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Selection Method Study on the Best Grounding Resistance for the Neutral Point of 10kV Urban Power Distribution System

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Abstract. With the rapid growth of urban load and the increase of cable rates in urban distribution network, the shortcomings of traditional neutral point grounding are more and more obvious, which lead to the application of resistance grounding. Considering the technical and economic factors, this paper presents a method for rational selection of neutral grounding resistance. In this method, on one hand, it uses technical requirements as constraints to limit the range of grounding resistance, on the other hand, it uses optimal economy as the objective function to choose the best grounding resistance. Furthermore, the result of example verifies the feasibility and effectiveness of the method.

Keywords: Urban distribution network; neutral grounding modes; resistance grounding; grounding resistance value.

1. Introduction

The current literature simply refers to select the resistance value according to the size of fault current of neutral point grounding, for the selection of neutral resistance value in 10-35kv distribution network. Based on the factors which influence the selection of neutral grounding resistance, this paper puts forward the optimal selection method, studying both economy and technicality factors.

2. The optimal selection method of neutral grounding resistance

In this paper, it uses technical requirements as constrains and optimal economy as the objective function to establish the optimal selection model of neutral grounding resistance.

2.1 Determination of constraint

The constraints are requirements to neutral grounding resistance from four aspects: internal overvoltage in system, relay protection, interference to telecommunication lines and personal safety. When metallic one-phase ground fault occurs in the resistance grounding system, a simplified equivalent circuit has appeared as Figure 1 shows.

The neutral point resistance from Figure 1: $\dot{U}_0 = -\dot{E}_A$; fault current caused by short circuit:

$$\dot{I}_K = \dot{U}_0\left(\frac{1}{R_N} + j3\omega C_N\right)$$

Among them, C_N is total grounding capacitance of one-phase line; R_N is neutral interposing resistance connects with grounding transformer [1].

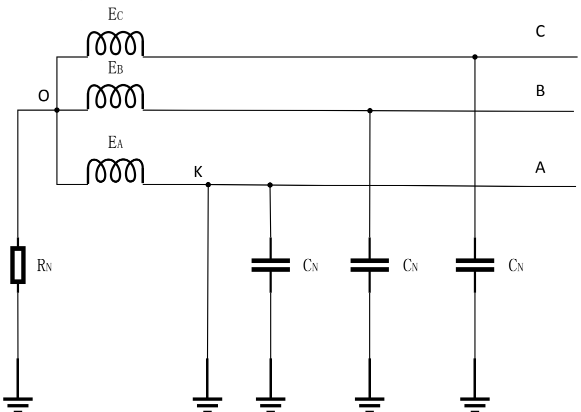

Figure 1 Single-phase equivalent circuit of resistance grounding system

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2.1.1 Internal overvoltage

The electric change accumulated by intermittent electric arc can leak into the ground through resistance, while arc grounding over-voltage occurred in resistance grounding system, and neutral potential decreasing rapidly [2]. With the curve of relationship between voltage amplification factor and I_R / I_C, two conclusions can be reached. When $I_R > I_C$, the sound-phase voltage amplification factor can be controlled under 2.6 times phase voltage; when $I_R > 1.5 I_C$, the effect of overvoltage limit have changed a little. Among them, I_R is single-phase grounding neutral resistive current, I_C is capacitive current of system [3].

When $I_R > 1.5 I_C$, the condition can be expressed as: $\frac{1}{3\omega R_N C_N} > 1.5$

2.1.2 Relay protection

Based on guaranteeing the reliable action of relay, ground fault current should make the zero-sequence current protection keeps sufficient sensitivity. Therefore, taking the relay protection into consideration, a larger single-phase ground fault current is more favorable. When grounding current is greater than 400-600A, no intermittent arc over-voltage caused by intermittent extinguish, and it is conducive to the right action of relay protection [4]. This paper selects grounding current which is greater than 400A that is (take A-phase fault for example) : $E_A\left(\frac{1}{R_N} + 3\omega C_N\right) > 400$

2.1.3 Interference to telecommunication lines

It has a great influence to telecommunication lines when neutral resistance grounding system occurs single-phase fault. Different regions has different limit to the biggest single-phase fault current. The interference test that 10kv distribution system to telecommunication lines is conducted in Shanghai, and the result shows that the single-phase ground fault current of 10kv distribution network is limited to 1000A in Shanghai which can ensure the interference effects within the scope of permit [4]. This paper limits the ground fault current to 1000A that is: $E_A\left(\frac{1}{R_N} + 3\omega C_N\right) < 1000$

2.1.4 Personal safety

When the distribution network ground fault occurs, the main threats for the person near to ground fault spot are contact voltage and step voltage. Multiple actual testing results express that when grounding current in 1000A, the contact voltage and step voltage in distribution network system are both within the range defined by authority [5]. This paper limits the ground resistance current to 1000A that is: $\frac{E_A}{R_N} < 1000$

2.2 Objective function establishment

When a system failure, the size of neutral grounding resistance can affect the current flowing through the grounding transformer and meanwhile affect the circuital overvoltage. Accordingly, affect the selection of grounding transformer capacity and cable insulation level. Other things being equal, these factors are the major determinant of the price.

This paper selects the price and the minimum to be the objective function that is: $\min F(R) = F_1(R) + F_2(R)$

Among them, $F(R)$ is the function of the neutral grounding resistance value considered the price of equipment, $F_1(R)$ is the function of the neutral grounding resistance value considered the price of grounding transformer, $F_2(R)$ is the function of the neutral grounding resistance value considered the price of cable line.

