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The Behaviour of an Enhanced Earthing System of Transmission Voltage

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***Abstract*—**Lightning strikes pose a major challenge to the safety of high voltage transmission and distribution lines. During a lightning strike a very high voltage is produced which can destroy the insulation and damage power systems. Not only are lightning strikes bad for power systems but also pose a serious threat to human life in the vicinity of electricity tower by increasing potential of the soil. Therefore, an effective lightening protections system is needed to cater those above mentioned problems. The effectiveness of a lightening protection system can be deduced by judging the earth connection of the system. Numerous and national standards are in place to help design a protection system that satisfy conditions necessary for the safety of both system and personnel. In this paper, the performance of a full scale 220kV & 500kV transmission tower base is investigated under DC, AC variable frequency and low and high impulse voltages and some of the values of Enhanced Earthling System are simulated through a MATLAB Program.

***Keywords*—** Lightning, insulation, strikes, Simulations

I. Introduction

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Lightning strikes pose a major challenge to the safety of high voltage transmission and distribution lines. During a lightning strike a very high voltage is produced which can destroy the insulation and damage power systems [1]. Not only are lightning strikes bad for power systems but also pose a serious threat to human life in the vicinity of electricity tower by increasing potential of the soil [2].

Therefore, an effective lightening protections system is needed to cater those above mentioned problems [3]. The effectiveness of a lightening protection system can be deduced by judging the earth connection of the system [4]. Numerous standards are in place to help design a protection system that satisfy conditions necessary for the safety of both system and personnel [5].

This paper provides an introduction to role of earthing system and components and also provide summary about various standards.

A. Earthing Mechanism

Earthing Mechanism in transmission and distribution lines is installed to achieve two objectives [6].

- Protection of personnel in the vicinity.
- Reduce damage to equipment and power system operation

B. Components

At the transmission level,it consists of the following two main components.

- Earthing grid
- Earth Electrode System's Extension

Earthing grid of a substation is made from horizontal conductor bars varies in size. It can span a large area like 30000 m2 for outdoor substation while for indoor substation it is quite small [7].

The shield wire which main role is to protect conductors from lightning strikes also plays a vital role in transmission earthing systems. This earthing is connected by the transmission line's shield wire. The same wire is also connected to the transmission lines that are located at the vicinity of the substations [8]. This connection between shield wire and substations earthing grids is called extension of the earth electrode system.

The advantage of the above mentioned connection is that it will reduce the impedances along the way of transmission line thus resulting in decrease of step and touch voltages in transmission tower's surroundings which means increased safety of personnel [9].

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In addition to above mentioned advantages, the earth wire greatly reduce overhead outage rate. Data show that changing from no earth wire to one and two earth wires reduces the outage rate from 29.8 per 100 miles to 9.8 and 7 outages per 100 miles respectively.

C. International Standards

Standards provides us with the mechanism and criteria to follow to ensure efficient completion of a task. Different Standards associated with Lightening Protection includeBS EN 50522:2008, BS EN 62305-3:2011 EA TS 41-24 [10]. Analyzing these standards provide some recommend measures that are necessary for safe and sound implementation of earthing systems. These include

- having low inductance path for current,
- Electrodes and conductors are form a network.
- Higher density earthing network in an area having high occurring chance of high transient current.
- Short length earthing connections.
- Low Resistance 10 Ω for earthing system.

D. Aims and objectives

The main aim of this thesis is to analyze a 220 KV high voltage transmission tower and its earthing system under different conditions and draw out some conclusion for the improvement of the system. To achieve the purpose of this thesis some objectives are set to effectively carry out the research.

- Investigate Transmission tower under AC conditions and find potential in its surroundings, effect of frequency change on surroundings Potential, Comparison of measured and computed values..
- Comparison analysis of computed and measured DC earthing resistance and examining effects of seasonal variation on the earthing resistance.
- Again investigating surrounding soil potential of the surrounding area of the tower but this time when transmission tower is subjected to low impulse current and comparing it with data from AC analysis.
- Investigating types of impulse currents and analyze transient response of the earthing system.
- Testing of a transmission tower under high voltage and high impulse current and examining the nonlinear behavior.
- Testing the earthing system under high impulse current and investigating different parameters associated with lightning protection system.

