EUROPEAN ACADEMIC RESEARCH
Vol. III, Issue 8/ November 2015

Impact Factor: 3.4546 (UIF)
DRJI Value: 5.9 (B+)

ISSN 2286-4822
www.euacademic.org

The Effect of Transient Voltages in Single-phase to Ground Fault in Case of Increase in the Y center Resistance of Power Station Transformers

SEYED SAJJAD SALEHI GHALEHSEFID
Regional Electricity Company of Khuzestan Province
The Northeast Region Exploitation Affairs
Masjed Soleiman, Iran

Abstract:

Short circuit is one of the most important risks for electrical networks that lead to several damages to them. One of the most important types of short circuit is the single phase to ground short circuit during which the voltage of normal phases reach $\sqrt{3}$ *of their rated voltage proportional to the length and line load. In order to limit the voltage it is possible to reduce the Y center resistance value of transformers. In this paper the intensity of the voltage created in normal phases and induced earthinging system was analyzed in all three transformers of Havanirooz power stations at different resistances of the Y center of transformers the results of which indicate the direct effect of the earthinging system Y center in the transformer resistance value on the mentioned over voltages.*

Key words: Phase-to-ground short circuit, over voltage, earthing system, transformer Y center, Havanirooz power station

1. INTRODUCTION

Over voltage play an important role in causing damage to insulation of electrical networks. This flaw is caused by short circuit particularly single-phase short circuit to the ground.

Most of the protections in the electricity networks are employed to limit the created short circuits. Extensive studies have been conducted in relation to these problems. For example in Amir Kabir university of Iran in order to predict the system behavior in case of short circuit, arc modeling and simulation is employed along the transmission lines (Mousavi. 1998). Or in distribution of Electricity Company in Gilan Province, the sustainability, short-circuit and load distribution study was conducted in the rated voltage level of this company (Shojaee. 2012). Some researchers have focused their studies on short circuit calculations of electricity networks because in order to limit short circuit in the network first it is necessary to understand the nature and then the measures should be taken to limit it. Providing a new equivalent circuit of the short circuit in dry transformers and calculating its level in the distribution network by means of an impedance matrix is among such actions (Azizian. 2012)(Moghaddam. 1993).

Important studies were conducted to reduce the level of short circuit; including changing the network configuration a successful example of which was conducted in Isfahan province regional power company (Karimi. 2007) or the use of inductance in the zero center of power transformers in Bushehr province or Ramin power plant in Ahwaz to restrict possible short circuit (Roghanian. 2004)(Nasiri. 2006).

The most important short circuit which is more likely to occur than other short circuits is single-phase short circuit to ground. About 85 percent of short caused circuits are of the same type (Khedarzadeh. 2004). This type of short circuit while triggering strong currents imposes transient overvoltage as big as the rated voltage in normal phases (Yaraei Rostami. 2013). One of the important factors determining the increased voltage in normal phases during single-phase short circuit to ground is the amount of resistance in transformer Y center. The resistance that should be limited to a maximum of 2 ohms standard level might increase for reasons such as rust and corrosion, the reduced moisture content of the ground, the lack of quality of the equipment used in the system, the lack of proper installation, intense vibrations and loosening of the connections, third harmonic currents and reduces ground path resistance due to increased longevity. The increase in the mentioned resistance level leads to overvoltage at normal phases during the creation of a single-phase short circuit to ground.

In order to limit the short circuit it is necessary to inspect and test the ground resistance of the transformers and other equipment regularly. In this paper Havanirooz power station which is one of the sub-stations in Khuzestan Regional Electricity Company and has the highest number of short circuit in the distribution network is selected and simulated in EMTP / WORK software which is the best program in the area of transients to analyze the created overvoltage in normal phases during single-phase short circuit to ground at different resistance levels of the Y center of the transformers. The results represent a very significant impact of the resistance levels of the Y center of the transformers on the overvoltage caused by single-phase short circuit to ground.

