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An Efficient approach for Shielding Effect of the Grounding Electrodes under Impulse-Current Voltage based on MATLAB

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Abstract

The lightning current waveform has a major influence on the dynamic performance of ground electrodes. While high lightning current intensity improves the dynamic grounding performance due to ionization of the soil, very fast fronted pulses might worsen the performance in case of inductive behaviour. The previous analysis has often been based on quasistatic approximation that is not applicable to very fast fronted pulses. Previous Research focused on analyzing the impulse current dispersal regularity of different branches when injecting at one point. Comparing with the leakage current distribution of a single ground electrode, it is found that the leakage currents along the branches increase with the distance to the current feed point, and the more conductors near the injection point, the more uneven the leakage current distribution is. In this paper by simulation result we indicate that shielding effect should be taken into account when analyzing the impulse characteristics of grounding electrodes. Based on the simulation results, new empirical formulas applicable for slow and very fast fronted lightning current pulses are proposed. The effects of the ionization of the soil are disregarded; therefore, the new formulas are applicable for a conservative estimate of the upper bound of the impulse impedance of ground electrodes. In this paper we also analyze and compare by the MATLAB. We also provide dynamic behavior of ground electrodes.

Keywords

Grounding electrodes, modeling, power system lightning effects, MATLAB.

I. Introduction

Simple arrangements of vertical and horizontal ground electrodes are often used for the lightning protection system earth termination [1]. Their basic function is to disperse the lightning current to earth without causing any potential differences or induced voltages that might endanger people or damage installations [2]. Grounding systems behaviour is well understood at power frequency and detailed procedures for their design are widely accepted [3]. However, during lightning strokes the grounding systems performance might be quite different, and in some cases it can critically deteriorate the efficiency of the protection. In spite of the large amount of work that has been devoted to this subject, there is still no consensus on how to apply present knowledge to the design of the actual grounding for better high frequency and dynamic performance [4]. It is worth noting that the potential rise of the grounding systems of transformers, poles or lightning protective devices under the influence of a lightning return stroke is one of the main sources of over voltages on the MV and LV installations [5].

Effects of an electric current passing through the vital parts of a human body depend on the duration, magnitude, and frequency of this current. The most dangerous consequence of such an exposure is a heart condition known as ventricular fibrillation, resulting in immediate arrest of blood circulation.

There are several important reasons why a grounding system should be installed. But the most important reason is to protect people! Secondary reasons include protection of structures and equipment from unintentional contact with energized electrical lines. The grounding system must ensure maximum safety from electrical system faults and lightning.

A good grounding system must receive periodic inspection and maintenance, if needed, to retain its effectiveness. Continued or periodic maintenance is aided through adequate design, choice of materials and proper installation techniques to ensure that the grounding system resists deterioration or inadvertent destruction. Therefore, minimal repair is needed to retain effectiveness throughout the life of the structure. The grounding system serves three primary functions which are listed below.

Personnel Safety
Personnel safety is provided by low impedance grounding and bonding between metallic equipment,

chassis, piping, and other conductive objects so that currents, due to faults or lightning, do not result in voltages sufficient to cause a shock hazard. Proper grounding facilitates the operation of the over current protective device protecting the current.

Equipment and Building Protection

Equipment and building protection is provided by low impedance grounding and bonding between electrical services, protective devices, equipment and other conductive objects so that faults or lightning currents do not result in hazardous voltages within the building. Also, the proper operation of over current protective devices is frequently dependent upon low impedance fault current paths.

Electrical Noise Reduction

Proper grounding aids in electrical noise reduction and ensures:

1. The impedance between the signal ground points throughout the building is minimized.
2. The voltage potentials between interconnected equipment are minimized.
3. That the effects of electrical and magnetic field coupling are minimized.

Another function of the grounding system is to provide a reference for circuit conductors to stabilize their voltage to ground during normal operation. The earth itself is not essential to provide a reference function. Another suitable conductive body may be used instead.

