iron foot of its insulator is grounded to protect thunder and lightning waves invading along the low-voltage overhead line.

9. Conclusion

According to the principles, contents and design process that must be followed in the power supply design of the factory, this research designs the substation of the electrical machinery repair plant.Firstly, load statistics and reactive power compensation are carried out according to the data. According to the results of load calculation, the capacity and number of transformers in main transformer and workshop are selected. In order to ensure the reliability of the power supply system, the main connection adopts the single bus sectional connection mode. This design calculates the short-circuit current, and chooses and verifies the primary equipment according to the relevant data.Finally, relay protection and lightning protection design are carried out to ensure the reliability of power supply.

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