E. Contribution of this research

This research will enable us to better understand the potential of soil in surroundings of high voltage transmission towers at different depths and also in different seasons. Further, we will have an increased knowledge about the effect of earthing systems in reducing damage by lightning strikes and better understanding towards different parameters of earthing systems. This research will provide a framework to design a testing facility to study transient responses in earthing systems.

F. Investigation of Characteristics of Earthing

The performance of the earthling system of the transmission system relies on the type of the earthing environment that is employed [11]. The high impulse current characteristic can reflect the robustness of the earthing system of the transmission system [12]. Previously the literature review suggests the common earthing system of the transmission system. The type of the soil detects the resistance that dominates the performance under high impulse current.

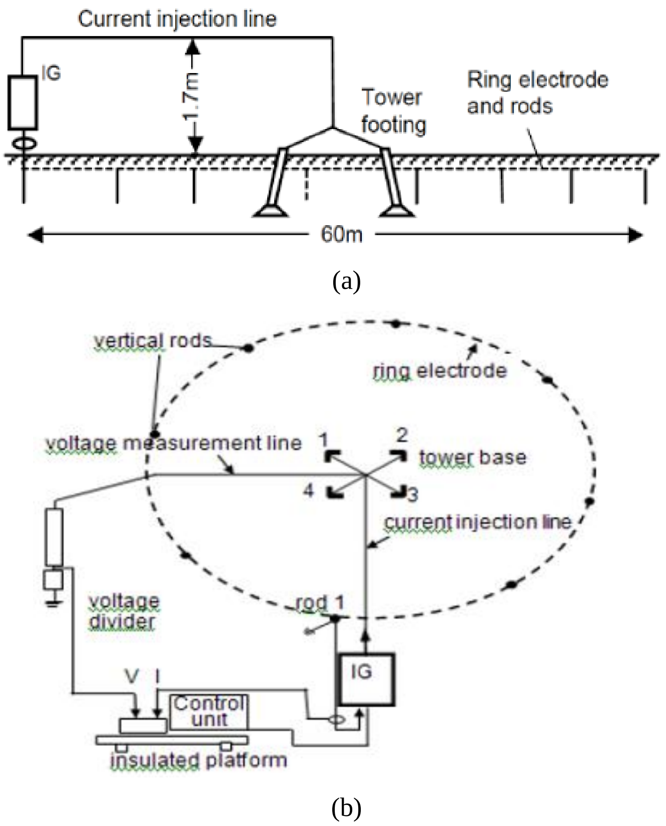
The earth resistance that is dominated by the electrode depends on many factors.

These factors are listed as

1) Peak value of impulse current.
2) Soil resistivity
3) Electrode geometry

G. Test setup

The following setup was used to test the characteristics. An impulse generator was used that was capable of generating impulse currents.an overhead transmission line was used that was able to connect the impulse generator with the tower. these are shown in the figures respectively. The impulse generator was connected to the test tower via the wooden poles.



(b)

