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Research paper

Analysis of current overflow disturbance towards neutral grounding resistance condition

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Abstract

The power transformer at the substation serves to deliver power from high voltage to low voltage or vice versa. In the transformer section, there is a neutral grounding resistance mounted serially with the secondary neutral on the transformer before connecting to the ground that serves to minimize the fault current. One of the disadvantages of the NGR grounding system is when there is a short-circuit one-phase interruption to the ground, the soil disturbance current may be larger than the limit of the NGR value that used. This can cause damage to NGR and other equipment. This study discusses about current overflow disturbance in NGR at State Electricity Company or PLN, PLN Lamhotma Substation application in normal condition with cable channel length 28,215,244 feet and at 20 kV voltage of ground capacitance with manual calculation obtained Ico = 1,16 A and if there is a one-phase disturbance to the ground then the greater the current will be Ig = 4.61A. To prevent the enlargement ofthis one phase short circuit current, then it is measured towards neutral grounding resistance.

Keywords: *Transformer; NGR; Ground.*

1. Introduction

The need for electric power that tends to increase every year, has encouraged the develop ment and addition of electrical power generation centers and substations that serve as the center of electric power delivery to various consumer areas [1]–[4]. The reliability of a system of electric power is determined by either the protection system on the generation side and the equipment at the substation such as the Power Transformer, busbar and protection equipment such as the Power Transmission Line (PMT), the separator (DS), the measurement Transformer (CT and PT) and others, as well as the work of the operator who operates and oversees the equipment [5]–[7].

Development [8]–[13] in all fields requires PLN to provide electric power in accordance with the needs of consumers. But to meet the needs of electric power, there is often a disruption in the network. Short circuit interruption as one of the disturbances in electric power systems that have transient characteristics that must be addressed by safety equipment. The occurrence of a short circuit leads to a surge of current with a magnitude higher than normal and the voltage at the site becomes very low which can lead to damage to the insulation, mechanical damage to the conductor, electric sparks and the worst state of overall operation systemfailure [14]–[16].

In the neutral grounding earthing system when there is a short-circuit to the ground, the resulting disturbance noise will be large and the arc can no longer extinguish by itself, the phenomenon of "arcing ground" is very dangerous because it creates more transient voltage that can damage equipment [17], [18]. If the above is allowed, then the continuity of the distribution of electricity will be` stopped which means it can cause considerable losses. Therefore, power systems are no longer floating which is commonly called the delta system, but its neutral point is grounded through resistance, reactor and directly grounded (solid grounding). In electrical systems, generally the power transformer at the substation is equipped with NGR (Neutral Grounding Resistance) with a value of permanent resistance that serves to limit the current disturbance of the soil. Neutral Grounding Resistance (NGR) is a resistance mounted between the neutral point of the transformer with the ground which serves to minimize the fault current. Usually grounding system using NGR is used on the power transformer secondary system, which on this side is feared there are many disturbances. When there is interference then NGR will reduce the noise and analyze the amount of noise current and send signal through current transformer (CT) to ground Fault relay which will break the circuit breaker when the noise current exceeds that allowed. The grounding system is a very important coordination of protection in an electrical network, because without good ground it can harm people and animals around it and may even cause damage to the equipment itself. Transformer is the heart in the electrical network because of the task of adjusting the incoming and issued voltage, either to raise the voltage or to lower the voltage, therefore it is needed a good grounding system to support the sustainability of the transformer work.

One of the disadvantages of the grounding system with NGR is when one phase of short circuit breaks to the ground, the ground disturbance current can be larger than the limit value of used NGR resistance. This can cause damage to NGR and other equipment. The increase of the grounddisturbance current magnitude is caused by the influence of the capacitance of the transmission line. In case of short circuit of one phase to the ground there will be a large soil disturbance due to line discharging from the transmission line [19], [20].

In this research it will be conducted a direct measurement on neutral grounding resistance to anticipate the enlargement of soil disturbance that can damage the equipment and detrimental to PLN.

