Frontiers in Computing and Intelligent Systems
ISSN: 2832-6024 | Vol. 1, No. 3, 2022

Demonstration of Neutral Grounding Mode of New 10kV Distribution System in Nuclear Power Station

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Abstract: Different grounding methods are used at the neutral point of distribution system, which have a direct impact on the reliability, continuity, insulation level of equipment, relay protection and action characteristics of automatic devices. It is a comprehensive technical and economic problem to choose the appropriate neutral grounding mode of distribution system. Taking the newly added 10kV power distribution system of a nuclear power plant as an example, this paper briefly analyzes the methods and principles of neutral grounding demonstration of distribution network, and provides a referential solution for subsequent similar projects.

Keywords: Power distribution system; Neutral grounding; Nuclear power plant.

1. Introduction

In recent years, China's nuclear power industry has developed rapidly. The level of nuclear safety supervision has been continuously improved, and the requirements for the safe and stable operation of nuclear power plant have become stricter. For this reason, all nuclear power plants are undergoing a large number of transformations, adding part of the distribution system. The different grounding methods used at the neutral point of distribution system have a direct impact on the reliability, continuity of power supply, insulation level of equipment, relay protection and operation characteristics of automatic devices. Therefore, the selection of the neutral grounding mode of the distribution system plays an important role in ensuring the safe and reliable operation of the station service power system. Taking the power load of new water plant in nuclear power plant as an example, this paper analyzes the selection method of neutral point grounding mode of 10kV distribution system in detail, which provides a reference for other similar projects.

2. System introduction

2.1. Project overview

The power supply for the water plant of a nuclear power station is from the off-site substation, which is a single loop power supply with poor reliability. It is planned to add one power supply, that is, the distribution network of the water plant will be connected to the auxiliary power system of the nuclear power plant, and the original external substation power supply will be used as the standby power supply to achieve one main power supply and one standby power supply, so as to increase the reliability of power supply. The power supply after the completion of the project is shown in Figure 1.

001JA.Water plant electricity system 6.6kV; 0LGB. Bus feeder circuit breaker; 002JA.Transformer inlet switch; 001TR.New dry-type transformer(6.6/10.5kV , YNd1); 004JA.Incoming circuit breaker of 10kV busbar section A in the water plant; 005JA.10kV busbar B inlet circuit breaker; 006JA. Bus tie circuit breaker between two 10kV buses in the water plant.

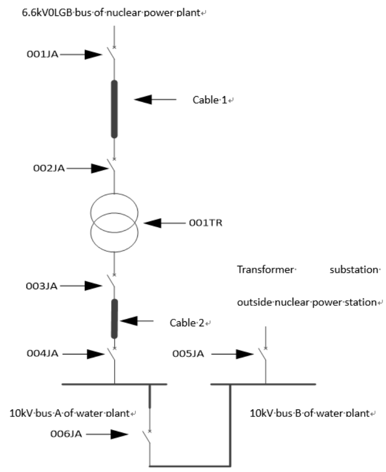

Figure 1. Power Supply System of Water Plant

2.2. Capacitive current calculation

The capacitance of high voltage plant power system is mainly the capacitance of cable. For 10kV cable lines, the single-phase ground capacitance current can be obtained according to formula (1):

$$Ic = \frac{95+1.44\times S}{2200+0.23\times S} Ue \times L \qquad (1)$$

Ic —Capacitive current（A）， S —Cross-section of cable（mm2）

Ue—Rated line voltage of water plant power system（kV）， L—Cable length（km）

The power equipment of the water plant is supplied by the 6.6kV0LGB bus through the boost transformer 001TR. The new boost transformer is installed in the substation outside the plant, and the original 10kV cable (cable 2) is used to supply power to the power equipment of the downstream water plant. Cable specification is 3×70 mm2, 3.6km long. The length of cable inside the water plant is about 3km, and the cable specification is 3×70 mm2. The calculation results of cable single-phase grounding capacitive current are as follows:

$$Ic = \frac{95+1.44\times 70}{2200+0.23\times 70} 10.5 \times (3.6 + 3) = 6.12(A) \qquad (2)$$

The obtained single-phase grounding capacitor current of the cable is multiplied by 1.25, which is the approximate value of the total single-phase grounding capacitor current of the whole system (including the windings of transformers used in factories and distribution devices, etc.). The single-phase grounding capacitor current of the system is:

$$6.12 \times 1.25 = 7.65(A) \quad (3)$$

3. Comparison of grounding methods

The common neutral grounding methods of power system are: ungrounded neutral point, grounded neutral point through resistance, grounded neutral point through arc suppression coil, and directly grounded neutral point. See Table 1 for comparison of different neutral grounding modes.