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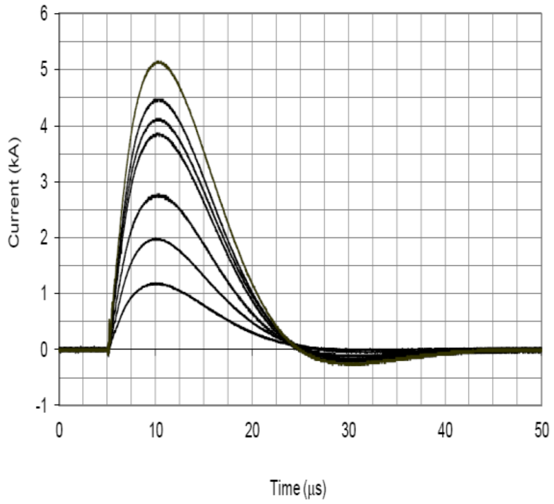
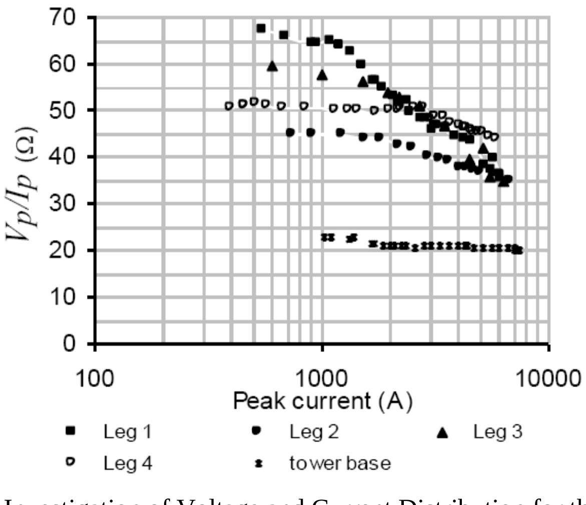
H. Impulse Resistance of Tower Base

Several impulse tests were carried out having delta rise of the current of 4500 m sec and a tailing time of 1300 m sec. These tests were useful to test the base of the tower with the magnitudes different to the different currents. The currents were ranging from the currents of 900 A to 5000 A. The results are being summarized of the different injected voltages and the currents respectively in the following figure.



Impulse tests at higher current magnitudes

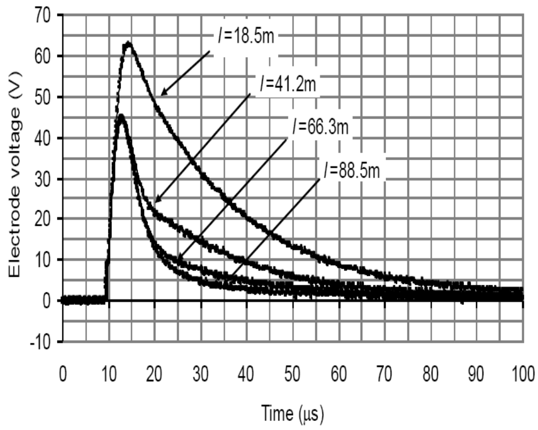
These tests are used to further extend the results of the tests were carried out in the previous sections. The difference between the previous and these tests that the ranges of the current are extended to the values of 4000A and 9000 A respectively. Another change was that the shape of the impulse was also changed. The resistance of the testing electrode was also included and the base of the tower was also included. The following figure shows that the resistance of the impulse is decreasing as the magnitude of the current is increasing for the towers.



Investigation of Voltage and Current Distribution for the Impulse Conditions

The protection system via earthing system is designated to reroute the fault current which of high magnitude to the ground thus quenching the high current and proving a safety for the persons working as well as for the persons living near the installations of the power systems. Therefore to effectively quenching the high fault currents under the faulty conditions and nominal power frequency, the earthing system should be able to withstand the high fault currents and effectively have a low value of impedance. In order to increase the earthing system of the transmission lines of the steel lines an electrode of the type of ring or may be a single rod may be used. However, in the land having a high resistance of the soil, the type of electrode is changed. For such land a horizontal electrode may be used. This would effectively reduce the impedance at a low frequency of the earth. However, they fail to dissipate the fault current under the lightning conditions. It is due to the fact that the effective length of the electrode may not be effective and it is much lower than the physical length of the electrode. The effective length of the electrode depends upon the resistivity of the soil, the characteristics of the impulse current and the geometry of the electrode. These characteristics have been analyzed in the following section by analyzing the distribution of the current and the voltage taking a horizontal electrode as a case study.

Some additional tests were carried out to further investigate the electrodes in the horizontal position. Both the individual as well as the combined sections were further investigated. There was the step wise increase in the length of the electrode. The first section was injected with the current of 5.0A and all the subsequent sections were then followed by the injection of 5.50 A. The following figure shows the recorded voltage and its shapes when the length of the electrode is increased in the subsequent steps.