2. Methodology

2.1. Distribution system

The distribution system is a part of the power system that is closest to the load/customer side. The function of the distribution system is to distribute and distribute electrical energy from the supply center, which in this case may be a substation or power plant to the load center and the customer through the Primary Distribution Network, called the Medium Voltage Network (JTM), ie in the form of Medium Voltage Cable Channel (SKTM) or Medium Voltage Air Channel (SUTM). This network connects the secondary side of the power transformer in the Substation to the Distribution Substation, the magnitude of the supplied voltage is 20 kV. Secondary Voltage Distribution Network or Low Voltage Network (JTR). connecting Distributors / secondary side Transformer distribution to consumers with reliable quality System voltage used is 380 Volt and 220 Volt [21]. In a simple distribution system can be seen in Figure 1.

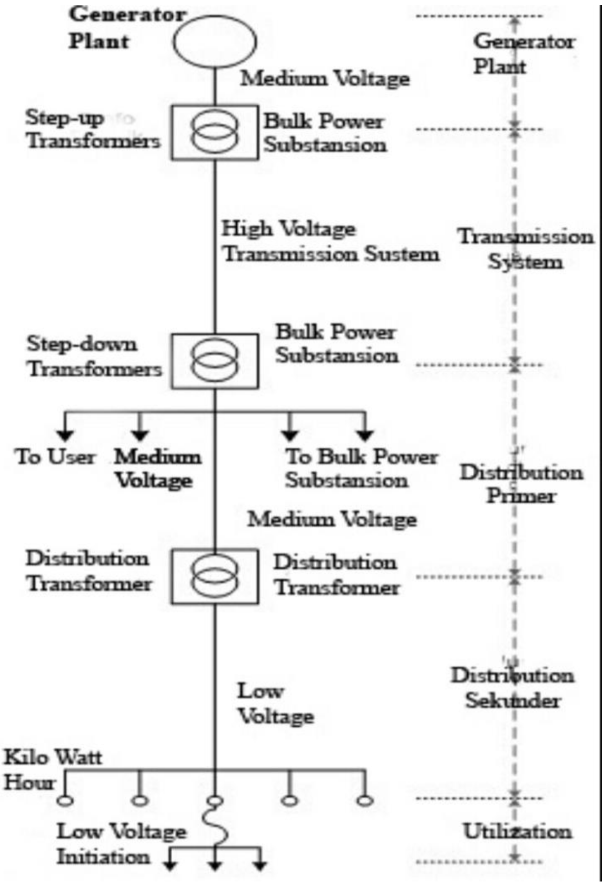

Fig. 1: Distribution System.

2.2. Types and causes of interference

Kinds of disruption to SKTM planted in the soil is of a permanent nature, in which to remove the interference required corrective action and remove the disturbance, where this interference causes termination. Causes of interference that comes from within the system include:

a) Abnormal voltage and current
b) Unfavorable installation
c) Aging (age)
d) Heavy weight
e) Failure to work on safety equipment

While the causes of interference that comes from outside, among others:

a) Mechanical disturbance due to excavation work
b) Vehicles passing on it
c) Lightning implants through the air passages
d) Land deformation
e) Man
f) Animals and other objects, such as yarn.

Various disturbances in the distribution system on the ground (air channel) can be divided into two groups, namely:

a) A temporary disturbance, which may be lost by itself or by a momentary interruption of the voltage source, ie the auto-recloser.
b) Permanent disturbance, where to free it necessary repairs and remove the interference [15], [22].

2.3. Disturbance on electric power system

Disturbance to the electrical system is any kind of incident that causes the condition of the electrical system to become abnormal. One of the causes of this condition is a short circuit. Short circuit interruption is a disturbance that occurs due to errors between the parts that are on hold. Short circuit breaks can also occur due to penetrating or damaged insulation because they are not resistant to overvoltages, either from inside or outside. When short hubuing disturbances are left to last longer on a power system many unwanted effects will occur. The following are the consequences of short-circuit interruption:

a) Reduced stability limits for power system.
b) Damage to equipment close to disturbance by unbalanced currents or low voltage generated by short circuit.