Table 1. Comparison of different neutral grounding methods

Item compared	Grounding method		
	Ungrounded	Grounding through resistance	Ground through arc suppression coil
Grounding current	Depends on the distributed capacitance	Large	Very small
Equipment damage degree in case of grounding fault	Large	Secondary	Small
Power supply continuity	Good	Good	Very good
Overvoltage	Highest	Lowest	High and low probability
Grounding type selection protection	Easy	Easy	Hard
Possibility of single-phase grounding developing into multi-phase grounding	Maximum	Less	Secondary

3.1. Related standards and specifications

Article 13.3.2 of Technical Specification DL5000-2000 for Design of Thermal Power Plants: "When the grounding capacitor current of the high-voltage factory power system is 7A or less, the neutral point of the system should be grounded in the high-resistance or ungrounded mode. When the grounding capacitor current is greater than 7A, the neutral point should be grounded in the low-resistance or ungrounded mode."

According to Article 4.13.3 of GB14285-2006 Technical Code for Relaying Protection and Safety Automatic Devices, "when the single-phase grounding current is 10A and above, the protection acts on tripping, and when the single-phase grounding current is below 10A, it can act on tripping, and it can also act on signal".

Technical Code for Design of Auxiliary Power in Fossil Fuel Power Plants DL/T 5153-2002, 4.2.1 stipulates that: "When the grounding capacitance current of the high-voltage plant power system is less than or equal to$10/\sqrt{2}$=7A, the neutral point should be grounded by high resistance or not. When the grounding capacitor current is greater than 7A, the neutral point of the capacitor should be grounded in low-resistance mode or in ungrounded mode.

4. Selection of neutral grounding method for the project

According to the Guidelines for Urban Electric Power Network Planning and Design, the neutral point of 10kV urban power grid can be operated by non-grounding, arc suppression coil grounding and resistance grounding. In addition, 35kV and 10kV urban grid is also provided with cable grounding, and neutral point can be grounded by small or medium resistance if necessary.

The neutral ground mode through medium resistance and small resistance is suitable for the urban distribution network and plant power system, which are mainly cable lines, are not prone to instantaneous single-phase ground fault and the system capacitance current is relatively large.

The two power supplies of the nuclear power plant are cable lines, and the distribution network has the following characteristics:

a) The capacitive current to ground is very large.

b) There are few transient grounding faults, which are generally permanent faults.

c) The grounding arc is not easy to go out by itself, which is easy to cause interphase short circuit and enlarge the accident.

d) Dual power supply, high power supply reliability, complex protection configuration.

After the power supply transformation of the waterworks, 0LGB is supplied as the main power supply through the step-up transformer (6.6kV/10kV) during normal operation, and only one cable comes out of the 10kV side. The single-phase grounding capacitor current of the system is not very large (7.65A). However, it is more likely that single-phase ground fault of cable line will develop into phase-phase or three-phase fault. The power supply of the water plant has high requirements for power supply reliability, and is equipped with standby power supply. At the same time, considering the following practical operation factors, the grounding mode through small resistance grounding should be selected:

a) The cables and water plant system equipment have been put into operation for a certain period of time, especially the 10kV cable laying trench environment from the substation outside the plant to the water plant is poor. As time goes on, the insulation of system equipment and cables will gradually age, and when single-phase grounding occurs, multi-phase grounding may be caused due to transient over-voltage; In addition, the cable is non-self-restoring insulation, and the single-phase grounding must be a permanent fault. The power must be cut off quickly to avoid expanding the accident.

b) One main power supply and one standby power supply are adopted, and the main power supply can be switched to the standby power supply after single-phase ground fault tripping, so as to meet the power supply reliability requirements of the electrical equipment in the water plant.

c) The standby power supply loop adopts neutral grounding mode through small resistance and is equipped with zero sequence current protection. The protection configuration of the primary and secondary power supplies should be consistent.