Effect of electrode length

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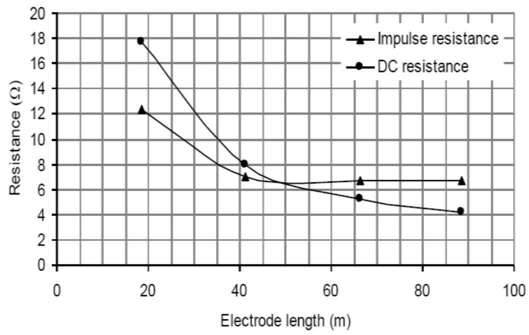
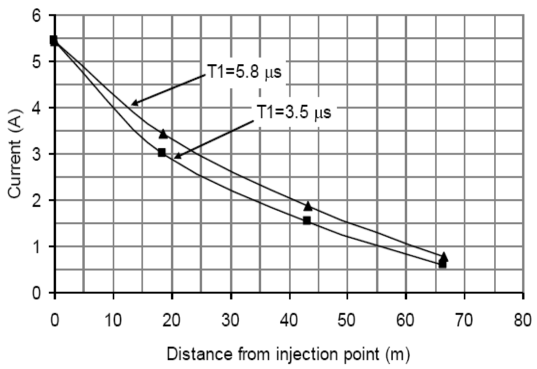
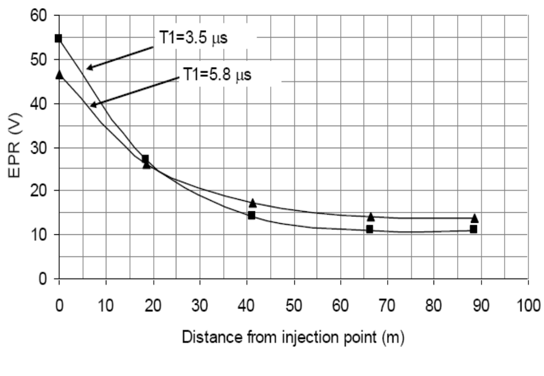


Current Rise Time Effect on cuurent And voltage Distribution

The impulse shape of both the current on the electrode as well as the Earth potential reduction on the electrode was further investigated by using the impulse currents having rise times as 3500 m sec and 5800 m sec It was concluded that the having the faster increase in the rise and the current reduction in the magnitude the impulse having the lesser rise time showed a slower reduction in the magnitude of the current as shown in the below figure.





II. Conclusions

These results show that the impulse current that is quenched depends upon the rise times of the impulse that is applied. It also shows that the length at which the current is injected is also depended on the rise of the earth potential. The effective length of the electrode is also calculated depending on the resistance of the impulse and is found to be coherent with the formula that is widely used in the literature studies. The results also indicated that the current injection at the mid-point of the electrode has the minimum impulse resistance.

A. Earthing Enhancement

Earthing frameworks are intended to disseminate high extent blame current to ground additionally to give wellbeing to people working or living near power framework establishments. With a specific end goal to disseminate current successfully under both electric power recurrence and transient blame conditions, the earthing framework ought to have a low impedance esteem. For enhancing or boosting the earthing arrangement of steel transmission lines, singular earth bars or terminals are utilized, in arrive with high soil resistivity, level anodes could likewise be utilized. The expansion of flat ground cathodes will add to the lessening of the low-recurrence earth impedance. All things considered, under lightning conditions, these extra terminals may not precisely be successful in scattering current on the grounds that there is a restricting compelling length of the anode, which is frequently that can be lower than the physical finish cathode. This successful size relies on the span of the cathode edges, soil resistivity and the motivation attributes, and this is the subject of enthusiasm of numerous specialists. The current and voltages appropriations along a side to side terminal have been examined set for a scope of soil resistivity and for low and high current sizes. Estimation models in light of appropriated parameter proportionate circuits have as of late been proposed to decide the drive reaction, the viable length and the impedance of level anodes.

