Research and Application on the Neutral Grounding Mode in Tianjin Distribution Network

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Abstract. The paper introduces the present situation of neutral grounding mode in 35kV and 10kV Tianjin distribution network. There are mainly four neutral grounding modes: neutral ungrounded, grounding via arc suppression coil, grounding via low resistance and grounding via intelligent reactor. The advantages and disadvantages of the four neutral grounding modes are compared. According to the development characteristic of Tianjin distribution network, the configuration principle of neutral grounding mode is formulated. In addition, the installation and configuration methods of low resistance and grounding transformer are both given, which provides experience and guidance for the application of low resistance grounding.

1. Introduction

The neutral grounding mode of distribution network influences the power supply reliability, equipment insulation level, personal safety and other related issues, which has an important impact on the safety and stability of the power system [1].

As the development of Tianjin distribution network, it has a higher cable rate, leading to a large capacitance current in single-phase grounding fault [2]. In order to restrain the arc overvoltage and avoid equipment damage, the ratio of neutral grounding via low resistance in Tianjin distribution network is relatively high.

![Figure 1. The proportion of four neutral grounding modes in Tianjin distribution network.](image)

By the end of 2019, there are mainly four neutral grounding modes in Tianjin distribution network, including ungrounded, grounding via arc suppression coil, grounding via low resistance and grounding via intelligent reactor. As shown in figure 1, in 35kV distribution network, the proportion of low resistance grounding has reached 47%, the arc suppression coil accounts for 45% and the ungrounded
accounts for only 8%. While in the 10kV distribution network, the proportion of low resistance grounding has reached 56%, the arc suppression coil accounts for 23%, the ungrounded accounts for 16% and the intelligent reactor accounts for 5%.

2. Advantages and disadvantages of Four Neutral Grounding Modes

2.1. Neutral ungrounded
Neutral ungrounded equals to grounding via a small equivalent capacitor. Its advantages are:

(1) The structure is simple and the investment is small.
(2) The protection can only signal without tripping and the system can operate for 1-2 hours with fault [3].

However, its disadvantages are:

(1) When single-phase grounding fault occurs, the non-fault phase voltage rises to line voltage, and the fault point current equals to the system capacitance current.
(2) If the fault current is large, it will result in intermittent arc overvoltage, which leads to insulation breakdown of equipment, protection action and system power loss.

2.2. Neutral grounding via arc suppression coil
Its disadvantages are:

(1) Using arc suppression coil to offset capacitance current, it can effectively suppress arc overvoltage [4].
(2) It can also prevent the system from ferromagnetic resonance overvoltage caused by PT [5].

With the extensive use of cables, neutral grounding via arc suppression coil also has some disadvantages:

(1) Only the frequency and amplitude of arc overvoltage can be limited, however the arc grounding overvoltage cannot be completely eliminated.
(2) As the rapid increasing of cables, the compensation capacity of arc suppression coil cannot meet the requirement.
(3) Lacking line selection function, the faulty lines can only be manually and tentatively removed, which is easy to cause secondary damage to the equipment.

2.3. Neutral grounding via low resistance
Its disadvantages are:

(1) It can reduce power frequency overvoltage caused by single-phase grounding fault, and effectively inhibit arc overvoltage and ferromagnetic resonance overvoltage [7].
(2) Using zero-sequence protection, it can quickly remove the faulty lines and avoid accident expansion.
(3) The insulation level of equipment can be lower, so that the investment cost can be reduced [8].

However, its disadvantages are:

(1) The trip rate of transient faults will be greatly increased and the reliability of power supply will be reduced.
(2) Zero-sequence protection requires effective coordination and sensitivity, otherwise it will easily occur override tripping accidents.
(3) When high resistance grounding fault occurs, it is difficult to be removed, easily leading to electric shock accidents.