5. Selection of neutral ground resistance value

At present, China has not made clear provisions on the selection of neutral point resistance. The selection of neutral point resistance value must be based on the specific conditions of the distribution system, considering the sensitivity of relay protection, limiting the multiple of gap arc grounding overvoltage, ensuring the reliability of power supply and other factors. It shall be selected according to the principle of the best comprehensive effect after analysis and comparison.

Definition: Rn --Neutral resistance; Uph --Rated phase voltage;

IR --Current flowing through Rn during a single-phase ground fault; $IR = \frac{Uph}{Rn}$

Ic--Single phase grounding capacitive current; $K = \frac{IR}{Ic}$

When Ic =4.17A (the total capacitive current of the system), the neutral ground resistance of the 10kV distribution system of the water plant power supply is 15Ω, that is, the rated current flowing through the resistance in case of single-phase ground fault is IR =400A. The selection basis is as follows:

a) Select as required to ensure relay protection sensitivity

With the current microcomputer protection technology, whether through the median resistance or through the small resistance grounding distribution system, can ensure the sensitivity of zero sequence protection requirements. According to the selected resistance value of 15Ω, according to the operation experience of Guangzhou, Shenzhen and other cities, the line selection accuracy of the relay protection device (the resistance current of these cities is selected 400A) is very high. Since the implementation of small resistance grounding mode for 10kV power grid in Shenzhen City in 1996, more than 50 220kV and 110kV substations and more than 150 sets of neutral point resistance cabinets have been operating in the urban area by 2012. After a long time of operation inspection, zero sequence protection of lines has operated nearly 1000 times, and the accuracy of zero sequence protection actions has reached more than 98% through statistical analysis, and major or catastrophic accidents of power distribution equipment have been significantly reduced.

b) Select according to the requirements of limiting arc grounding overvoltage

The principle of limiting arc grounding overvoltage by neutral ground resistance is the energy dissipation effect of resistance. According to relevant literature data, when IR =Ic, the intermittent arc overvoltage multiple can be limited within 2.5 times. When IR=4Ic, the multiple of intermittent arc overvoltage can be limited to 2.0 times. Generally, IR = (1~4) Ic can meet the requirements of limiting intermittent arc overvoltage.

When IR =400A, Ic =7.65A, K =400/7.65=52, the arc over-voltage can be limited within 2.0 times, meeting the requirements of limiting arc grounding over-voltage.

c) To ensure the reliability of power supply

According to the power regulation, when the fault current is greater than 10A, the cable is not allowed to run live for a long time, and the fault line should be accurately selected and cut immediately. Therefore, the current flowing through the fault is larger, which improves the sensitivity of the protection device, ensures the quick fault removal, avoids the occurrence of interphase short-circuit fault, and strengthens the reliability of power supply. Therefore, 400A resistance current can well meet the above requirements.

In conclusion, the selection of neutral grounding resistance is a comprehensive technical and economic issue. If the selection of neutral point resistance value is too low, the single-phase grounding current is large and the interference to the communication line is large; If the resistance value is too large, the relay protection action is unreliable.

Therefore, according to the characteristics of the cable line distribution network and the resistance grounding mode of the neutral point, various factors should be considered as a whole. The 10kV power distribution system of the water plant should retain the grounding mode of the original system neutral point through a small resistance, and limit the grounding current to a certain range, so that the protective grounding point will not be seriously burned because of the strong grounding current, and also meet the sensitivity requirements of relay protection. The main parameters of neutral ground resistance are shown in Table 2.

Table 2. Main Parameters of Neutral Grounding Resistance

System rated line voltage Ue	10.5(kV)
Nominal voltage of resistor UR	6.06(kV)
Short time allowable flow IR	400(A)
Nominal resistance of resistor Rn	15(Ω)
Short time flow time	10(S)
Short time allowable temperature rise	760 °C when the short-time flow time is 10S, and 385 °C when the flow time is more than 2H.

6. Conclusion

To sum up, the selection of neutral grounding mode of distribution system is a comprehensive technical and economic problem. To ensure the safe and stable operation of the power distribution system in the long run, the optimal neutral grounding mode must be selected according to the requirements on the reliability and continuity of power supply, the insulation level of the equipment, the requirements on the relay protection configuration, and the actual situation of the site.

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