The function of a grounding electrode system and a ground terminal is to provide a system of conductors which ensures electrical contact with the earth. Two Fine Print Notes (FPN) that appear in Section 250-1 of the NEC provide a good summary of the reasons for grounding systems and circuit conductors and the conductive materials which enclose electrical conductors and equipment.

The remaining of this paper is organized as follows. We discuss types of grounding in Section 2. In Section 3 we discuss about Shielding Effect of the Grounding Electrodes. The Evolution and recent scenario in section 4.In section 5 we discuss about proposed approach. The conclusions and future directions are given in Section 6. Finally references are given.

II. Types of Grounding

As noted above, grounding and bonding are not the same. In addition, not all grounding is the same. We will describe one or more of the various types of grounding and bonding that are widely used in the electrical industry. Topics of primary interest are:

- Power System Grounding Including
- The “Service Entrance”
- Bonding
- Grounding Electrical Equipment
- Lightning Protection
- Protection of Electronic Equipment

Grounding is a very complex subject. The proper installation of grounding systems requires knowledge of soil characteristics, grounding conductor materials and compositions and grounding connections and terminations. A complete guide to proper grounding is often part of national and international standards. For example, IEEE Std 80, Guide for Safety in AC Substation Grounding, is a comprehensive and complex standard for only one particular grounding application.

Despite the electrical designers’ best efforts, electrical ground faults, short circuits, lightning and other transients can and often do occur in building electrical distribution systems. ERICO believes that, besides attempting to minimize the occurrence of these faults, designers and installers of electrical grounding systems should design these systems to clear these faults in the quickest possible manner. This requires that the grounding system be constructed to achieve the lowest practical impedance.

Many factors determine the overall impedance of the grounding system. Building components, such as structural steel and interior piping systems, can be used to create an effective grounding system. The manner in which these components are installed and interconnected can have a dramatic effect on the overall effectiveness of the grounding system. One of the primary factors that can increase the impedance of the grounding system is the type and manner in which the electrical connections to the grounding system are made. ERICO has a complete line of connectors which can be used to make grounding connections without affecting the integrity of the grounding system. Contractors and others who install these systems cannot underestimate the importance of ensuring that each grounding connection is made in a manner that is efficient and effective.

Interconnected electronic equipment, such as telecommunication systems and computer systems, also require a low impedance grounding system. Specific bonding and grounding techniques are available.

Designers and installers of these systems will do well to include all aspects of facilities protection in the initial design. The figure 1 below includes the major subsystems of facilities grounding. Any omission of these subsystems by design personnel is risky at best. Later additions and/or modifications to the system can be very costly.

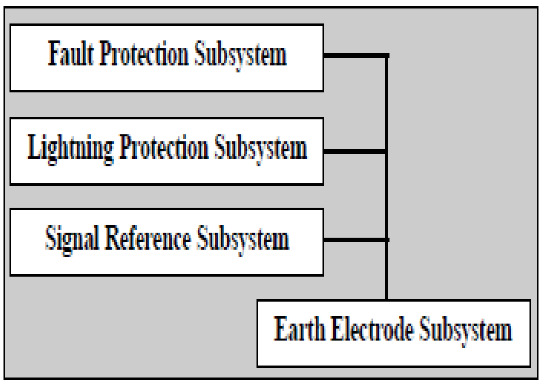

Figure 1: Major Subsystem of Facilities Ground

Ground resistance is usually measured using an instrument often called an earth resistance tester. This instrument includes a voltage source, an ohmmeter to measure resistance directly and switches to change the instrument's resistance range. Installers of grounding systems may be required to measure or otherwise determine the ground resistance of the system they have installed. The National Electric Code (NEC), Section 250-84, requires that a single electrode consisting of rod, pipe, or plate that does not have a resistance to ground of 25 ohms or less shall be augmented by one additional electrode of the type. Multiple electrodes should always be installed so that they are more than six feet (1.8 m) apart. Spacing greater than six feet will increase the rod efficiency. Proper spacing of the electrodes ensures that the maximum amount of fault current can be safely discharged into the earth.

To properly design a grounding system, the earth resistivity must be measured. Several methods can be used to measure earth resistivity: the four-point method, the variation in-depth method (three-point method) and the two-point method. The most accurate method and the one that ERICO recommends is the four-point method. The details of making these measurements and the set-up for the measurements are included with the testing equipment.