2.4. Neutral grounding via intelligent reactor
This grounding mode is an alternative technology for arc suppression coil. Using a fault detection device, it can quickly judge the fault phase and set the phase bus grounded through a small reactor, forcing the fault point voltage to be zero and extinguishing the arc. Its disadvantages are:

(1) Without being limited by capacitance current, effective arc extinguishing can be realized.
(2) Compared with arc suppression coil grounding, the fault lines selection accuracy of intelligent reactor grounding is quite high.

(3) Compared with low resistance grounding, it needs smaller area, less transformation scope and lower investment cost.

3. Configuration principle of neutral grounding mode
With the accelerating process of urbanization in Tianjin, the cable rate of urban power grids has increased year by year and the capacitance current grows continuously. Thus, the neutral grounding mode of Tianjin distribution network presents following characteristics:

(1) Due to the rapid increasement of capacitance current, several substation capacitance current has exceeded the maximum compensation capacity, arc suppression coil grounding mode cannot meet the compensation requirement.

(2) Cable faults are mostly permanent grounding faults with strong concealment, which makes it difficult to find the fault location quickly. Long-term operation under fault voltage may cause fire and other accidents.

(3) Tianjin distribution network has a strong structure and high reliability of power supply, which will not cause load loss after fault lines being removed.

According to the development characteristic of Tianjin distribution network, the configuration principle of neutral grounding mode is formulated as followed:

(1) For the newly-built substations in Tianjin central city, 35kV and 10kV neutral points are all grounded with low resistance. As to newly-built substations in other areas of Tianjin, the grounding mode shall be selected according to the magnitude of capacitance current.

(2) For the in-service substations, if the capacitance current of the ungrounded system exceeds 10A or the capacitance current of the arc suppression coil grounding system is under-compensated, the low resistance grounding mode is preferred.

(3) If the low resistance grounding mode cannot be adopted due to the limitation of area size or transformation scope, the intelligent reactor grounding mode can be used instead.

4. Installation and configuration methods of low resistance and grounding transformer

4.1. Installation mode of low resistance
In the substation design process, the installation mode of low resistance is affected by the connection mode of main transformer. As to 220kV and 110kV transformer, 35kV side mainly adopts Y-type connection, while 10kV side mainly adopts \( \triangle \)-type connection. The following are described separately:

4.1.1. 35kV installation mode. Since the 35kV side of the main transformer is connected by Y-type, the low resistance can be directly installed at the 35kV neutral point without installing a grounding transformer, which is shown in figure 2.

4.1.2. 10kV installation mode. Since the 10kV side of the main transformer is connected by \( \triangle \)-type with no neutral point, a neutral point needs to be led out by adding a grounding transformer. There are mainly two ways to realize this.

(1) The grounding transformer is connected directly to the low-voltage side lead of the main transformer. The grounding transformer is visible as part of the main transformer, so there is no need to add switch cabinet, as shown in figure 3. In this way, the power transmission of the main transformer does not involve the switching of neutral grounding, but grounding transformer or low resistance fault will cause the main transformer to shut down.

(2) The grounding transformer is connected to 10kV bus, and two additional switch cabinets are required, as shown in figure 3. In this way, the power transmission of the main transformer will
involve the switching of neutral grounding, but grounding transformer or low resistance fault will not cause the main transformer to shut down. Moreover,

![Figure 2. 35kV installation mode of low resistance.](image)

![Figure 3. 10kV installation modes of low resistance.](image)

4.2. Configuration method of grounding transformer
There are two configuration methods of grounding transformer. One is grounding transformer and station transformer configured respectively, the other is grounding transformer dual purposed as station transformer, saving the position of a station transformer. When the rated resistance of low resistance is $10\Omega$ and the rated current is 600A, the capacity of grounding transformer in the first scheme can be selected 400kVA. And considering the power demand of substation, the capacity of grounding transformer in the second scheme should be more than 500kVA.

5. Conclusion
As the distribution network in Tianjin takes cable as the main transmission medium, the system capacitance current has often exceeded the maximum compensation capacity of arc suppression coil.
The low resistance grounding mode can fundamentally prevent the occurrence of resonance overvoltage, ensuring the safety of the power grid and the reliability of power supply.

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