

# The Research on Neutral Grounding Scheme of Fengxian 35 kV and 10 kV Power Grid

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## ABSTRACT

Combined with actual situation of Fengxian power Supply Company, the neutral grounding modes of Fengxian 35 kV and 10 kV power grid are studied in the paper. The different frequencies injected method is used to measure the capacitive current of Fengxian 28 substations, and the neutral grounding modes of the 28 substations are determined based on the measured values of capacitive current.

**Keywords:** Neutral Grounding Mode; Different Frequency Injected Method; Capacitive Current; Arc Suppression Coil; Low Resistance

## 1. Introduction

Shanghai fengxian power grid has eight 35 kV transformer substations and forty 10 kV transformer substations. The neutral grounding modes of these substations include: ungrounded, grounded via arc-suppression coil and grounded via low resistance. Among them, 21 substations such as Qixian station are use ungrounded, 7 substations such as Taidong station are use grounded via arc-suppression coil, and 20 substations such as Zugang station are use grounded via low resistance.

With the increasing of cable line in fengxian 35 kV and 10 kV distribution systems, the capacitive current of single-phase grounding fault is growing, which brings new topic to the choice of neutral grounding mode in Shanghai fengxian distribution network. In this paper, according to the measured value of capacitive current, the 28 substations which use ungrounded and grounded via arc-suppression coil were studied.

## 2. The Analysis of Neutral Grounding Mode in Distribution Network

### 2.1. Common Neutral Grounding Modes

There have four common ground modes in power system: the neutral point directly grounded, grounded via arc-suppression coil, grounded via low resistance and ungrounded. Among them, ungrounded and grounded via high resistance are called as non-effectively grounded system, the neutral point directly grounded and grounded via low resistance are called as effective grounded system [1].

1) Neutral point directly grounded system: the required levels of over-voltage and power transmission equipment insulation are low in neutral-point solid ground system, thereby it can reduce the cost of equipment and line, but the current of single-phase grounding is high at the fault of single-phase grounding, which inevitably lead to the tripping of the circuit breaker and reduce supply continuity, thereby, it reduce supply reliability.

2) Neutral point ungrounded system: the current of single-phase grounding fault is very small in ungrounded system. It can operate with fault for some time in order to find the fault line, thus the reliability of power supply can greatly improve. And the interference with communication lines is low. But it will emerge arc restricting over-voltage, thus it requires a higher level of insulation. If the line is long, grounding capacitive current will be very high that easy to form intermittent arc grounding or stable arc grounding. It requires other neutral grounding modes to avoid the impact on the safe operation of power grid.

3) Neutral point grounded via arc-suppression coil: arc suppression coil is adjustable inductor coil which installs in the neutral point of grid. The inductive current be formed when single-phase ground fault occurs, which close to but direction opposite to grounded capacitor current, so that the current at fault point becomes small or close to zero. According to compensation rate, it can be divided into: under compensation, full compensation and over compensation. In the grid, the over compensation widely use. When single-phase ground fault occurs, this grounding mode can improve the reliability of power

supply, and significantly reduce the current of single-phase grounding fault. So arc at fault point can quickly extinct and prevent over-voltage which due to the intermittent arc.

4) Neutral point grounded via resistance: neutral point grounded via resistance divided into high resistance grounded and low resistance grounded. High resistance grounded is adopted when the current of single phase grounding fault is less than 10 A. This mode can eliminate most of the resonance over-voltage and it are certain restrictions on single-phase intermittent arc grounding overvoltage, but it requires a higher level of insulation; Low resistance grounded is adopted when the current of single phase grounding fault 100 - 1000 A. This mode can remove fault quickly and overvoltage is low, so cable and equipment which insulation level is lower can be used.

### 2.2. Main Factors in the Selection of Neutral Grounding Mode

The selection of neutral grounding mode is a comprehensive question which involves many aspects of power system. The following aspects are mainly considered when select neutral grounding mode [2]:

- 1) The insulation levels of electrical equipment and wiring;
- 2) The reliability of relay protection works;
- 3) Power supply reliability of distribution network;
- 4) The interference on communication and signaling system;
- 5) The influence of over voltage;
- 6) Personal safety.

Combining the actual situation of the grid is the key to selection of neutral grounding mode. For meeting the need of running, it can make timely adjustments according to the development trend of the grid.

### 2.3. Present Situation of the Selection on Neutral Grounding Mode

In the United States grid, neutral point directly grounded and via low resistance have been adopted [3]; In Japan Grid, neutral point grounded via arc-suppression coil, grounded via resistance and ungrounded are commonly used [4, 5]; In Germany, grounded via arc-suppression coil has been widely used before the 1970s, but grounded via resistance is proposed recently. In former Soviet Union and Moscow city, grounded via arc-suppression coil has been used [6, 7].

Most of the domestic provinces and regions remains neutral point grounded via arc-suppression coil. But in recent years, Shanghai Urban Power Supply Company, Guangzhou, Shenzhen, Zhuhai, Suzhou have selected the grounded via low resistance [8].