III. Shielding Effect of the Grounding Electrodes

Signal-to-noise ratio (often abbreviated SNR or S/N) is a Analysis of lightning-induced transients in electric power systems requires careful modeling of each part of the system: here the attention is given to the groundings of the shielding wire. In technical literature, the evaluation of the current distribution in both aerial and buried electrodes is carried out by means of numerical codes based on circuit models or on field approach.

The response of the earth to an impressed coherent signal of frequency f can be described by an equivalent circuit, which includes the nature of the measurement system and its interaction with the earth. For a differential-input, dipolar system grounded to the surface of a conductive, homogeneous half-space, the equivalent circuit of Figure 2 provides a good first approximation to half the dipole response, with

VR = Received voltage
V1 = Voltage detected at the electrode
V2 = Average potential difference between the electrode and the reference Electrode (or ground)
RC = Contact resistance of the electrode plus internal resistance of the electrode
CW = Distributed capacitance between the wire and ground
RW = Distributed resistance of the wire
LW = Distributed inductance of the wire
RI = Equivalent input resistance of the measuring device
CI = Equivalent input capacitance of the measuring device
L = Length of the wire

For frequencies considered in this discussion, the resistance and inductance of the wire and the input impedance and capacitance of the measurement device can be ignored, although they should be taken into account as signals in the 10 kHz or higher range are considered.

The capacitive reactance of the coupling between the wire and the earth is $jX_C = \frac{j}{2\pi f L C_W}$

and the received voltage will be

$$V_R = \frac{jX_C V_1}{R_C + jX_C} + \frac{R_C V_2}{R_C + jX_C}$$

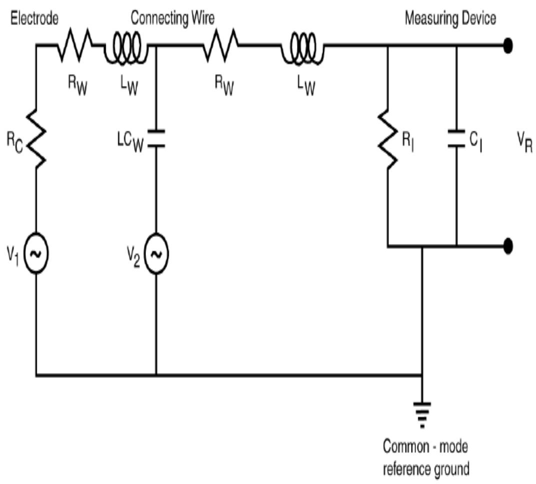

Figure 2: Simplified equivalent-circuit model of one-half of a differential-input grounded dipole.

For a homogeneous earth far from current sources the potential gradient across the wire will be constant, and the average potential difference V2 between the wire and the ground will be half the electrode potential (V2 = ½V1). This simplifies equation to

$$V_R = \frac{jX_C V_1}{R_C + jX_C} + \frac{\frac{1}{2} R_C V_1}{R_C + jX_C}$$

This can be written to contain

$$V_R = \left(\frac{1}{1 - j2\pi f L C_W R_C} - \frac{j\pi f L C_W R_C}{1 - j2\pi f L C_W R_C} \right) V_1$$

Testing the lemma of this equation proves to be useful. For zero contact resistance (RC → 0), which is the normal assumption in geophysical work, the second term drops out and VR = V1. In other words the capacitive effect of the wire is shorted out and the measurement consists only of the ground potential at the electrode, which is the desired measurement. On the other hand, as the contact resistance goes to infinity (RC → infinite), the first term drops out and we have VR = ½V1.

In this case the wire is effectively ungrounded and capacitive effects dominate. Between these two lemma the voltage is frequency-dependent. For low frequencies (f →0), the limit VR = V1 is approached, as before; for high frequencies (f = Infinite), the limit VR = ½V is approached. Hence, the received voltage is dependent upon electrode contact resistance, and the magnitude of the effect is a function of signal frequency. We call this behavior the "electrode contact resistance" or "ECR" effect.