Short circuit interruption is a disturbance that occurs due to errors between the parts that are on hold. Short-circuit interference may also occur due to penetrating or damaged insulation because it is not resistant to overvoltages, either from inside or from outside. (Due to lightning strikes). Short circuit interruption is a condition in the power system where the conductor is connected to the other conductor or with the ground. Disorders resulting in short circuit can cause currents much larger than normal currents. When short circuit interruptions are allowed to last for a long time on a power system, many undesirable effects may occur.

a) Reduced system power stability limit.
b) Damage to equipment close to disruption by unbalanced currents, or low voltage generated by shorr circuit.
c) A possible explosion on the equipment which contained insulating oil at the time the occurrence of a short circuit.

Disturbance on the electrical system is any kind of incident that causes the condition of the electrical system to become abnormal. One of the causes of this condition is a short circuit. Short circuit breakdown is divided into 2, namely:

a) Symmetrical disturbance

Symmetrical disturbance is an interruption where the magnitude of the disturbance current is the same on each phase. This disturbance occurs on the three phaseshort circuit. The calculation of the disturbance current is calculated using the equation, only when the symmetrical interference occurs, no arc occurs because the conductor does not touch the ground. So the equation becomes:

$$I_{fault} = \frac{Vsource}{Zs - ZL} \tag{1}$$

Where,
I_{fault}: Disturbance current (A)
Vsource: System voltage (V)
Zs: Transformatorimpedance (Ω)
ZL: Line system impedance (Ω)

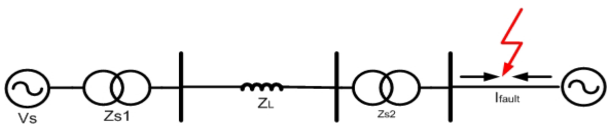

Fig. 2: Simple Single Line Diagram.

b) Asymmetric disturbance

In general the amount of disturbance current is calculated using formula:

$$I_{fault} = \frac{Vsource}{Zs - ZL - Zf} \quad (2)$$

Where,
I_{fault}: Disturbance current (A)
Vsource: System voltage (V)
Zs: Transformatorimpedance(Ω)
ZL: Line system impedance (Ω)
Zf: Dsiturbance impedance: arc, ground resistance (Ω)
The point at which the conductor touches the ground during disturbance is usually accompanied by a bow (arc). This arc is resistively resilient, but the arc resistance is large. The resistance of the disturbance depends on the resistance of the arc and the resistance of the ground when there is disturbance to the ground [14], [23].

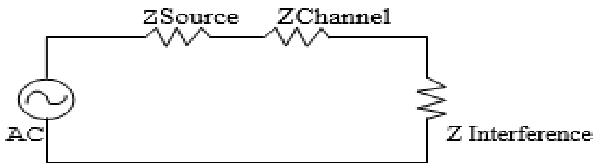

Fig. 3: Circuits on the State of Interference.

2.4. Understanding NGR (neutral grounding resistance)

NGR is a serial mounted resistance with a secondary neutral on the transformer before it is connected to ground. The purpose of NGR is to control the amount of disturbance current flowing from the neutral to the ground. This is related to Security Pattern of Secondary Power Transformer (Distribution System). NGR is also a resistance mounted between the neutral point of the transformer with the ground, which serves to minimize the disturbance current. Resistance is mounted at the neutral point of the transformer connected to Y (star). NGR is usually installed at the neutral point of the transformer that is 70 kV or 20 kV, while at the neutral point of transformer are 150 kV and 500 kV directly digrounded (solid). Neutral grounding resistance serves for limiting current in the transformer's neutral channel. In order for NGR to function according to its design it is necessary to ensure that the resistance value of the NGR is in accordance with its specifications and does not suffer damage.

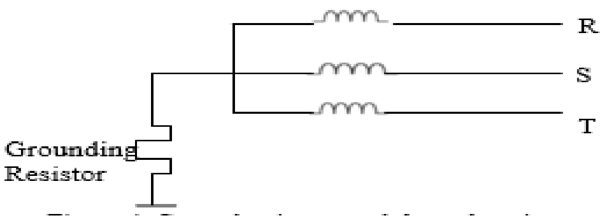

Fig. 4: Ground Point Neutral through Resistance.