## 3. The Solution Configuration of Neutral Grounding Modes in Fengxian Power Grid

### 3.1. The Detection Method of Capacitor Current

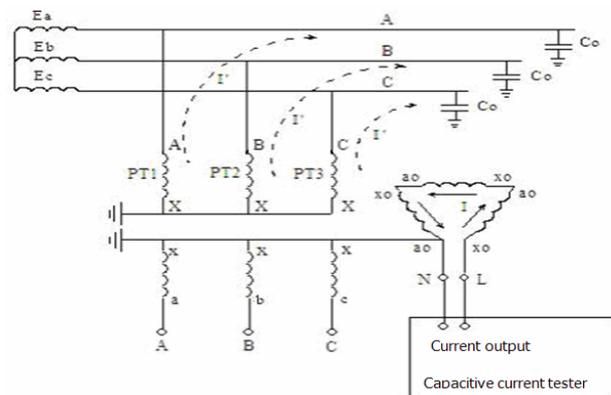
The determination of neutral grounding mode is based on the accurate detection of bus capacitor current. The traditional capacitive current measurement methods have two kinds: direct and indirect methods. The two methods need directly contact with the main circuit of grid, so the operator and the distribution system are not safe, and the operation is more complex. For safely measuring the capacitor current of the neutral point, the measurement method from the secondary side of the grid is proposed, and different frequency injected method to measure the capacitive current is widely used.

Different frequency injection method is injecting weak different frequency test signal from the voltage transformer (PT) triangular openings, and then measuring the voltage magnitude and phase of opening triangular side, thus calculating the capacitive current of power grid. This method reduces the risk of testing, and improves the efficiency of testing [9]. The schematic is shown in **Figure 1**.

In the figure:  $E_a, E_b, E_c$  as the power supply side;  $A_X, B_X, C_X$  as the high voltage windings of bus PT;  $a_x, b_x, c_x$  as the secondary windings of bus PT;  $N, L$  as triangular openings windings;  $C_0$  as capacitance to ground.

### 3.2. The Solution Configuration of Neutral Grounding Modes

In this paper, the determination of measured capacitive current neutral grounding modes is based on the measured capacitive current of 28 substations. According to the regulations: when the capacitor current of 10 kV grid is less than 30 A, or the capacitor current of 35 kV grid is less than 10 A, Neutral point ungrounded is adopted; when the capacitance current of 10 kV grid is greater



**Figure 1. The schematic of different frequency injection method.**

than 30 A, or the capacitance current of 35 kV grid is greater than 10A, grounded via arc-suppression coil is adopted; when capacitor current is greater than 100 A, grounded via low resistance is adopted.

In the Fengxian grid, the substations of neutral point ungrounded are shown in **Table 1**.

As seeing from **Table 1**, the capacitor current of Nongchang station, Qixian station and Qingcun station is less than 30 A, but they are very close to 30 A. When the three substations change the overhead lines to the cable line, or increase line, their capacitance current value may be greater than 30 A, therefore these three substations must be given great attention.

In the Fengxian grid, the substations of neutral point grounded via arc-suppression coil are shown in **Table 2**.

The choice of arc suppression coil capacity is based on present capacitive current of grid, and is taken the development vision for 5-10 years into account.

$$Q = kI_c U_n / \sqrt{3} \quad (1)$$

where,

$Q$  —The compensation capacity of arc suppression coil, KVA;

$k$  — Coefficient;

$I_c$  — The capacitor current of grid circuit, A.

$U_n$  —The nominal voltage of the circuit, kV.

The capacity of arc suppression coil is calculated according to equation (1), and the model of arc suppression coil is selected according to the calculated capacity, as shown in **Table 3**.

For describing the compensation degree of arc suppression coil, it is need to calculate out-of-resonance degree of arc suppression coil. Out-of-resonance degree  $\nu$  is calculated as following:

$$\nu = (I_c - I_L) / I_c * 100\% \quad (2)$$

**Table 1. The substation of neutral point ungrounded.**

No.	Station Name	Capacitive Current(A)
1	Nongchang station(10 kV)	29.68
2	Qixian station(10 kV)	28.12
3	Xiaotang station(10 kV)	17.21
4	Xiaotang station(10 kV)	13.17
5	Qianqiao station(10 kV)	19.56
6	Qingcun station(10 kV)	25.62
7	Liaoyuan station(10 kV)	17.09

**Table 2. The substation of neutral point grounded via arc-suppression coil.**

No.	Station Name	Capacitive Current(A)
1	Pingan station(10 kV)	39.44
2	Mingcheng station(10 kV)	39.68
3	Baishi station(10 kV)	47.19
4	Taidong station(10 kV)	41.49
5	Fengpu station(10 kV)	38.22
6	Fengcheng station(10 kV)	48.44
7	Pengcheng station(10 kV)	54.89
8	Zhangwenmiao station(10 kV)	63.18
9	Yaojiaxiang station(10 kV)	71.27
10	Jingxing station(10 kV)	47.06
11	Wuqiao station(10 kV)	32.66
12	Hongmiao station(10 kV)	44.78
13	Caijian station(10 kV)	35.67
14	Youyi station(10 kV)	74.33