One way of visualizing the ECR effect is that the limits R belongs to 0 and R tends to infinite are the asymptotic bounds of an envelope inside of which all finite-value voltage curves will fall, with both contact resistance and frequency determining the shapes of the voltage curves within this envelope. An example is provided in the calculated electric field values of Figure 2, in which we have taken L=152 meters, CW = 23 pf/m, and a frequency range of 4 to 4096 Hz, all typical values for CSAMT survey work. Note the dispersion of voltage values for high frequencies at contact resistances as low as 3 k, which are not uncommon in field survey work. This suggests that the ECR effects are of great importance in CSAMT, and could be important in IP work when long arrays and high frequencies are used.

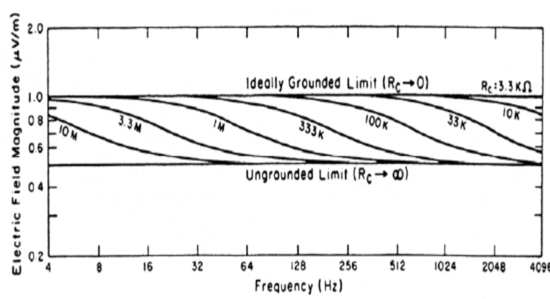

Figure 3: Calculated ECR effect for a homogeneous earth for various contact resistances. Values are referenced to an electric field magnitude of 1.0 V/m. A dipole length of 152m and a wire capacitance of 23 pf/m were assumed.

IV. Evolution and Recent Scenario

In 2006, H. Norikane et al. [6] have improved the RF magnetic shielding characteristics of a bincho-charcoal plate to realize a broadband frequency by the superposition of a ferrite plate over the bincho-charcoal plate. This configuration is termed the compound plate. The RF magnetic shielding effects of the compound plate have been examined, including the characteristics of the RF magnetic effect against both the frequency and the RF magnetic power. In addition, RF electric shielding effects have been examined as functions of the frequency and the RF electric power.

In 2006, Xiaowei et al. [7] accelerated soft error data in embedded SRAM in an advanced CMOS DSP are used to determine the impact of geometry and shielding effects on the accuracy of extrapolated product failure rates due to terrestrial neutrons.

In 2008, SIMA Wen-xia et al. [8] basing on the principle of dimensional similarity, impulse simulation experiments are performed on the common ground electrodes with conductor branches. They focus on analyzing the impulse current dispersal regularity of different branches when injecting at one point. Comparing with the leakage current distribution of a single ground electrode, it is found that the leakage currents along the branches increase with the distance to the current feed point, and the more conductors near the injection point, the more uneven the leakage current distribution is. This work indicates that shielding effect should be taken into account when analysing the impulse characteristics of grounding electrodes.

V. Proposed Approach

In this paper we present a comparative variation based on current and voltage. The dissipation of voltage from a grounding electrode (or from the grounded end of an energized grounded object) is called the ground potential gradient. Voltage drops associated with this dissipation of voltage are called ground potentials. Figure 4 is a typical voltage-gradient distribution curve (assuming a uniform soil texture). This graph shows that voltage decreases rapidly with increasing distance from the grounding electrode.

The work of grounding systems is probably one of the best kept set of secrets in the electrical industry. At first glance, the deceptively simple passive elements of grounding systems obviously could not do very much, or could they? The answer is that grounding systems come in many shapes, forms, and sizes and do many duties, many of which are absolutely essential. If they are designed and constructed well, then the systems they support have a good chance of working well. However, if the grounding system is flawed in design or installation, or if it is damaged by impact or chemical attack, the related systems are negatively affected.

Consider the case of a static grounding grid with its variety of grounding electrode shapes in an industrial plant that is energized through a high-voltage utility substation. This almost completely hidden grounding system performs all these tasks:

It minimizes the ground potential rise and coincident step and touch potentials that occur from high-voltage system zero sequence current flowing through the earth during utility system ground faults, such as insulator string arc-over.