Grounds with NGR can be divided into several types, namely:

a) Ground system with low resistance (12 and 40 Ohm)
b) Ground system with high resistance (200 and 500 ohm)
c) The use of NGR with the type of low or high depends on the design of power subsystem, basically the greater the value of NGR, the phase noise current to the ground is getting smaller.

2.5. Grounding through prisoners

A system is said to be earthed with a resistor or resistance when the system's neutral is connected to the ground through one or more resistors as shown in Figure 4. In grounding in this way the phase to ground voltage occurs when a phase to ground disturbance approaches the voltage of the system except the transition voltage.

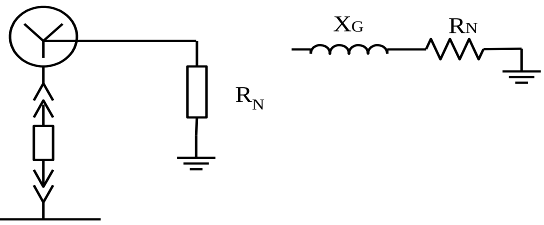

Fig. 5: Grounding through Prisoners and Equivalent Diagrams

Where:
XG= Reactance transformer or generator
RN= Ground Resistant

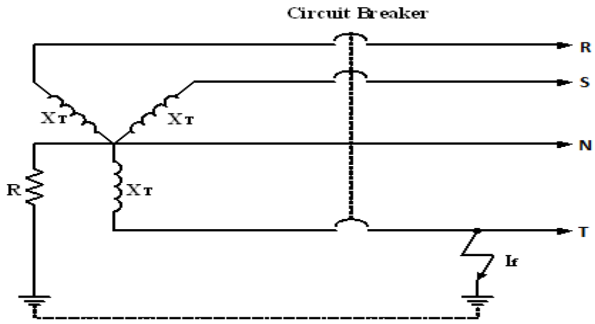

Fig.6: One Phase to Land Disturbance in A System Grounded through Prisoners.

To know the magnitude of noise current in neutral grounding resistance (NGR) can be done through resistance when the ohm value of resistor installed between neutral system with soil meets the criteria [20]:

$$RN \leq \frac{Xco}{3} \quad (3)$$

$$IR \geq 3I_{CO} \quad (4)$$

Where:
RN= Resistance of the resistance
X_{CO}= Capacitive reactance from phase to phase soil
IR= Current flowing in earthing prisoners
I_{CO} = Capacitive current (charging current) flowing between soil phases.

$$I_F = 3I_{CO} = \frac{E_{LN}}{X_{CO}/3} \quad (5)$$

2.6. Cabling capacity loading flow

For systems using insulated cables in long enough repeater circuits, the percentage contribution of the loading current from the total loading current is considerable. In order to determine the exact flow of the current it must first know the size, length, voltage, type of insulation and thickness of insulation used. From these data the capacitive loading current can be calculated. Cable loading capacitance for single and triple shielded cables can be calculated by the formula [24] :

$$Co = \frac{0{,}00735.(SIC)}{log\,D/d} \ (\mu F / 1000\ ft) \quad (6)$$

As for the cables without the shield of three conductors are:

$$Co = \frac{0{,}00834.(SIC)}{log(d+3t+b)/d} \ (\mu F / 1000\ ft) \quad (7)$$

Where:
C_0= Capacitance to the ground
SIC= Dielectric constant
D= Diameter of all isolation
d= Diameter of conductor

b= Thick ribbon insulation
t= Thickness of conductor insulation
From equation 5:

$$3\ ICo = \frac{ELN}{XCo\ /\ 3} \tag{8}$$

3 ICo = 3, 4641.10-3.f.ELL.SIC.Co (9)

Of equations, (5) and (6) are found:

$$3\ ICo = \frac{4.8.ELL}{log\ D/d}\ (mA\ /\ 1000\ ft) \tag{10}$$

3. Result and discussion

The power transformer data obtained from the implementation of this research is power transfor mer data of Lamhotma Substation. The data can be seen in Table1 below.