B. Enhancing Earthing System for a substation of 132KV/220KV

This research uncovers of earthing framework for 132KV/220KV substation and reproduction for calculation of required factors. This exploration is to give data fundamental to safe earthing systems of schedules strategies in AC substation plan likewise for earth to set up the sheltered impediments of potential distinction under ordinary and anomalous conditions. The establishing framework arrangement of is a sensible 220 kV substation is controlled by MATLAB program. The information has been removed from real field examined at the substation. Standard conditions are being utilized as a part of type of earthing framework to get wanted factors, for example, touch and step voltage (conditions benchmarks) for wellbeing, protection, network measure of protection, most extreme matrix current, conductor size and cathode estimate, greatest current level and resistivity of earth soil. By determination even conductor measure, vertical terminal size and soil resistivity, the best decision of the errand for security is led. This examination specifies the calculation required parameters that which can be happen to be recreated by MATLAB program. Some mimicked outcomes are assessed.

In substation earthing framework is basic not only to give the assurance of people working in the region of earthed offices and hardware's against t danger of electric stun yet to keep up proper function of electrical framework. Dependability and security are to be taken in contemplations and in addition adherence to statutory commitments (IEEE and natural angles). Earthing framework subsequently configuration must be effectively kept up and future extension must be utilized under thought while planning the measurements of earth tangle This paper is giving earthing practices and outline for open air AC substation for control recurrence in the quantity of 50 Hz. DC substation GIS and helping impacts are not shrouded in this paper. With appropriate alert, the technique depicted here is likewise material to indoor level of such substation. By utilizing legitimate conductor and cathode s ize, earthing system might have the capacity to beat helping impacts.

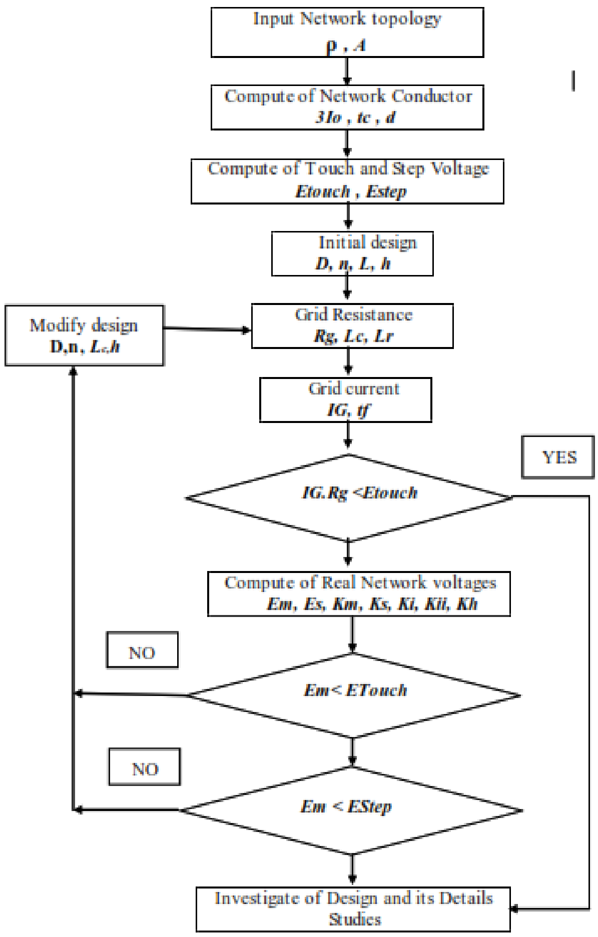
C. Components required for enhancement earthing system

A productive substation earthing process for the most part comprises of earthing poles, interfacing lines from shrouded earthing lattice to metallic zones of structures and equipment's, contacts to earthed process neutrals, and the planet earthing surface protecting covering material quickly talked about in. Current streaming to the earthing framework from helping arrester operation wish or exchanging s empower flashover of separators and point to surface blame current from the transport or related transmission lines all reason potential varieties between earthed focuses in the substation. Without a sufficiently made earthing process, extensive potential varieties may happen between different focuses inside the substation itself. Beneath normal conditions it's the current constitutes the primary hazard to individual.