It equalizes the direct-current (dc) potentials within the plant that build up from process flows. It limits the system-to-frame voltage for human safety and prevents overstress in phase-to-ground voltage. For all practical purposes, it provides an equipotential plane on which humans can stand and not be harmed during times of ground fault within the plant. The Resultant graph is shown below.

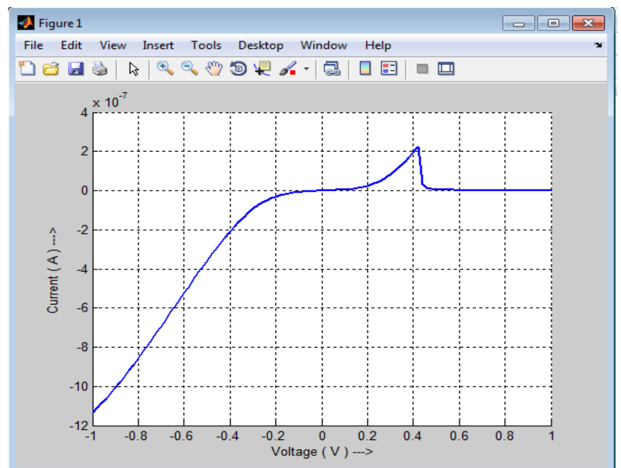

Figure 4: Output1

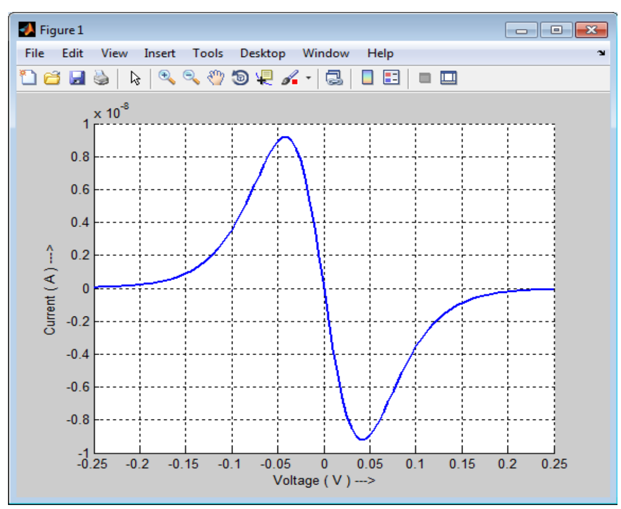

Figure 5: Output2

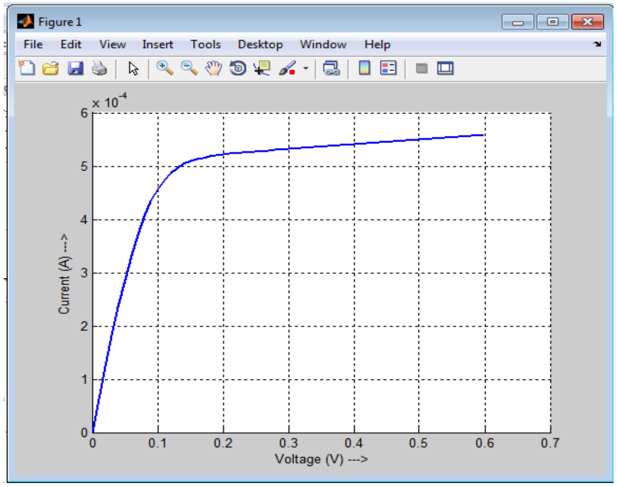

Figure 6: Output3

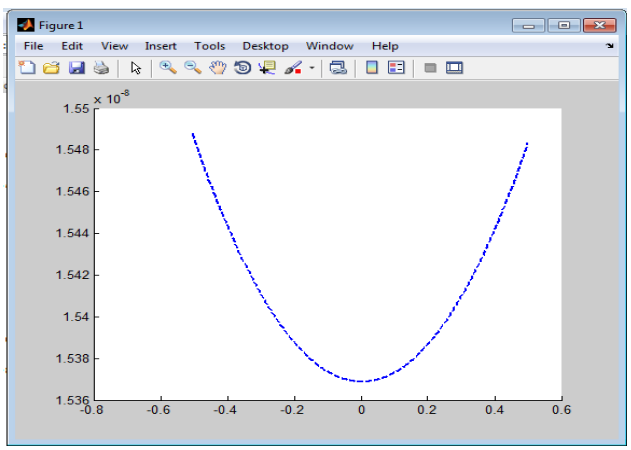

Figure 7: Output4

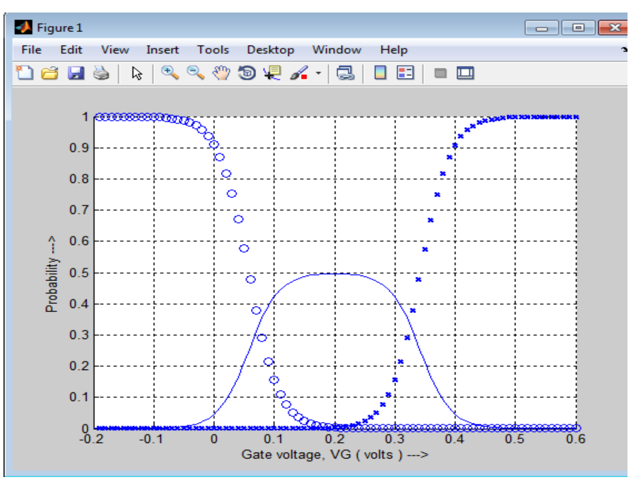

Figure 8: Output5

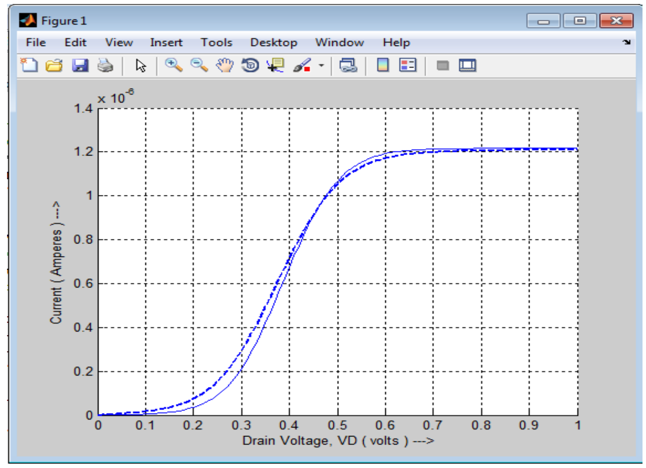

