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ENHANCE GROUND ELECTRODE (E.G.E) FOR GROUNDING SYSTEM RELIABILITY APPLICATION

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ABSTRACT

Equipment damages cause by electrical surges can be attributed to ineffective grounding system which by right should provide protection to equipment and personnel safety. The grounding system ineffectiveness to surge protection is due to the remoteness of earth terminal or ground system entry points from the lightning surge occurrence. Despite all considerations taken such as maintaining low resistivity soil, multiple grounding terminal rods, mesh ground system still the problems remain unsolved. The underlying reason is that the connection between the earth terminal to the lightning induced surges occurrence points are as such, creating potential rises at points of unmatched surge impedance junctions thus effecting equipment reliability. The rise in ground potential magnitudes to remote earth at equipment proximity should be eliminated. This work has shown that by employing test-model grounding electrodes that used certain materials that have low thermal transfer impedance, acts like a kind of a portable earth to absorb lightning surge current energy, can be used for grounding system enhancement by connecting the tested ground.

Keywords: ground electrode, potential rise, thermal- conductivity.

INTRODUCTION

With the growing importance of electronic technology and production of sensitive electronic equipment, the protection of the equipment is a top priority for utilities like telecommunication companies. Generally the electricity can damage the equipment if it not properly handle. While sensitive electronic equipment with high integration system are frequently destroyed by lightning induced surges when improper and ineffective grounding system are installed. This equipment are damaged by surges entering equipment by differential and common mode mechanisms. The grounding systems connected to the surge protective devices are provided via a conductor to the grounding system. The surges in a electrical system are of the following:

1: Induced due to lightning direct strike to building and structures.

2: Lightning indirect strike to ground induced surges because of resistive coupling, capacitive coupling and inductive coupling.

Caused by the phenomena, the most important element to reduce the risk of damaged equipment caused by electricity is to provide good, proper and effective electrical grounding system to eliminate the ground potential rise to earth and to supresses over current entering the equipment. Commonly used electrical grounding system such as multiple grounding terminal rods, low resistivity soils on earth, mesh cage grounding system does not give full protection to the equipment, due to its long path current travelled to the earth terminal. Which mean the equipment still have risk to damage attributable to the propagation of reflected and transmitted in the conductive current path which results to rise in potential in the electrical grounding system.

Long path current travelled to the earth means high impedance from the path which is the copper bar and the copper terminal rods. Cause of that, it will cause ground potential rise to occur. It has been proved on Ohm's Law (1) when resistance and current is high, it will cause the voltage will high also.

$$Vground = If * Zground \quad (1)$$

Due to the effect, ground potential rises will occur and struck nearby equipment before travelled to the earth. Thus, it important to place the grounding system closes proximity to the equipment to reduce the risk.

GROUND POTENTIAL RISE

Ground potential rise occurs when a large current flows to earth through the grounding terminal impedance. The potential relative to a distant point on the earth is highest at the point where current enters the ground, and declines with distance from the source. Ground potential rise is a concern in the design of electrical grounding system because the high potential may be a hazard to people or equipment. The change of voltage over distance (potential gradient) may be so high that can damaged the connected equipment and nearby person in the grounding distance. Any conducting object connected to the grounding system, may also be energized at the ground potential in the grounding system. This transferred potential is a hazard to people and equipment nearby (Sakis, 1998).

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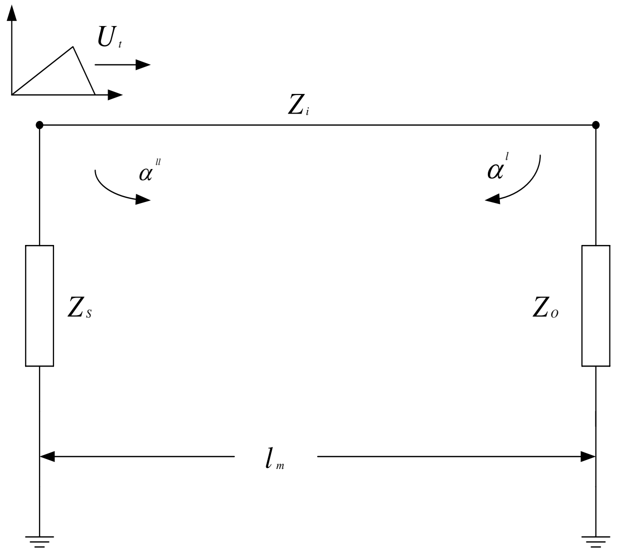

Figure-1. Grounding system impedance circuit.

