

# The calculation of short-circuit current in the electrical design of traction substation

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**Keywords:** short-circuit current, traction substation, traction substation.

**Abstract.** This paper mainly studies the calculation of short-circuit current in the electrical design of a domestic electrified railway traction substation power supply system. The choice of short-circuit point depends on the main transformer capacity that determined according to the traction substation main connection mode and load calculation results, calculation of short-circuit current, Completed the main electrical equipment and selection of busbar according to the results of the short circuit calculation.

## 1. Introduction

The power supply system of electrified railway traction substation that we studied in this paper, use the AT power supply mode, it is double line, section of ascending and descending parallel power supply. Combined with the actual situation of substation, the choice of connection mode is feeder circuit breaker 50% spare. Because of the 220/10kV distribution substation built with the substation together, leads to two private electricity transformers from 10 kv bus bar for the needs of the resources reasonable use and safety of power supply. Traction transformer capacity should be able to bear the maximum load of substation, and meet the requirements of railway transport normal, therefore chooses four 50000 kva single-phase traction transformer.

According to JB/T 10776-10776, choose D-QY50000 traction transformer, its parameters are shown in table 1.

Table 1 The parameters of single-phase traction transformer

High Voltage (kV)	Low Voltage (kV)	Connection Symbol	No-load loss (kW)	Load loss (kW)	No-load Current	Short-circuit Impedance
220±2×2.5%	27.5	Ii0	40	154	0.6%	12%

## 2. The required raw materials for Calculate

Feeding section1—— $n=3.5$ ,  $N=140\text{pair/day}$ ,  $N_{1k}=180\text{pair/day}$ ;

Feeding section2—— $n=3.8$ ,  $N=150\text{pair/day}$ ,  $N_{1k}=200\text{pair/day}$ ;

$n$ —— interval number;

$N$ ——The train logarithm of the feeding section;

$N_{1k}$ ——Maximum number of train.

The rest of the original calculation data are shown in table 2.

Table 2 The required raw materials for Calculate

Feeding section	The total running time $\sum t(\text{min})$		Electricity running time $\sum t_g(\text{min})$		The energy consumption of train in $\sum t(\sum t_g)$ $\sum A(\text{kVA.h})$	
	up train	down train	up train	down train	up train	down train
1	15.5	15	10.8	10.5	2380	2498
2	16.2	15.5	11.2	10.8	2450	2492

### 3. Calculation of short-circuit current

Short circuit is a low impedance short sub on conductive part of different potential, includes conductive parts to ground between subs. The main purpose of the calculation of short-circuit current is complete electrical equipment selection and busbar selection, In this design, the calculation of short-circuit current in accordance with the three phase short circuit calculation, and assumes that the system for the infinite power[1].

Unit reactance of transmission lines  $x_1 = 0.4\Omega/\text{km}$ , Base Capacity  $S_B = 100\text{MVA}$ , reference voltage  $U_B = U_{\text{av.n}}$  (Average voltage rating of power lines).

#### (1) Equivalent circuit diagram and the calculation of each component reactance

Network diagram of this design is simplified according to the main connection mode selection and operation mode for a long time, draw the network diagram as shown in figure 1, T1, T2 are the two 50 mva single-phase traction transformer in figure.

First of all, short-circuit point selection, according to the analysis can select k1, k2 two short-circuit point to calculate short circuit current, as shown in figure 1. 220 kv side USES is a bridge connection, when the switch is closed, when run in parallel with two way power supply, it is the largest operation mode, simplified equivalent calculation of network diagram is shown in figure 2.