Figure 9: Output6

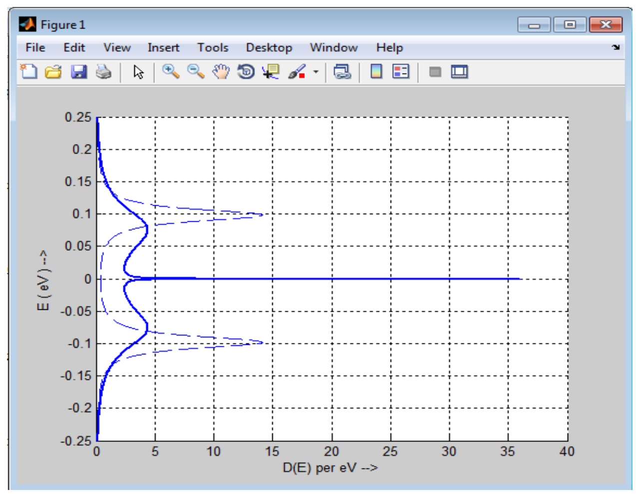

Figure 10: Output7

VI. Conclusion and Future Directions

In this paper we analyze several aspects with their variations so that we can measure the axial current distribution with voltage; we obtain the impulse-current dispersal regularity of grounding electrodes with various structures in homogeneous soil. From the analyzed experimental results, it can be concluded that shielding effect should be taken into account when analyzing the impulse characteristics of grounding electrodes with conductor branches. In this paper we also analyze and compare by the MATLAB. We also provide dynamic behavior of ground electrodes.

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