Table 1: Power Transformer Data of Lamhotmasubstation

Specification	Information
Power Transformer	30 MVA
Voltage	150 / 20 KV
In	866 A
Brand/Type	HYOSUNG/MTB M229
Impedancy	12,33 %
Vector Group	YN ynOds
Serial	TP 95 – 8501
IEC	76
Year	NOV – 95
Made In	Korea

The NGR data obtained from the implementation of this research is the data of NGR substation of Lamhotma. The data can be seen in Table 2.

Table 2: Lamhotma Substation Data Table of Hyosung Brand NGR Prower Transformer

Specification	Information
NGR 20 KV	OZ DIRENC
Brand	P – 422- NIX 125
Type	10- A 304
Serial	SN 12 – 12 -2020
OHM	40 Ohm
Amper	300 A
CLS	5P20, 20VA, 24KV,1000/5A
Year	2012
Made In	Turky

This research is applied to a case, where case's object is the influence of NGR value condition during short circuit happen one phase to the ground, starting from May 16th to June 2nd placed at PT. PLN LamhotmaSubstation.
Here the calculations are done manually to determine the current of one phase to the ground and the current flowing in the neutral grounding resistance (NGR). Where is the power transformer on Lamhotma Substation, 30 MVApower, with channel length LM -1 that is about 8.6 km (28.215,224 ft), 20 kV power cord with cable type PE (AAAC) 1 / c 1000 kcmil. From the data can also be calculated the amount of capacitive loading of the system by using the formula. And in this research, direct measurement is done to know the neutral grounding resistance. When a system is in normal condition as shown in Figure 7.

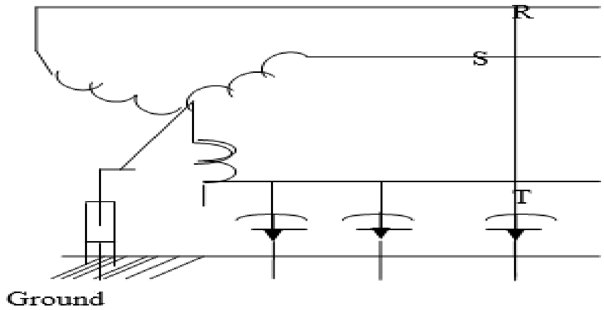

Fig. 7: The System under Normal Circumstances.

Eight, 6 km = 28.215.244 feet 1000 KCM power at (20 kV) so:

Outside Diameter (D) is 240 mm (0, 0787 ft)
Outside Diameter (d) is 17,5mm (0, 0574 ft)
Solution:

$$Co = \frac{0{,}00735(SIC)}{log\frac{D}{d}}\left(\mu\frac{F}{1000\ ft}\right);\ SIC = 5$$

$$Co = \frac{0{,}00735\ (5)}{log\frac{0{,}0787}{0{,}0574}}\left(\frac{F}{1000\ ft}\right)$$

Therefore, the X_{CO} is $X_{CO} = \frac{10^6}{2.\pi.f.Co}$

X_{CO} = 9.902,95 Ω/1000ft

In normal circumstances, if Xco balance:

$|I_{ca}| = |I_{cb}| = |I_{cc}| = Ico = \frac{Vl-n}{Xco}$ A

So, $Ico = \frac{20\ kV/\sqrt{3}}{9.902{,}95}$

Ico = 0,268 A / 1000 ft x 28.215,224

Ico = 1,167 A

Ico total current = 3 Ico = 3 x 1,167 A = 3,502A

So we can describe the vector of voltage and current in normal condition as in Fig. 8.

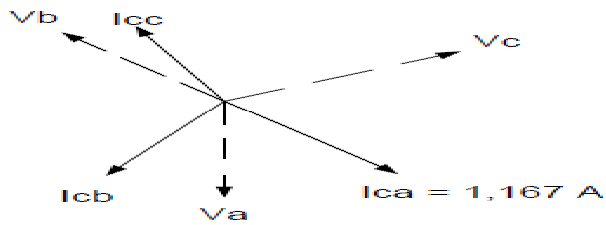

Fig. 8: Vectors of Voltage and Current under Normal Circumstances.

