Leak Current Monitoring System on the Ground Cables Medium Voltage Transformer 150/20 kV

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Abstract. There had been fault trip at PMT 150/20 kV transformer in Jatirangon substation. For fault detection, that rele differential phase T and REF 20 kV have worked to detect this fault. The resulted impact of this fault is Power outage in feeder a 1350 A, 35 MW and 5 Mvar. The cause of this fault is the occurrence of breakdown on ground cables 20kV T-phase-core 1. This results in a short circuit to the ground so that the differential protection relay and REF 20kV work because the relay detects a fault in the ptotection zone. The result of this research is the design of an early detection monitoring tool. This tool is used to determine the amount of leakage current on the ground cable in order to minimize the occurrence of interference that causes the occurrence of electrical power outage. The result of the leakage current monitor on the ground phase cable T obtained a current of 0.6A with temperature 35 oC. With thermal failure calculation method for leakage current obtained result of 0,56180A with same temperature. Comparison of the calculation with the measurement of leakage current on the ground cable is obtained at 6.36%..

1 Introduction

The distribution of electric power transformer power step down voltage of 150 kV System to a medium voltage (MV) system in large capacity, is generally done using a medium voltage cable. Distribution of electrical energy step down power transformer from 150 kV voltage system to 20 kV medium voltage system in a large capacity, generally carried out using medium voltage cable network [1]. This is because for the distribution of 20 kV medium voltage power System air conduct is sometimes difficult to implement because it reduces the aesthetics of space. For this reason, an important factor to be considered in using ground cable is the isolation characteristics. One of the obstacles to the use of ground cable is the failure of isolation in carrying out its function as a medium voltage isolation medium [2]. Because in the manufacture of cables is sometimes not perfect so there are cavities in isolation. If the rate of heat at a point in the cable material exceeds the rate of heat dissipation, there will be an unstable state and at some point the material will cause a thermal failure. If this thermal failure lasts a long time, it will reduce the reliability of the cable so that it will cause isolation failure and damage to the cable [3]. The failure of the isolation of the 20 kV medium voltage ground cable occurred in the

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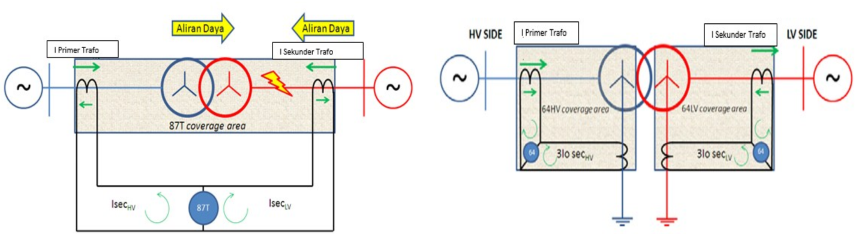
150/20 kV Transformer #4 at the Jatirangon Substation, which caused a disturbance and the electrical power outages. Before the power outage, no monitoring of the leakage current of the power cable was made so that it was not detected early that an increase in the leakage current of the medium voltage cable resulted in the Fault. For this reason, it is necessary to have a tool to detect early increase in the MV leakage current so that it can minimize the disturbance that causes the power to be disconnected to the consumer, the productivity stops and causes losses to the Industries due to damaged equipment. [4]

2. Transformer Protection

The transformer at the substation that functions to distribute electrical energy to the distribution electricity system must be protected properly.[5]. The transformer is protected by using protection relay; the relay is in charge of identifying the fault that occurs in the transformer, fault around the transformer, and fault with the network supplied by a transformer. The protection relay is grouped into 2 types of protection, namely mechanical and electrical relay [6]. All mechanical relays are the main protection relay. Differential relay is relays that work when detecting phase differences and or instantaneous difference in input current and output current. The principle of this relay work is the comparison of the primary, secondary and or tertiary winding currents. In Figure 1.a. explains the workings of the RD when fault conditions. In this condition the differential relay does not detect the difference in the primer current and the secondary current so that the differential relay does not work. Figure 1.b describes the Fault condition in Protection Zone. In this condition differential relay detected any difference in primer current and secondary current, so differential relay will operate.



a) b)

Figure 1. Scheme of internal a) fault condition and b) REF [6]

3 Ground Cable

For connecting between Outgoing of Transformator to feeder outgoing 20 kV is used Ground Cable.[7]. The cable construction basically consists of 4 components, namely: [8].

3.1 Conductor

The conductor is intended as a good electrical conductor of low voltage, medium voltage or high voltage and called the core of the cable, including in the ground cable section. On the research had used medium Voltage ground cable 20kV with a core made of aluminium is then seen table 1. The electrical conductivity of a conductor material is expressed by conductivity, which is the opposite of resistivity, or the resistance type of conductor, where the resistance type is defined as [9]:

$$\rho = \frac{R.A}{L} \tag{1}$$

Where:

A= cross-sectional area (m^2), L= Cable length (m), R= conduct resistivity (ohm-m), ρ= Conductivity.