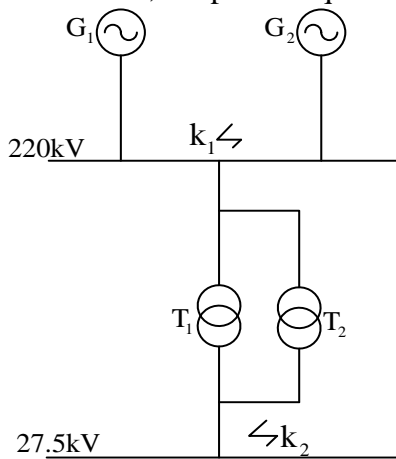


Fig.1 Short circuit network wiring diagram

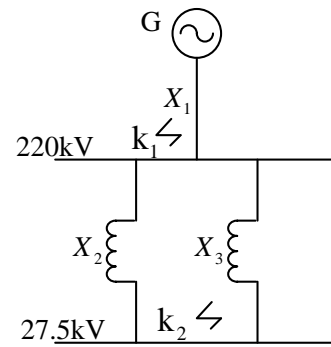


Fig.2 Equivalent network diagram

According to the provisions in China standard, take 220 kv voltage benchmark of  $U_{B1}=230\text{kV}$ . Set G1, G2 short-circuit point from k1 distance of  $l_1=l_2=100\text{km}$ , The MAO value of linear reactance is:

$$X_1^* = X_2^* = x_1 l_1 \frac{S_B}{U_{B1}^2} = 0.4 \times 100 \times \frac{100}{230^2} = 0.08$$

Above formula:  $x_1$  —— Line reactance,  $\Omega/\text{m}$ ;

$l$  —— line length, m.

#### (2) The calculation of short-circuit current

① The calculation of short-circuit current of k1 point

The current benchmark is:

$$I_{B1} = \frac{S_B}{\sqrt{3}U_{B1}} = \frac{100}{\sqrt{3} \times 230} = 0.25 \text{ (kA)}$$

Above formula:  $S_B$  —— Three-phase power value, Generally take 100MVA;

$U_B$  —— Voltage reference value, kV.

The MAO value of total reactance:

$$X_{\Sigma 1}^* = X_1^* // X_2^* = \frac{0.08}{2} = 0.04$$

The MAO value of three phase short circuit current cycle componen:

$$I_{k1}^* = \frac{1}{X_{\Sigma 1}^*} = 25$$

Impact currentFor of three-phase short-circuit:

$$i_{\text{imp}} = 2.55I_{k2} = 15.94 \text{ (kA)}$$

Maximum RMS of the three-phase short-circuit current:

$$I_{\text{imp}} = 1.52I_{k2} = 9.5 \text{ (kA)}$$

Maximum continuous working current:

$$I_{\text{gmax}} = 1.05 \frac{S_N}{\sqrt{3}U_N} = 1.05 \frac{(50+50) \times 10^3}{\sqrt{3} \times 220} = 275.6 \text{ (A)}$$

② The calculation of short-circuit current of k2 point

Approximate equivalent circuit of V/X wiring traction transformer as shown in figure 3 (a), Y type equivalent circuit as shown in figure 3 (b)

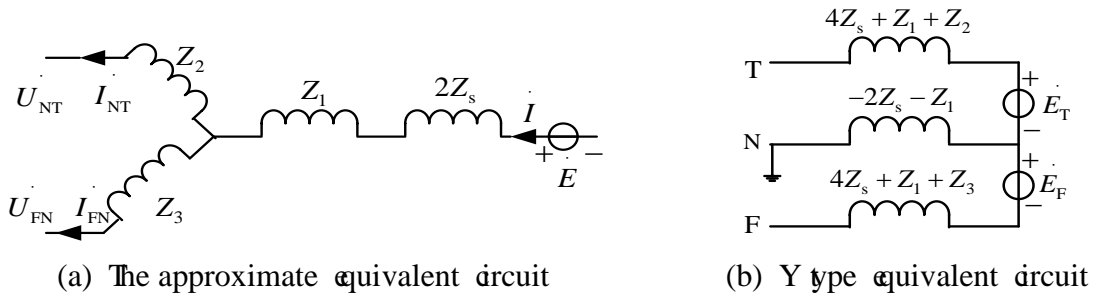


Fig.3 Equivalent circuit of V/X wiring traction transformer

$$\text{System impedance: } Z_s = Z_s^* \cdot \frac{U_{B2}^2}{S_B} = X_{\Sigma 1}^* \cdot \frac{U_{B2}^2}{S_B} = 0.04 \frac{27.5^2}{100} = 0.3 \text{ (}\Omega\text{)}$$