Required data for designing of enhance earthing system

- Maximum grid current
- oilresistivityat thesite
- Substationgridarea
- Resistivityofsoilitssurface
- Faultclearingtime

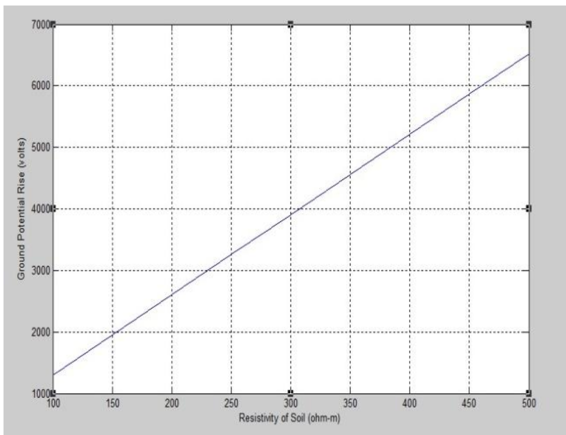
The process can be shown by the following flowchart

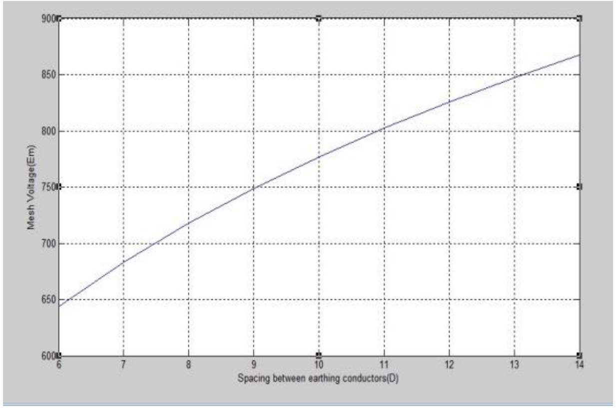


III. RESULTS

These result are obtained by MATLAB program as given below.

A. Voltage and Conductor Spacing





The Fine mesh Voltage relationship with the conductor spacing implies that as we continue to raise the spacing between conductors the fine mesh voltage increases. For a set grid area and all the fixed guidelines as except grid conductor spacing, that upsurge in spacing between adjacent horizontal conductors triggers increase in fine mesh voltage but it'll lowers in step voltage. Nonetheless it can be viewed that reduction in step voltage is more than upsurge in fine mesh voltage. For set grid area, smaller the length between horizontal conductors more the amount of conductors required.

B. GPR and Soil Resistivity

From the safeness perspective the resistivity of the land should essentially be kept at the very least so that GPR value is looked after within the permissible limit as is shown by the results in above figure, with the upsurge in soil resistivity the worthiness of GPR boosts as the land resistivity directly influences the part of lightning current diffusing in to the earth when it moves in to the conductor and various soil resistivity will create different results. The productivity results demonstrated that combined with the increase in land resistivity all variables steadily boosts .The increase of garden soil resistivity directly leads to the increase of impulse grounding level of resistance and maximum potential surge of the grounding grid.

C. Analysis and Conculsion

In this paper increased earthing system for a substation is talked about, various issues associated with safe practices have been discussed. Standard mathematical formula have been used to compute different parameters associated with enhanced earthing system and several end result have been simulated by using a MATLAB program. From the results obtained from MATLAB programme we concluded that the designer must carefully take decision for conductor parting to keep real fine mesh and step voltage within tolerable limit also should take necessary agreements to keep carefully the ground resistivity within the limit so the ground potential surge is held within the limit.

IV. Future Work

Some important research areas of the future work related to the work mentioned in this thesis could be the following

1) Changing the conditions in which impulse current is being applied
2) Different Depths of the earthing electrodes having different diameters
3) Studying and designing the experiments to further investigate the earthing mechanisms and pitfalls related to the investigated methods

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