MINIMUM RATIO OF SHORT CIRCUIT CURRENTS FROM SOLIDLY EARTHED NETWORK ASPECT

Ivan Sarajcev, Ph.D.
Faculty of Electrical Engineering, University of Split
Matislav Majstrovic, Ph.D., IEEE member
Energy Institute "H. Pozar", Zagreb
Ivan Medic, Ph.D., IEEE member
Faculty of Electrical Engineering, University of Split
Croatia

Abstract

Single-phase and phase-phase-earth short circuit are often faults on earthing networks. Determination of single-phase to three phase short circuit current minimum ratio that satisfies solidly neutral earthing criteria is important into power system analyses. Calculation method for the maximum earth fault factor and the minimum ratio of short circuit currents, when the network is considered solidly earthed are presented in this paper. The proposed method is simple and applicable into power system analyses.

***Key words*:** network, short circuit, earthing, neutral point

1. INTRODUCTION

Solidly earthed networks are three phase networks whose star points or neutral of system are earthed directly. These networks have automatic operation to isolate fault on the network in a minimum time. The earth fault factor (k_e) is [1]

$$k_e \le 1.4 \tag{1}$$

The earth fault factor at a given location of three-phase system, and for a given system configuration, is the ratio of the highest r.m.s. phase-to-earth power frequency voltage on a healthy phase during a fault to earth affecting one or more phases at any point on the system to the r.m.s. phase-to-earth power frequency voltage which would be obtained at the selected location in the absence of any such fault. The earth fault factor determination on the base of single-phase short circuit current direction will be presented in this paper.

2. CALCULATION METHOD

Single-phase and phase-phase-earth short circuit are often faults on earthing networks. It is known on the base of investigations that the earth fault factor is higher in single-phase short circuit than in phase-phase-earth short circuit.

The earth fault factor of health phase that goes before faulted phase is higher than the earth fault factor of other phase [2]. The earth fault factor is defined as follows

$$k_e = \left| a - \frac{a \cdot Z_1 + a^2 \cdot Z_2 + Z_o}{Z_1 + Z_2 + Z_o} \right| \tag{2}$$

where are:

Z_1 , Z_2 , Z_o - positive, negative and zero-sequence network impedance, respectively, on the single-phase short circuit location

a - complex operator ($a=1/\underline{120^o}$)

Z_1 is equal Z_2 if the fault location is far away from generators. In this case the earth fault factor is

$$k_e = \left| a + \frac{1 - \frac{Z_o}{Z_1}}{2 + \frac{Z_o}{Z_1}} \right| \tag{3}$$

Z_1 and Z_o can be calculated from single-phase and three-phase short circuit current as follows

$$Z_1 = \frac{U_n}{\sqrt{3} \cdot I_{k3}} \tag{4}$$

$$Z_o = \frac{U_n}{\sqrt{3}} \left(\frac{3}{I_{k1}} - \frac{2}{I_{k3}} \right) \tag{5}$$

where is U_n - rated voltage

The next form follows from foregoing equations

$$\frac{Z_o}{Z_1} = 3 \cdot \frac{I_{k3}}{I_{k1}} - 2 \tag{6}$$

and the earth fault factor is

$$k_e = \left| a - 1 + \frac{I_{k1}}{I_{k3}} \right| \tag{7}$$

Short circuit currents have an inductive character. They can be written as follows

$$I_{k1} = I_{k1} \cdot e^{-j\varphi_{k1}} \tag{8}$$

$$I_{k3} = I_{k3} \cdot e^{-j\varphi_{k3}} \tag{9}$$

The next inequality is usually satisfied in real power systems

$$\varphi_{k3} \geq \varphi_{k1} \tag{10}$$

The earth fault factor is now

$$k_e = \left((\xi \cdot \cos\varphi - 1.5)^2 + (\xi \cdot \sin\varphi + 0.866)^2 \right)^{\frac{1}{2}} \tag{11}$$

where are

$$\xi = \frac{I_{k1}}{I_{k3}} \quad \text{and} \quad \varphi = \varphi_{k3} - \varphi_{k1} \tag{12}$$

The next inequality follows from (1) and (11).

$$\xi^2 - (3 \cdot \cos\varphi - \sqrt{3} \cdot \sin\varphi) \cdot \xi + 1.04 \geq 0 \tag{13}$$

Roots are

$$\xi_{1,2} = \frac{3 \cdot \cos\varphi - \sqrt{3} \cdot \sin\varphi}{2} \pm \frac{\sqrt{(3 \cdot \cos\varphi - \sqrt{3} \cdot \sin\varphi)^2 - 4.16}}{2} \tag{14}$$

Roots must be real figures and the next condition must be satisfied.

$$(3 \cdot \cos\varphi - \sqrt{3} \cdot \sin\varphi)^2 - 4.16 \geq 0 \tag{15}$$

The solution of this inequality is

$$-83^\circ \leq \varphi \leq 23^\circ \tag{16}$$

Furthermore, φ is in accordance with equations (10) and (12)

$$0^\circ \leq \varphi \leq 23^\circ \tag{17}$$

This interval is relatively wide. In real systems the difference of three-phase and single-phase short circuit current's angle will be in this interval.

$\xi_{1,2}$ are real, different and positive figures. The chosen root must be less than 1.0 since single-phase short circuit current is less than three-phase short circuit current. It follows

$$\xi_1 = \frac{3 \cdot \cos\varphi - \sqrt{3} \cdot \sin\varphi}{2} - \frac{\sqrt{(3 \cdot \cos\varphi - \sqrt{3} \cdot \sin\varphi)^2 - 4.16}}{2} \tag{18}$$

This is the minimum single-phase to three-phase short circuit current ratio from solidly neutral point earthing aspect. Hence, if the network has to be solidly earthed then the following relation must be satisfied at every network point.

$$\frac{I_{k1}}{I_{k3}} \geq \xi_1 \tag{19}$$

3. EXAMPLE

Results of the minimum single-phase to three-phase short circuit current ratio calculation (ξ_1), when the network remains solidly earthed, are presented in Table 1. The calculation was done for usually values of φ.

Table 1

φ [°]	ξ_1
0	0.400
5	0.432
10	0.478
15	0.546
20	0.666

4. CONCLUSION

Determination of maximum earth fault factor as function of the single-phase to three-phase short circuit current ratio is presented in this paper. The minimum ratio of before mentioned currents when the network is considered solidly earthed is presented as well. This method is easy applicable into real power system analysis.

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