Figure-1 shows a schematic diagram of a grounding system connected to a conductor with surge impedance Zi where both sides are in turn connected to Zs and Zo which is on the far right side. The following are considers; firstly when Zo is Rg -the ground resistance magnitude of the grounding system. Secondly is when Zo comprising Zc and Rg where Zc is the surge impedance of the conductor which interconnects the conductor Zi with the grounding system Rg.

$$\alpha' = \frac{Z_o - Z_i}{Z_o + Z_i} \quad (2)$$

$$\alpha'' = \frac{Z_s - Z_i}{Z_s + Z_i} \quad (3)$$

CONDITION 1:

$Z_o = R_g$ where Z_o is greater than R_g

At the R_g side, the magnitude of α' is negative which means the summation at V_{bb} of the Figure-2 is decreasing rapidly to zero. This scenario shows that there will be no ground potential rise will take place when the ground system is connected in closed proximity with the cable Z_i end (Siranagaraju and Satyanaryana, 2009).

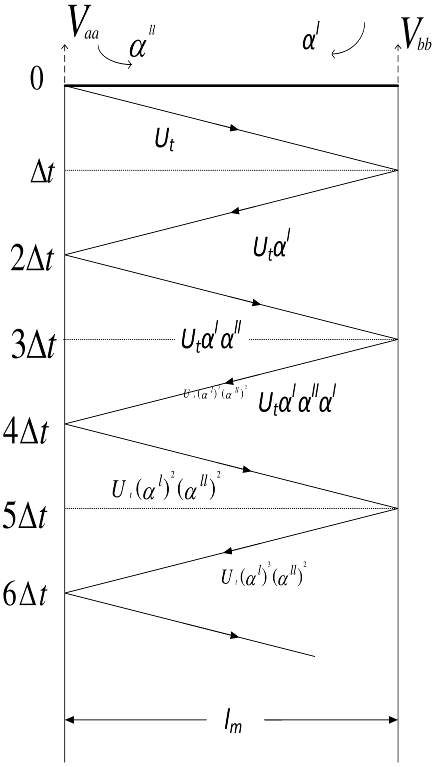

Figure-2. Bewley lattice diagram showing surge propagation.

Where: U_t – transient voltage step function

Δt – transient voltage transit time for a length l_m

α' – coefficient of reflection at point *bb*

α'' - coefficient of reflection at point *aa*

Z_s – impedance at supply side

Z_o – impedance at output side

Z_i – surge impedance of the service cable

ℓ_m – service cable length

The surge propagation in a piece of cable length l_m is shown in Figure-2 where the accumulative potential at point *bb* is dictates by equation (4).

$$V_{bb} = U_t(t-o)(1+\alpha') + U_t(t-\Delta t)(1+\alpha') + \alpha'\alpha'' U_t(t-3\Delta t)(1+\alpha'') + \ldots\ldots\ldots \quad (4)$$

The magnitude of V_{bb} will quickly goes to zero when the magnitude of α' and α'' are negative, after the transit period of $3\Delta t$ the magnitude will quickly goes to zero.