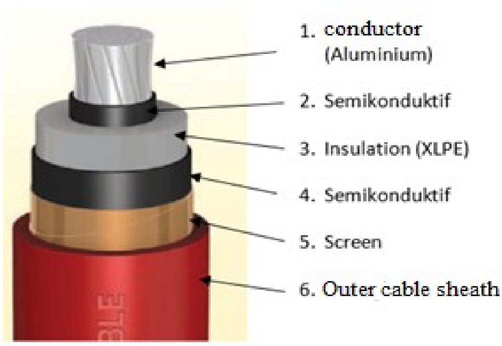


Table 1. Properties of aluminum

Properties of Materials	Unit	Alumunium (Ac)
Electrical Conductivity (ρ)	$(\text{ohm meter})^{-1}$	$3{,}8 \times 10^{7}$
Thermal Conductivity (k)	J / m.s °C	200
	Kkal / m.s °C	$500 \,.\, 10^{-4}$
Resistance Type	Ωm	$2{,}65 \times 10^{-8}$

Figure 2 Nucleated single ground cable

3.2 Isolation

Cable isolation is often called the dielectric material, whose function is to limit or to prevent direct contact between the conductors that are voltage with the surrounding objects. Its Protective functions prevent the isolation from being affected from the outside such as the entry of water into the cable isolation, or humidity mechanical or pressure that could damage the cable isolation. (Figure 2). that is the kind of NA2XSY ground cable 1x150 cm/12/20kV declares a single nucleated, cables for nominal voltage 12/20 kV XLPE insulated, conductor, aluminium with a broad cross-section of 150mm2 copper layers, on the outside of the core arrangement with a broad cross-section of 25 mm2, PVC. These cables are used in this research are already installed.

3.3 Thermal Failure

Cable insulation failure is a situation where isolation cannot anticipate an abnormal condition that exceeds the isolation capability. Isolation failure is caused by the type of electrode material, the configuration of the electric field, temperature, pressure, voltage, and the life time of the used isolation material. Thermal failure is a failure that occurs if the speed of heat at a point in the used material exceeds the rate of heat dissipation out. According to Whitehead, the minimum voltage of thermal failure (Vm) is: [3]

$$V_m = \int_{Tm}^{To} \left| \frac{(8\,k)}{\sigma} \right| dt \tag{2}$$

Where, Vm: Voltage fails the minimum thermal [V], k : thermal conductivity [J / m.s oC] To :Temperature on surface equal to the temperature of the circumference) [^{o}C]. Tm: critical Temperature of materials, σ: electrical conductivity [ohm meter]-1

3.4 Leakage Current

Inside the cable there are often cavities that contain gas or air. As it is known that a cable consists of several types of layers made of different materials and has different expansion coefficients [2]. In case of heating and cooling, either at the time of manufacture or at the time of loading with the current depreciation expansion and then from each ingredient will differ. As a consequence will thus the cavity-cavity containing the gas or air between the layers that and cavity gas or air has a dielectric strength of materials isolation materials. The air cavity is a hole with pressurized air and low power dielectric isolation, is the weak point of isolation because the permittivity is lower, it will be an increase in the electric field in the air in the cavity exceeds the power to penetrate the air. Leakage current is a current that flows through the isolation surface. Leakage currents also caused by leaky cavities on isolation material, which caused an error in the manufacture of isolation material. Isolation resistance affects the leakage current. [10]. The equation of the isolation as follows:

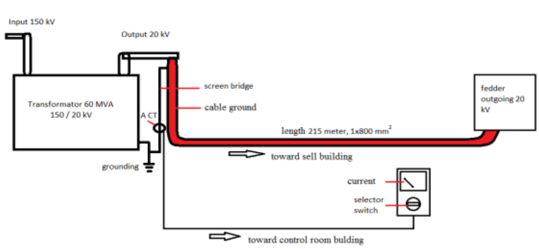
$$I_b = \frac{Vm}{R} \quad (3)$$

Where, I_b: Leak current [A], V_m: voltage of minimum thermal, R: thermal resistance [Ω]. Normally the current will flow through the cable conductor, while unwanted leakage current will flow radially from the conductor through the dielectric to the protective layer. In the cable cross section then it will become larger when it is started from the conductor.