2.2.1 Relationship between grounding transformer and resistance

According to the literature [6], short-time capacity of grounding transformer $Q_d = U_L I_R / \sqrt{3}$, rated capacity $Q_e = Q_d / K$. Among them, U_L is power grid rated line voltage, K is overload multiples, refer to the external condition of 10s thermal stability, take K as 10.5. The relationship among grounding transformer capacity, price and grounding resistance value as shown in table 1:

Table 1 Relation table of neutral resistance and transformer price

Grounding resistance R_N /Ω	Neutral current I_R /A	Transformer capacity S_e /KVA	Grounding transformer price（yuan per）
350	17.32051	10	6800
70	86.60254	50	15600
35	173.2051	100	21000
17.5	346.4102	200	28000
11.11111	545.596	315	35800
8.75	692.8203	400	41000
7.777778	779.4229	450	45600
7	866.0254	500	48000
6.363636	952.6279	550	49000
5	1212.436	700	56000
4.375	1385.641	800	60000

To fit the data in Figure 1 with curve fitting in MATLAB, a curve between neutral resistance value and grounding transformer price has obtained as shown in Figure 2. The functional relationship is: $F_1(R) = 12.77 * R_N^{-0.5138}$ (ten thousand yuan)

The parameter of fitting degree is: SSE: 0.08486; R^2: 0.9971; RMSE: 0.0971. The result shows that fitting degree can express the relationship between neutral grounding resistance and grounding transformer price correctly.

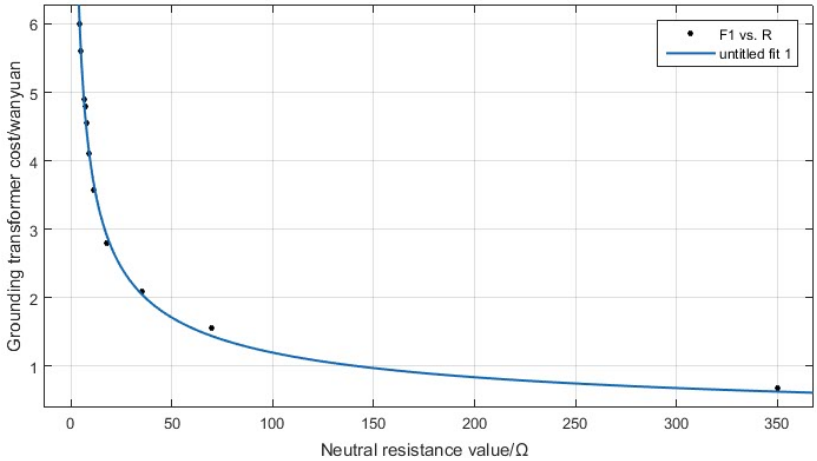

Figure 2 Relationship between neutral grounding resistance and transformer price

2.2.2 Insulation selection of cable line

For 10kv system, there are two kinds of nominal voltage values of cable: 6/10kv and 8.7/10kv [7], when $U_t \leq 21kv$, to select the cable line with 6/10kv nominal voltage; when $U_t > 21kv$, to select the cable line with 8.7/10kv nominal voltage.

The size of arc grounding over-voltage will reduce with the decrease of neutral grounding resistance [8]. Therefore, for a certain system, there is always an R_{mid} makes the arc grounding over-voltage is 21kv, when $R_N = R_{mid}$.

Then we can get the function of neutral grounding resistance related with cable line price:

$$F_2(R) = \begin{Bmatrix} X_1 \times L(R_{min} \leq R_N \leq R_{mid}) \\ X_2 \times L(R_{mid} \leq R_N \leq R_{max}) \end{Bmatrix}$$

Among them, R_{min} and R_{max} are the lower limit and upper limit of the value range of R_N in constraint condition; X_1 and X_2 are the price of 6/7kv cable and 8.7/10kv cable respectively with the same type and same sectional area, and the unit is ten thousand yuan per kilometer; L is cable length required by system.

2.3 Decision method

From the analysis of 2.1 and 2.2, we can get the objective function in this paper:

$$\min F(R) = F_1(R) + F_2(R) = \begin{cases} 12.77 \times R_N^{-0.5138} + X_1 \times L(R_{\min} \leq R_N \leq R_{mid}) \\ 12.77 \times R_N^{-0.5138} + X_2 \times L(R_{mid} \leq R_N \leq R_{\max}) \end{cases}$$

Constraint condition (deduced from the formulas in 2.1) is:

$$\begin{cases} R_N < \dfrac{1}{4.5\omega C_N} & \text{(internal overvoltage)} \\ R_N < \dfrac{1}{\dfrac{400}{E_A} - 3\omega C_N} & \text{(relay protection)} \\ R_N > \dfrac{1}{\dfrac{1000}{E_A} - 3\omega C_N} & \text{(interference to telecommunication)} \\ R_N > \dfrac{E_A}{1000} & \text{(personal safety)} \end{cases}$$

3. Conclusion

The selection of neutral grounding resistance involves every aspects of electrical power system. This paper takes the requirements of internal overvoltage in system, relay protection, interference to telecommunication lines and personal safety as the constraint condition, uses optimal economy as the objective function to establish the optimal selection model of neutral grounding resistance. According to the constraint conditions, the value of neutral grounding resistance is selected as a certain range. In a real case, distribution network has different characteristic in different area, therefore, combining with real situation, we should select the optimum grounding resistance in the reasonable range according to the technical condition and economy.

Acknowledgements

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