CONDITION 2:

The grounding system consisting of Z_o and R_g , where Z_o is greater than R_g and R_s is less than Z_i

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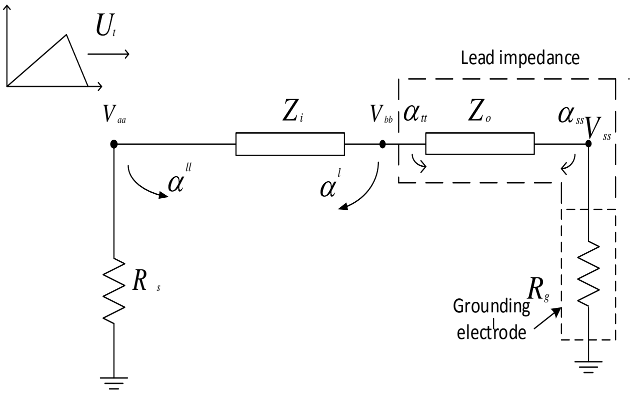

Figure-3. The surge propagation when lead impedance is introduce between service cable and ground electrode with resistance R_g.

In this scenario as shown in Figure-3, where the incoming surge U_t gets reflected at the point *bb* and also at *ss* invariably causing potential rise of magnitude noted by V_{ss} and V_{bb} respectively. The introduction of lead with surge impedance Z_o will delay the time the transient goes to zero. The successive reflection and transmission in the lead conductor of surge impedance Z_o, will produce higher magnitude of potential rise V_{bb}. The preceding thing is of concern is to come up with a grounding system that has a feature which made it portable and can be placed very near to the output terminal of the service cable removing the necessity of connected lead conductor to the earth terminal. Thus creating a possibility where the use of native grounding electrode is not necessary can be achieved (Jones *et al*., 1993).

MATERIALS FOR ENHANCEMENT OF GROUND SYSTEM

The main objective of this paper is to describe methods and testing of a grounding system that can be placed close to equipment. With the fact that energy cannot be destroyed once it is created become the fundamental and the underlining factor used for a search of material either inorganic or organic that can absorb electrical energy of low magnitude and disperse it to the material bulk. The concept used here is that an electrical energy needs to be converted to the heat energy before heat dissipation could place. To achieve the objective, the dreamed material needs to have thermal conductivity element. For this project we use the natural material and mix with certain chemical and Table-1 show the tabulated raw material used in the test.

Table-1. Material list.

Materials	Thermal conductivity (W/mK)
Natural	
Dry Sand	0.15 – 0.25
Saturated Clay	0.6 – 2.5
Lime	1.26 – 1.33
Chemical	
Magnesium Oxide	30
Iron Oxide	60

All of the material has been mix properly with the mass ratio of the material before it has been placed in the insulator case in Figure-4

Figure-4. Grounding system enclose made of plastic.

CONTRUCTION OF GROUNDING TERMINAL

The terminal is designed according to a heat exchanger concept which used heat sinks for cooling purposes through thermal dissipation action. For the terminal electrode material, we used copper because of its high magnitude of thermal conductivity and low resistivity to current flow as shown in Table-2.

Table-2. Thermal conductivity of copper.

Materials	Thermal conductivity
Copper	400W/mK

According to heat transfer theory, an exchange of kinetic energy of particles through the boundary between two systems which are at different temperatures from each other or from their surroundings. Heat transfer always occurs from a region of high temperature to another region of lower temperature. Similarly to electrical potential difference where the electrons move from a high potential to the lower one. Heat transfer changes the internal energy

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of both systems involved according to the First Law of Thermodynamics (Cengel and Michael 2009, Cengel and Michael 2009). InE. G.E, the thermal energy from the copper which is energized by current AC, DC or Impulse are absorbed within the bulk of the materials before converted to heat energy and being dissipated around the copper terminals. The total energy dissipated can be calculated with the aid of equation (5).