4. Monitor of Leakage Current

4.1 Concept and Measurement

To be able to monitor the leakage current on ground cables transformer-4 GI Jatirangon, then a device monitoring facilities of leaked cables was designed base on grounding. On operated transformer, the only leaked currents of cable ground can be monitored. The leakage current flows from the part of the cable called the screen which is grounded on one side of the cable end. The screen functions as the location of the flow of short circuit current in phase fault to the ground to the nearest ground flow the capacitive current that arises in isolation because of the phase to ground voltage. For this reason, a leakage current monitoring facility can be made by using the screen that is grounded. To be able to monitor the current, a current transformer ring is used for current measurement. After that, the ct ring is connected to a measuring device so that it can monitor the current value. Because in T phase there are 3 cables with a core, then 9 CT rings are needed for each cable. For more details, see Figure 3 below.



a)

b)

Figure 3. a) Monitor of Leaked current Concept, b) Measuring of Leakage Current

Monitoring the leakage current can be done in a calculation based on thermal failure by monitoring the temperature on the cable surface. According to Whitehead the voltage of thermal failure can be calculated by using formula 1 and the leakage current can be calculated using the formula 2. Monitoring by Measurement of leakage current can be seen Figure 3.b.

4.2 Result

To be able to monitor Specifications techniques for ground cable for transformer 4 the length of the 215 meters with a cross-section area of 1x800 mm^2. Electrical conductivity, thermal conductivity and resistance type of aluminum can be seen in tabel 1. By substituting to the formula 1 the value of the parameter value, then the value obtained for the 20kV ground cable resistance is R = 0.00712 Ω. To get the value of the leakage current, the ground cable must first find the voltage of the thermal cable ground failure then the thermal failure voltage can be calculated by using formula 3 as follows:
Ground cable the T phase core 1:

$$V_m = \int_{Tm}^{To} \left|\frac{(8k)}{\sigma}\right| dt = \int_{130}^{35} \left|\frac{(8.\ 200)}{3{,}8 \times 10^7}\right| dt = 0.004 \text{ V}$$

Then obtained for failed cable ground thermal voltage for V_m = 0.004003 V, then for the flow of leaked cables can be calculated as follows:

$$I_b = \frac{Vm}{R}\ ,\ I_b = 0.56180 \text{ A}$$

After the calculated then obtained for the leaked cable of core 1 for I_b = 0.56222A. For other cable core calculation result can be seen in table 2. For the calculation of ground cable with thermal failure method, the result of leakage current is 0.56180A with a temperature of 35°C, while the results of monitoring by a measuring device obtained the leakage current of 0.6 A with the same temperature. Obtained for the difference between the calculation and the measurement is of 6.36%. Specifications techniques for ground cable for transformer 4 the length of the 215 meters with a cross-section area of 1x800 mm^2. Electrical conductivity, thermal conductivity and resistance type of aluminum can be seen in tabel 2. By substituting the value of the parameter value to formula 1, then the obtained value for ground cable resistance is R = 0.00712 Ω. To get the value of the leakage current as the result, the ground cable must first find the voltage of the thermal cable ground failure then the thermal failure voltage can be calculated by using formula1 and 2 for the Ground cable the T phase core 1:

$$V_m = \int_{Tm}^{To} \left|\frac{(8k)}{\sigma}\right| dt = 0.004 \text{ V} \quad \text{and} \quad I_b = \frac{Vm}{R}\ ,\ I_b = 0.56180 \text{ A}$$

After the calculated then obtained for the leaked cable ground T phase of core 1 for I_b = 0.56222A. For other cable core calculation result can be seen in table 2. For calculation results are smaller than the results of monitoring the equipment directly. For the calculation of ground cable with thermal failure method, the result of leakage current is 0.56180 A with a temperature of 35°C, while the results of monitoring by a measuring obtained the leakage current of 0.6 A with the same temperature. Obtained for the difference between the calculation and the measurement is of 6.36%.

Table 2. Calculation and the measurement Comparison

Phase	Core Cable	Thermal (°C)	Calculation		Measurement (A)	Calculation : Measurement (%)
			V_m (V)	I_b (A)		
R	1	33	0.00140	0.57163	0.8	28,54
	2	20	0.00463	0.65028	1,1	40,88
	3	30	0.00421	0.59129	0,8	26,08
S	1	20	0.00463	0.65028	1,1	40,88
	2	25	0.00442	0.62079	0,9	31,02
	3	20	0.00463	0,65028	0,8	18,71
T	1	35	0.004	0.56180	0,6	6,36
	2	20	0.00463	0,65028	1,0	34,97
	3	20	0.00463	0.65028	1,2	45,81

5. SUMMARY

1. The leakage current can be calculated by using thermal failure method. The results of leakage current of T phase core 1 ground cable is 0.56180 A with a temperature of 35°C. While using a measurement results in 0.6 A with the same temperature. Difference between calculations with measurements of 6.36%.
2. With a leakage current monitor equipment can detect early on the leakage current. If there is a significant increase in leakage currents, there can be a minimization of fault caused by a recurring ground cable breakdown so that electricity distribution to consumers and electrical equipment at the Jatirangon substation becomes more reliable.

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