**Table 3. The capacity and the model of arc suppression coil.**

No.	Station Name	Neutral grounding mode in current	The capacity of arc suppression coil (kVA)	The model of arc suppression coil
1	Pingan station	ungrounded	307.4382	2*XDJI-150/10
2	Mingcheng station	ungrounded	309.2958	2*XDJI-150/10
3	Baishi station	ungrounded	367.8045	XDJI-150/10+ XDJI-300/10
4	Taidong station	via arc-suppression coil	323.3696	XDJI-150/10+ XDJI-300/10
5	Fengpu station	via arc-suppression coil	297.9188	2*XDJI-150/10
6	Fengcheng station	ungrounded	377.5265	XDJI-150/10+ XDJI-300/10
7	Pengcheng station	ungrounded	427.8252	XDJI-150/10+ XDJI-300/10
8	Zhangwenmiao station	via arc-suppression coil	492.4212	2*XDJI-300/10
9	Yaojiaxiang station	via arc-suppression coil	555.4687	2*XDJI-300/10
10	Jingxing station	ungrounded	366.7704	XDJI-150/10+ XDJI-300/10
11	Wuqiao station	ungrounded	254.5855	2*XDJI-150/10
12	Hongmiao station	ungrounded	348.9996	XDJI-150/10+ XDJI-300/10
13	Caijian station	Neutral point ungrounded	278.0461	2*XDJI-150/10
14	Youyi station	Neutral point ungrounded	579.345	2*XDJI-300/10

where:  $I_C$  -the capacitive current, A;

$I_L$  -the inductor current of arc suppression coil A.

Under normal circumstances, the neutral point voltage displacement should not exceed 15% of the system phase voltage for a long time in the grid which takes grounded via arc-suppression coil. Therefore, it is required to verify the neutral point displacement voltage.

Neutral point displacement voltage be verified according to the following formula:

$$U_o = U_{bd} / \sqrt{d^2 + v^2} \tag{3}$$

where,  $U_{bd}$  is the asymmetric voltage of neutral point before arc suppression coil into the grid operation kV, the value normally takes 0.8% of system phase voltage;  $d$  is damping rate, it takes 5% for 35 kV overhead lines and below, and it takes 2% to 4% for cable lines.

In order to improve the success rate of arc suppression coil and reduce the operational burden of operating personnel, it should be preferred arc suppression coil which has a good automatic tracking compensation effect. Automatic tracking arc suppression coil device can automatically and timely track the changes of grid operation mode, and can quickly adjust the inductance value of arc suppression coil. According to the different methods of changing the inductance, automatic Tracking Compensation Arc can be broadly divided into multitap, adjust the air gap, tuning capacitors and tune DC biasing type. Among them, tuning capacitors is widely used, mainly because of its fast response, good linearity of the volt-ampere characteristics and continuously adjustable.

In the Fengxian grid, the substations of neutral point grounded via low resistance and resistance value are shown in **Table 4**. The value of neutral point resistor is calculated as the following:

$$R_N = U_X / (2 \sim 3)I_C \tag{4}$$

where,  $R_N$  is the resistance of neutral point,  $U_X$  is the phase voltage of distribution network,  $I_C$  is the grounded capacitor current of distribution network.

**Table 4. The substations of neutral point grounded via low resistance and resistance value.**

No.	Station Name	Capacitive Current(A)	resistance Value $\Omega$
1	Gangxiao station(35 kV)	135.02	50
2	Xinghuo station(35 kV)	231.33	29
3	Tairi station(35 kV)	138.41	49
4	Xinhai station(10 kV)	122.23	16
5	zhuangxing station(10 kV)	116.77	16
6	Yuxiu station(10 kV)	123.48	16
7	Laonanqiao station(35 kV)	120.38	56

Whether transforms small current grounding system into low resistance grounding system is considering a number of factors, the first is the factors of grid operation. Changing substation does not mean that all the small current grounding system transformed into large current grounding system; Secondly, the small current grounding system changing into low resistance grounding system is relatively difficult, the related substation need to install a small resistance, in addition, it need to transform the feeder protection.

### 4. Conclusions

The correct detection of system capacitive current is the basis of determination the neutral point operation mode. There is a certain risk or personnel and equipment whether takes direct method or the indirect method to measure the capacitance current. This paper suggests that takes different frequency injection method, because it is measuring the capacitive current directly from the secondary side of the PT, thereby, it reduces the risk of test.

In this paper, the neutral grounding modes of Fengxian grid is determined based on the measured value of capacitive current: due to the current value is less than 30 A, the 7 substations, such as Qixian station, Xiao Tang Station, is taken ungrounded. The 14 substations, such as Taidong station, Pingan station, is taken grounded via arc-suppression coil. The 7 substations, such as Xinghuo station, Tairi station, is taken grounded via low resistance.

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