Total energy dissipated, $Q = m*C*\Delta T$ (5)

Where: m – Mass (kg)
C – Specific heat of material (w/mK)
ΔT – Change in temperature (second)

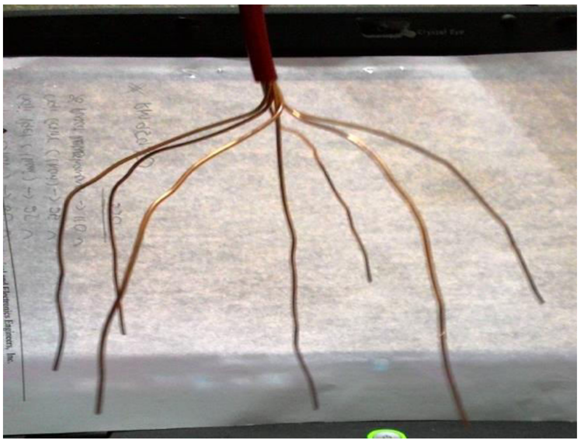

Figure-5. Root-like dangling grounding terminal surrounded by the material.

EXPERIMENTAL PROCEDURE

Three methods of testing were conducted using TERCO HV 9000 High Voltage Modular Training Set. One of the sub-system here is a set of 5-unit Lightning Air Terminal (LAT) which is made of steel were arranged on a place of platform made of plastic as shown in Figure-6. Figure-7 depicts the 3-D display of Figure-6.

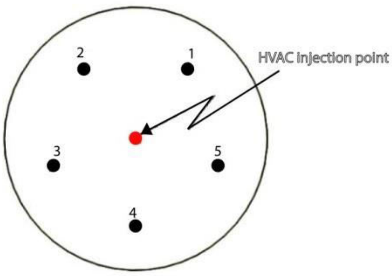

Figure-6. Illustration of the 5-unit LAT arrangement with top view.

Figure-7. The 5-unit LAT installed perpendicularly to the plastic support.

Three methods of experimentation conducted to show that without native ground, EGE is effectively worked like a grounding system.

METHOD 1: TEST SAMPLES LAT CONNECTED TO THE NATIVE GROUND

The arrangement of the lightning leader electrode and the 5-unit LAT is shown in Figure-8. The High Voltage test set of Universiti Tun Hussein Onn Malaysia (UTHM) ground terminal was connected to the test sample lightning air terminal (LAT) in turn from the one indicated as # 1 and subsequently to #2 in sequence and finally # 5.

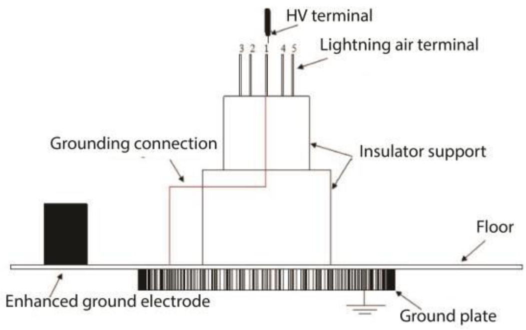

Figure-8. LAT connected to the ground plate.

The TERCO HV 9000 generator was used where the voltage output could be controlled from a panel; its voltage was increased slowly and gradually until breakdown took place. The breakdown voltage obtained was of average value of 59.72kV and the primary current at the point of breakdown was 2.29A. The flash over took placed between HV Terminal and the LAT which was solidly grounded to the laboratory ground terminal. Notwithstanding, the flash over was with LAT #1 that was solidly grounded, and no false flashover took place to other unintended LAT. The same testing procedures as previous stated but replacing with LAT # 2, #3, #4 and #5 respectively as shown in Figure-9. The results are shown in the Table-3.

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Table-3. Method 1 experimental value.

LAT #	Voltage (kV)	Current (A)
1	59.5	2.3
2	60	2.23
3	59.7	2.32
4	60.1	2.3
5	59.3	2.3

Figure-9. Flash over struck the LAT connected to native ground.

METHOD 2: TEST THE SAMPLE LAT CONNECTED TO THE E.G.E

The second method is important to be conducted to prove the E.G.E can behave like an actual grounding system which means that the flash over arc from HV Terminal safely grounded at the E.G.E as in Figure-10. The E.G.E is been placed at the floor (insulator side) means that the E.G.E itself is not been grounded. In this method, we use the same LAT sample and same equipment that being used in Method 1.

