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GSM BROADCASTING STATION GROUNDING SYSTEM ANALYSIS. MEASUREMENTS AND COMPUTER MODELING

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Abstract: This paper was undertaken in order to evaluate the adequacy of the existing grounding system of GSM broadcasting station and to verify adequacy of the work out computer model. The final design was to approximate touch and step voltage during lightning strikes for personnel within the GSM broadcasting station area, based on up-to-date system data, appropriate measurement techniques and instrumentation, and state-of-the-art computer modeling methods.

1. INTRODUCTION

Most GSM engineers must regularly deal with design and operational problems whereby of the lightning currents following along undesirable paths result in various effects ranging from minor annoyances to spectacular failures. A significant number of these subjects are related to grounding and electromagnetic interference. A good understanding of these subjects and appropriate engineering software tools is critical to every GSM utility which is concerned with the safety and reliability of its system and its responsibility towards the public and its employees. The following paper underlines the importance and the adequacy of the grounding and electromagnetic interference to humans and devices safety.
SES's proprietary CDEGS software package was used for computer modeling throughout this paper in order to meet demanding requirements described above. CDEGS was used to model the voltage measurements (i.e., soil resistivities, grounding system impedance, step voltage, and scalar potential) and verify it with measurement data.

2. GSM BROADCASTING STATION DESCRIPTION

GSM broadcasting station structure depends on the terrain shape and GSM operator specifications. The infrastructure of typical GSM station basically consists of the following systems: container, hybrid power system, masts and satellite antennas.
The container is divided into two rooms by a sound absorbing wall, 1.6 meters from one of the end walls. The small room is to be used for a diesel generator and a fuel tank, the large room is for the batteries and the communications equipment. A feeder rack will connect the equipment in the container to external equipment and antennas. The containers are equipped with heating or air conditioning equipment.
A typical 60m high GSM broadcasting station is connected to the grounding system which consists of two grounding rings connected to another grounding ring, which is the grounding of the container of the electronic devices and associated grounding of the fence.
A hybrid power supply system. The equipment can be supplied by external power, if available. If power is to be generated on site this can be done by the generator in the container. In this case a large external tank will be needed.
Masts and antennas for satellite communications are installed beside the container. The masts can be 15, 25, 50 or 60 meters, self-supporting or equipped with bardunes [1].

3. GSM BROADCASTING STATION GROUNDING SYSTEM MEASUREMENTS

Soil resistivity measurements was made by injecting current into the earth between two outer electrodes and measuring the resulting voltage between two potential probes placed along a straight line between the current injection electrodes. When the electrodes are close together, the measured soil resistivity is indicative of local surface soil characteristics. When the electrodes are far apart, the measured soil resistivity is indicative of average deep soil characteristics throughout a much larger area. Figure 3 shows a plan view of the soil resistivity measurement arrangement based on the

Wenner method. Traverse of soil resistivity measurements shows figure 4.

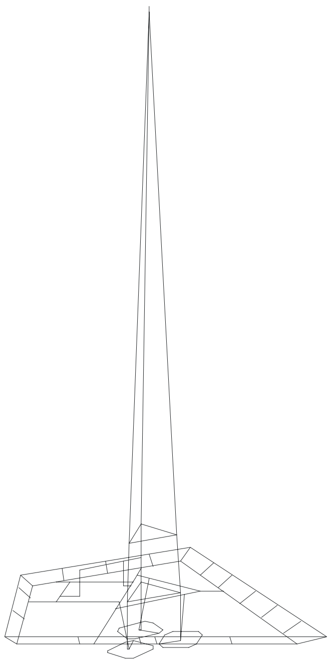

Fig. 1. Model of GSM broadcasting station in SESCAD

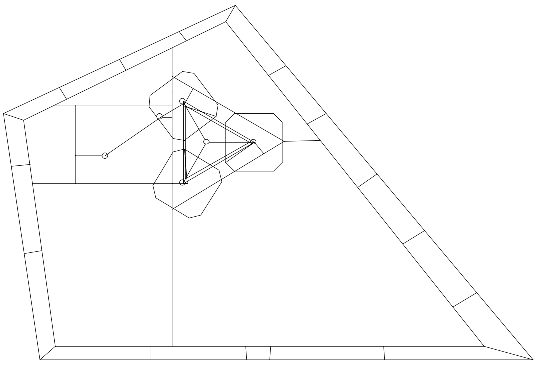

Fig. 2. GSM broadcasting station metallic structure in SESCAD (top view)