2. SINGLE-PHASE SHORT CIRCUIT TO GROUND

The three-phase system vectors can be divided into three components two of which have opposite flow direction and one component has the same phase. The three mentioned components are known as positive, negative and zero components. In Figs. 1 and 2 the phase voltage breakdown into the mentioned components in the network are presented. The relationship between the components is as follows (Khedarzadeh. 2004):

$$\overline{E_a} = \overline{E_1} + \overline{E_2} + \overline{E_0}$$
$$\overline{E_b} = a^2\overline{E_1} + a\overline{E_2} + \overline{E_0}$$
$$\overline{E_c} = a\overline{E_1} + a^2\overline{E_2} + a^2\overline{E_0} \qquad (1)$$

$$\overline{E_1} = \frac{1}{3}(\overline{E_a} + a\overline{E_b} + a^2\overline{E_c})$$
$$\overline{E_2} = \frac{1}{3}(\overline{E_a} + a^2\overline{E_b} + a\ \overline{E_c})$$
$$\overline{E_0} = \frac{1}{3}(\overline{E_a} + \overline{E_b} + \overline{E_c}) \qquad (2)$$

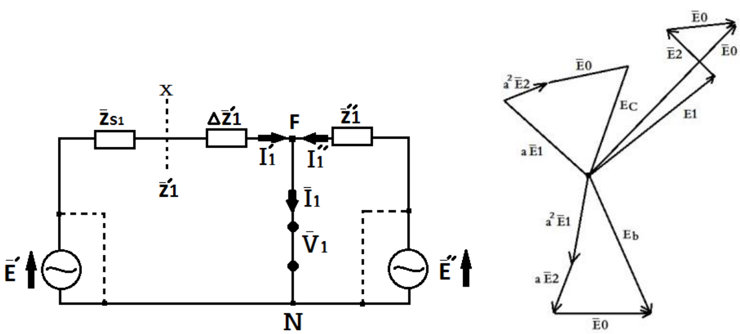

Figure. 1. The decomposition of a voltage system into symmetric components

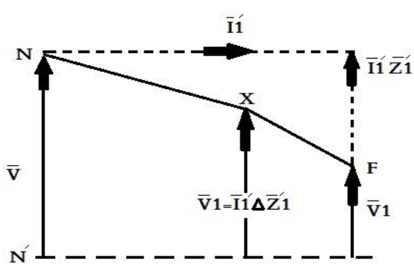

Figure 2. The diagram of the positive component of a simple system with a fault in point F

In the case of single-phase short circuit to ground as shown in Figure 3, we have:

$$Va = 0 \qquad Ia = IF$$
$$Vb = ? \qquad Ib = 0$$
$$Vc = ? \qquad Ic = 0 \tag{3}$$

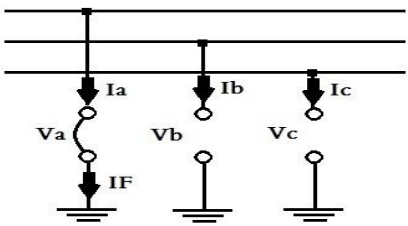

Figure. 3. Single-phase short circuit to ground

$$I_a = I_{a1} + I_{a2} + I_{a0} = I_F$$
$$I_b = a^2 I_{a1} + aI_{a2} + I_{a0} = 0$$
$$I_c = aI_{a1} + a^2 I_{a2} + I_{a0} = 0 \tag{4}$$

Solving the above equations yields:

$$I_F = 3I_{a1} = 3I_{a2} = 3I_{a0}$$
$$V_a = V_{a1} + V_{a2} + V_{a0} = 0 \tag{5}$$

According to the equation (5) the short-circuit state equivalent circuit in Figure 3 will be in accordance with Figure 4

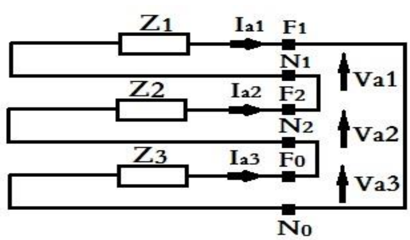

Figure. 4. Equivalent circuit of a single-phase short circuit to ground

Now we can simplify the Figure 4 as the following circuit.