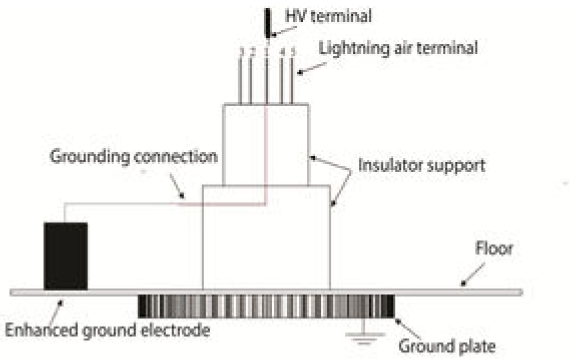

Figure-10. LAT connected to the E.G.E.

Based on this method, the result shows that, when breakdown happen and the flash over arc occur as in Figure-11, it will struck the LAT point 1 that has been connected to the E.G.E without affected the other LAT point. The breakdown happen at average voltage value of 53.54kV and 2.26A which mean by using this method, the breakdown happen earlier than method 2 because current travel to the ground at short path, which mean the risk of ground potential rise is reduced. The testing was repeated by using the other LAT #2, #3, #4 and #5 and the result shows that the breakdown arcs were perfectly grounded in the E.G.E. The details of result shows in the Table-4.

Table-4. Method 2 experimental value.

LAT #	Voltage (kV)	Current (A)
1	53	2.3
2	53.2	2.28
3	54	2.23
4	53.5	2.25
5	54	2.23

Figure-11. Flash over struck at LAT that connected to E.G.E.

METHOD 3: TEST THE SAMPLE LAT NOT CONNECTED TO THE NATIVE GROUND

The third method was carried out to prove that the laboratory simulated flashover will not take place without proper ground terminal. So Figure-12, depicts the connection lead was intentionally unconnected to the native earth.

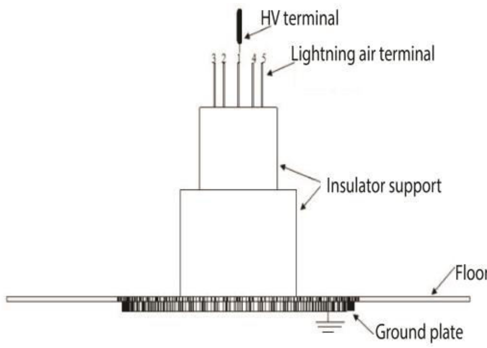

Figure-12. LAT not grounded.

Despite the generator output voltage increased to a voltage magnitude with high possibility to cause flashover to the LAT still there was not any flashover occurrence in Figure-13. The reason is that the flashover streamers could not find the opposite upwards streamer from the earth potential to create a bridging leaders or flashover connecting the high voltage potential

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Figure-13. No flash over at the LAT.

DISCUSSIONS

Standards documents explicitly explain the use of native earth for the safety of personnel and equipment safety when fault current flows in an electrical system. For high magnitude of fault current connection to native earth is not enough without the use of proper and efficient grounding system which could limit the step potential and touch potential to a tolerable level. Grounding system should also function as the zero reference to electronic equipment like Telekom centre for subscriber services. Even in the Petronas City Gate and Petroleum Compressed Centre there instruments required solid zero reference planes derive from ground terminal. In combination with the complexed installation of surge protective devices enhanced grounding electrode is so useful and for higher current rating of surge current than combined grounding system is useful that is using the enhanced grounding system with the native earth grounding system. With proper choice of material and exhibiting characteristics of high thermal transfer and high absorption of heat have potential to produce enhanced grounding electrode system.

CONCLUSIONS

This paper presents the results of the study material and based on the three methods of experiment that has been conducted, we were able to prove that E.G.E is able to act as like the existing grounding system and able to withstand voltage up to 54kV and current of 2.3A. Subsequent studies devoted to the study of materials and experiments to withstand high transient over current.

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