If the system in the event of a phase disturbance towards the ground as Figure 9.
30 MVA, 20 kv, 28.215,224 feet power cable 1/c 1000 kcmil
If the system in the event of a phase disturbance towards the ground as Figure 6.
30 MVA, 20 kv, 28.215,224 feet power cable 1/c 1000 kcmil

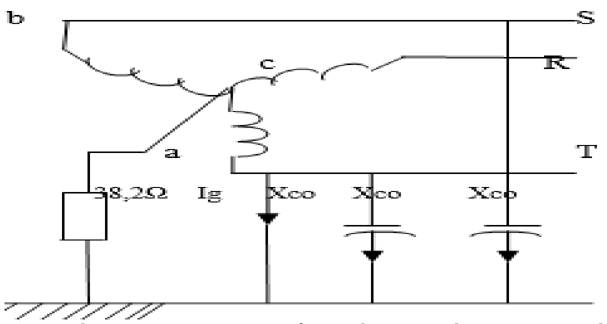

Fig. 9:.The System is in A State of Disturbance on Phase T to Ground.

So Ica = 0; $|Icb| = |Icc| = \frac{V1-1}{Xco} = \frac{\sqrt{3}V2-n}{Xco} = \sqrt{3}$ IcoA

$= \sqrt{3}$ x 1.167 A

= 2, 0189 A

$|(Icb + Icc)| = \sqrt{3}\ |Icb| = 3$ Ico = 3,502 A

That IR current must be ≥ 2, 0189 A

Assume I_R = 3 A

Therefore, the ground disturbance current is

Ig = $\sqrt{}$ $I_R^2 + (3Ico)^2$ A; where I_R = 3 Ico

Ig = $\sqrt{}$ $(3)^2 + (3{,}502)^2$ A

Ig = $\sqrt{}$ 9 + 12, 26

Ig = 4, 61 A

So we can describe the vector of voltage and current in the event of a phase disturbance towards the ground in Figure 7

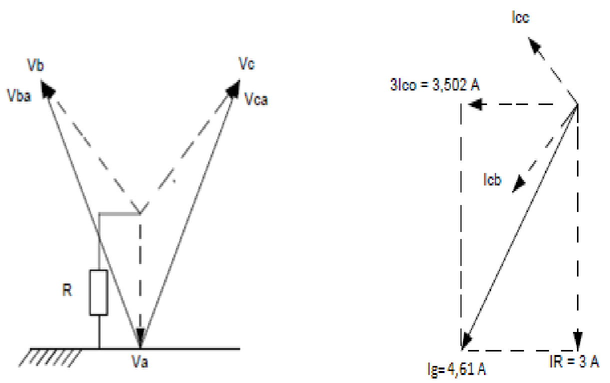

Fig. 10: Vectors of Voltage and Current now of Disturbance Occurs atthe-phase Towards Ground.

Table 3: Measurement Result of NGR Substation of Lamhotma with OZ DIRENC Brand with 40 Ohm Resistance Value

Activities description	Final condition	Explanation
Measurement of NGR element resistance / liquid	38,2 Ω	
Measurement of NGR isolation resistance	118.000 M	
NGR element :	Ω	Normal
Elemt–Body	50.000 MΩ	
Body–Ground	0,2 Ω	
Measurement of ground resistance		

4. Conclusion

With the cable line 28,215,244 feetlength and at a voltage of 20 kv with 30 MVA power it can be calculated the amount of disturbance current through it, thats is equal to(Ig) = 4,61 A. NGR measurement is done directly to determine the final condition of NGR element resistance value = 38,2 Ω, NGR element – body = 118.000 Ω, body – ground = 50.000 Ω, and ground resistance = 0,2 ΩThe conclusion of this research are as follows. First, Truth and justice can not be separated from the substance and purpose of law. Law in the sense of right and justice is a concept that everyone desires. Second, it is confirmed that Etical Decision Support System can determine whether a person has behaved ethically especially in terms of the rules of truth and justice from a hermeneutic point of view.

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