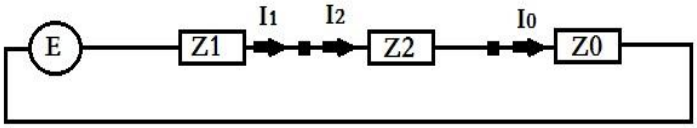

Figure 5. Simplify Equivalent circuit of a single-phase short circuit to ground

According to Figure 5:

$$I_{a1} = I_{a2} = I_{a0} = \frac{E}{Z_1 + Z_2 + Z_3}$$

$$IF = 3I_{a0} = \frac{E}{Z_1 + Z_2 + Z_3} \quad (6)$$

And

$$V_{a1} = E - I_{a1}Z_1 \quad V_{a2} = -I_2 Z_2 \quad V_{a0} = -I_{a0} Z_0 \quad (7)$$

Thus the numerical value of phases B and C voltages will be equal to equations 8 and 9 (Khedarzadeh. 2004).

$$|Vb| = \frac{\sqrt{3}(Z_0 + Z_2)}{Z_1 + Z_2 + Z_3}.E \quad (8)$$

$$|Vc| = \frac{\sqrt{3}(Z_0 + Z_2)}{Z_1 + Z_2 + Z_3}.E \quad (9)$$

Equations 8 and 9 show that the normal phases at short circuit phase to ground situation will increases as equal as the rated voltage.

3. HAVANIROOZ POWER STATION

For the case study, Havanirooz Power Station as one of the subsets Khuzestan Regional Electricity Company was selected. The station was operated in 1976 and had three transformers with 27 MVA power which has a total of9 distribution feeders with 11 kV voltage level. Figure 6 shows the performance of the breakers in Havanirooz Power Station. According to the statistics the station is faced with 360 times of switching in its breakers which is a relatively high and worrying rate. According to Figure 7, about 44 percent of the performance of the relays in this station is related to single-phase short circuit to ground.

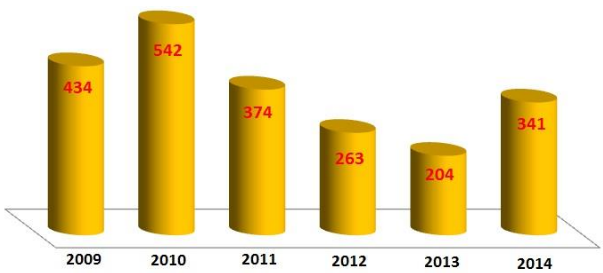

Figure. 6. The performance of Havanirooz Power Station breakers from 2009 to 2014

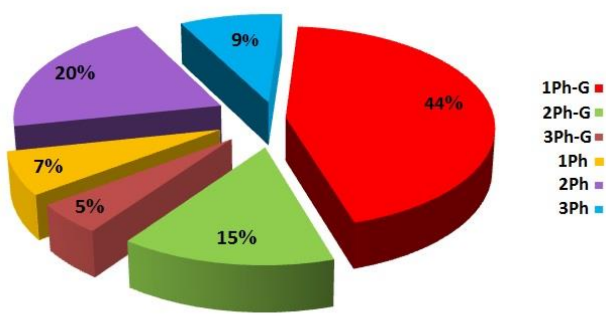

Figure. 7. The performance of Havanirooz Power Station relays

2 of three transformers in Havanirooz Power Station are relatively old. These transformers are built and installed in 1981 in the station. Y center transformer connections that are presented in Figure 8 suffer from oxidation, reduced quality and increased resistance due to long life, high temperature,

lack of proper installation and toxic and corrosive gases from oil and gas wells.

Figure. 8. The oxidationand reduced quality of Havanirooz Power Station earthing system

4. ANALYZING THE EFFECT OF TRANSIENT VOLTAGES IN SINGLE-PHASE TO GROUND FAULT IN CASE OF INCREASED RESISTANCE IN HAVANIROOZ POWER STATION Y CENTER TRANSFORMERS

To investigate the effect of transient voltages on single-phase to ground fault in Havanirooz Power Station EMTP/WORK is used. The whole Havanirooz Power Station and its feeders were simulated by the software EMTP/WORK. Phase to ground fault has been created from each transformer on a feeder with high consumption and less length to create more severe effects in terms of short circuit. First, assuming that the resistance of the Y center of all three transformers is less than 2 ohms and in perfect condition, we created single-phase short circuit on the sample feeders the results of which are shown in Figure 9. In this simulation single phase fault was caused on phase C and the overvoltage was analyzed and phase B was selected.