Analyzing the characteristics of the V/X wiring traction transformer connection, and according to the single-phase traction transformer parameters are known to be elected in table 2:

$$U_{k(1-2)}(\%) = U_{k(1-3)}(\%) = 12$$

Traction transformer primary side after short circuit impedance seen from secondary side is:

$$Z_{12} = X_{12} = \frac{U_{k(1-2)}(\%) \times 27.5^2}{100S_T} = \frac{12 \times 27.5^2}{100 \times 50} = 1.82 \text{ (}\Omega\text{)}$$

Similarly, Traction transformer primary side after short circuit impedance seen from tertiary side is:

$$Z_{13} = X_{13} = \frac{U_{k(1-3)}(\%) \times 27.5^2}{100S_T} = \frac{12 \times 27.5^2}{100 \times 50} = 1.82 \text{ (}\Omega\text{)}$$

When T busbar one-phase ground fault at 27.5 kV side, short circuit current is:

$$I_{\text{dNT}} = \frac{27.5}{2Z_s + Z_1 + Z_2} = \frac{27.5}{2 \times 0.3 + 1.82} = 11.36 \text{ (kA)}$$

When F busbar one-phase ground fault at 27.5 kV side, short circuit current is:

$$I_{dFN} = \frac{27.5}{2Z_s + Z_1 + Z_3} = \frac{27.5}{2Z_s + Z_1} = 11.36 \text{ (kA)}$$

When phase fault between F and T busbar at 27.5 kV side, short circuit current is:

$$I_{dTF} = \frac{55}{8Z_s + 4Z_1 + Z_2 + Z_3} = \frac{27.5}{4Z_s + Z_1 + Z_{12}} < I_{dNT}$$

From the above analysis, When F or T busbar one-phase ground fault at 27.5 kV side, Short circuit current is greater than phase fault between F and T busbar at 27.5 kV side, so  $I_{k2}=I_{dNT}=I_{dFN}=11.36\text{kA}$ .

short circuit impact current is:

$$i_{imp} = 2.55I_{k2} = 28.97 \text{ (kA)}$$

The biggest valid values for short circuit current:

$$I_{imp} = 1.52I_{k2} = 17.27 \text{ (kA)}$$

Maximum continuous working current is:

$$I_{gmax} = 1.05 \frac{S_N}{\sqrt{3}U_N} = 1.05 \frac{(50+50) \times 10^3}{\sqrt{3} \times 27.5} = 2204.4 \text{ (A)}$$

#### 4. Electrical equipment and the choice of bus

According to the actual short circuit state calibration, is to check the thermal stability and dynamic stability of electrical equipment[2]. It is concluded that the choice of the electrical equipment as shown in table 3:

Table 3 Electrical equipment

Electrical Equipment	Type	Model
Primary Cut-Out	Vacuum Circuit Breaker	ZW-2×27.5
High Voltage Isolator	220kV Side Disconnecter	GW4-220
	2×27.5kV Side Disconnecter	GW-2×31.5
Current Transformer	220kV Side Current Transformer	LCWB7-220
	2×27.5kV Side Current Transformer	LDGB-35
Voltage Transformer	220kV Side Voltage Transformer	JDCF-220
	2×27.5kV Side Voltage Transformer	JDZ-27.5

The choice of the bus: LGJ - 95/15 type steel core aluminum stranded wire is chosen as the 220 kv busbar side bridge[3];Choose LF - 21 y type aluminum manganese alloy tubular busbar as 3 2 x 27.5 kV bus side.

#### 5. Summary

According to the result of short circuit calculation, and considering the actual situation of the traction substation, completed the selection of electrical equipment and bus, provide the basis for the whole electrical design of traction substation of electrified railway power supply system.

#### References

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- [3] IEEE Guide for Measuring Earth Resistivity, Ground Impedance and Earth Potentials of a Ground System, IEEE Standard 81, 1983.