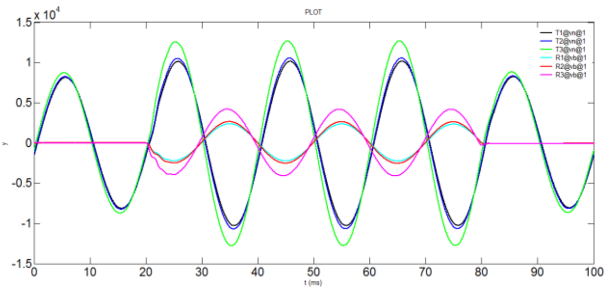

Figure. 9. Overvoltage created on the normal phases and the Y center of the transformers at the time of single-phase to ground short circuit in Y center resistance less than 2 ohms

The over voltage created in normal phases is increased by the distance between the fault location and station and the consumed load. Of the transformer Y center during single-phase to ground short circuit about some kV reverse pulse the voltage is induced that by reducing this fault this overvoltage is attenuated. According to Figure 9, the average over voltage in normal phases in all three transformers at 11 kV line becomes 19.2 kV and average over voltage induced in transformer Y centers of this station is about 3 kV.

As mentioned previously to deal with the creation of over voltage in normal phases in case of single-phase to ground short circuit, they reduce transformer Y center resistance. But the increase in longevity or lack of proper installation of the earthing system and even other factors can increase Y center transformer resistance in operation and in case of single-phase to ground short circuit the overvoltage created in the normal phases is significantly increased and can cause severe damage to station insulation. Figure 10 presents the overvoltage of the normal phases and the Y center at three transformers in Havanirooz Power Station when the Y center transformers' resistance is increased several times.

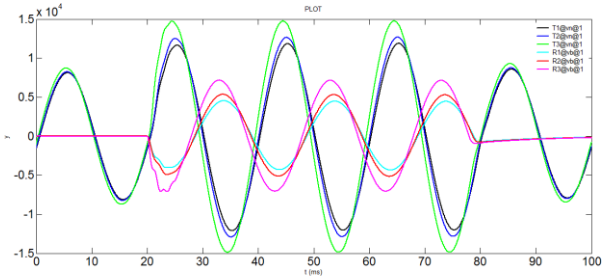

Figure. 10. overvoltage created on the normal phases and Y center of transformers at the time of single-phase to ground short circuit in Y center resistance of more than 2 ohms

According to Figure 10 average normal over voltage of normal phases in all three transformers in such case was 22.7 KV and the average induced overvoltage in Y center of transformers is about 22.7 kV.

For a closer look at this issue for each 1 ohm of increased resistance in Y center of transformers in Havanirooz Power Station the created overvoltage in normal phases and Y centers in single-phase to ground short circuit was analyzed and the results are presented in Figures 11 and 12. According to the diagrams provided in the mentioned Figures it can be easily found that increasing earthing resistance of the Y center of transformer can lead to increased over voltage in normal phases and induction in the earthing system of the transformers at the time of single-phase to ground short circuit.

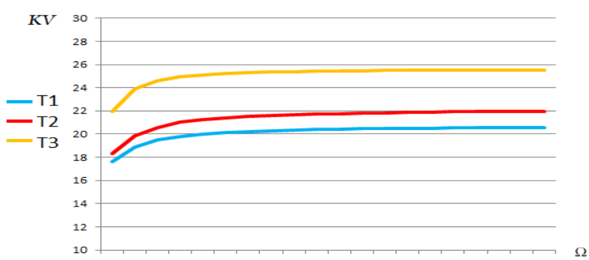

Figure. 11. over voltage created in the normal phase of the transformers in Havanirooz Power Station

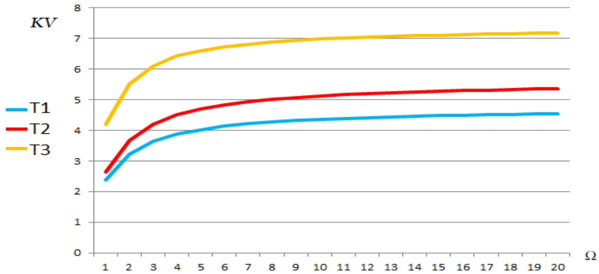

Figure. 12. over voltage induced in the earthing system of the transformers at Havanirooz Power Station at different levels of resistance of their Y center

5. RESULTS

The earthing system of Havanirooz Power Station connected to Y center of the transformers is 35 years old. At that time in order to create the earthing they used salt and coal soil which was washed away during the winter and it led to the increased resistance in earthing system. With the increase in resistance, in case of single-phase to ground short circuit the voltage of normal phases exceeded the common situation which was equal to the rated voltage by the increase in resistance in Y center of the transformer while at the earthing center of the transformers a significant voltage in induced which is followed by the destruction of the earthing system of the transformers. The results show that if the Y center resistance in all transformers is increased from 2 ohms to 3 ohms, the overvoltage created in normal phases at single-phase to ground short circuit is an average 650v higher than the normal condition which is equal to the rated voltage. However, increasing the resistance to 4 Ohms is followed by an overvoltage of 1 kV. At the voltage of over 4 ohms the slope of over voltage is reduced and finally at the resistance of 20 ohms this over voltage at normal phases is about 8% more than the time that the resistance of Y center of transformers is 2 ohms. The same is true regarding the induced voltage in the Y center of transformers. If preventive measures such as annual testing of the station and modern methods such as the use of bentonite instead of salt and coal soils are not applied, this over voltage can cause damages to the station insulation.

RESOURCES

Mousavi, K. Hosseinian, H. Abedi, M. (1998). "Modeling and simulation of single-phase arc on short circuit lines," Thirteenth International Conference on Electricity.

Shojaee, A. Ghadimi, R. Alipoor, K. Talebi, J. (2012). "short circuit stability and load flow of hydropower DG in electricity distribution network of Iran," regional conference of Syrdan.

Azizian, D. Vakilian, M. Feiz, J. (2012). "a new non-linear circuit for short circuit and no-load calculations in dry tensile four-coil transformer," the twenty-seventh International Conference on Electricity.

Moghaddam, P. Modir Shanehchi, MH. (1993). "a short circuit calculations for distribution networks," the eighth International Conference on Electricity.

Karimi, E. Aqtarnya, F. Pooraqababa, R. (2007). "changing the network configuration to reduce the level of short circuit," the twenty-second International Conference on Electricity.

Roghanian, H. Poormand, M. Khaleghi, Sh. Kargar, Sh. (2004). "Reducing the level of ground short circuit in Bahmani and Boudar of Bushehr stations," Nineteenth International Conference.

Nasiri, A. Brahmandpoor, H. (2006). : the reduced level of short circuit in Ramin power plant.

Khedarzadeh, M. Mortajei, M. Safar noorallah, A. Hamedani Gulshan, ME. (2004). "Fundamentals of Power

Protection Systems," first edition, the Applied science Institute of Water and Power Industry.

Yaraei Rostami, H. Akbarnia, A. Mansouri, B. Khodakhast, Nasiryabi. (2013). "Simulating the effect of transients over voltages in single phase-to-ground fault and Repetitive Restriking in case of point zero resistance cutoff electrical system using PSCAD the software, sixteenth Conference of students of Electrical Engineering Iran.

AUTHOR INFORMATION:

Seyed Sajjad Salehi Ghaleh Sefid Was Born in Masjed Soleyman, Khuzestan, Iran on Septamber 21, 1983. He Received the B.Sc. Degree in Power Transmission and Distribution Engineering from Islamic Azad University, Shoushtar Branch, Khouzestan, Iran, in 2009. He Received the M.Sc.Degree in electrical engineering from Islamic Azad University, Najafabad Branch, Isfahan, Iran, in 2012. He has published and presented several papers. His research interests include power electronics, power quality and renewable energy.

Email Address: s.salehi1983@gmail.com