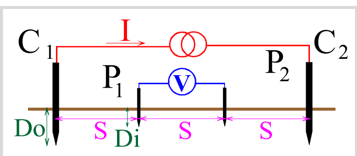

Fig. 3. Soil resistivity measurement. Wenner method

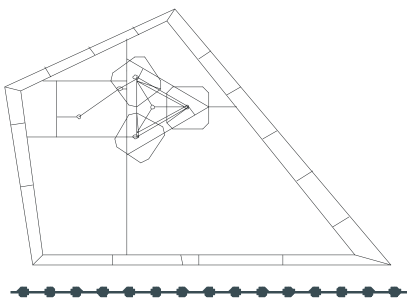

Fig. 4. Soil resistivity measurements traverse

4. SCALAR POTENTIAL MEASUREMENTS

Figure 5 is a functional block diagram of the equipment used for the scalar potential measurements – a surge generator and a frequency-selective voltmeter (i.e., digital oscilloscope). As shown in Figure 5, a current is injected from a surge generator 8/20 0.1kA between the substation's grounding grid and a remote return electrode. A frequency-selective voltmeter measures the potential difference between the two potential probes. This latter is placed at a series of locations, beginning close to the grid and ending near the return electrode, moving along a linear traverse.

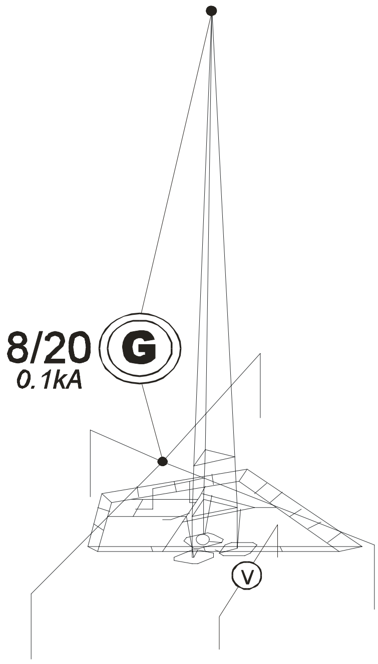

Fig. 5. Functional block diagram of the equipment used for the scalar potential measurements

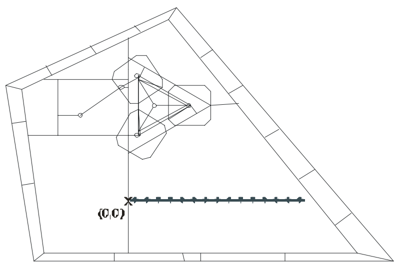

Fig. 6. Scalar potential measurements traverse

Scalar potential measurements were made according to the ANSI/IEEE Std 80-2000 along traverse shown on figure 6 [5].

5. THEORETICAL BACKGROUND FOR COMPUTER SIMULATION

The computation of electromagnetic fields due to energized conductors is a two-step process: the current distribution in the conductors must first be obtained and then the electromagnetic fields caused by these circulating currents must be computed – Maxwell's

equations are used. Both of these steps rest on the ability to compute the electromagnetic fields caused by a given current distribution. The field of the current source is expressed as a sum of contributions from electric dipoles.
Maxwell's equations with source terms in a uniform medium can be written generally:

$$\begin{aligned} \nabla \cdot \vec{D} &= \rho \\ \nabla \cdot \vec{B} &= 0 \\ \nabla \times \vec{E} &= \dot{\vec{B}} \\ \nabla \times \vec{H} &= \dot{\vec{D}} + \vec{J}_{\text{total}} \end{aligned} \tag{1}$$

where the total current density consist of the sum of a conduction term and of an external source:

$$\vec{J}_{\text{total}} = \sigma \vec{E} + \vec{J}_{\text{ext}} \tag{2}$$

where σ is the conductivity of the medium and $\vec{J}_{\text{ext}}$ is given by Eq. (1) above.

Assuming a harmonic time-dependence of the form $\exp(j\omega t)$ and the constitutive relations

$$\begin{aligned} \vec{D} &= \varepsilon \vec{E} \\ \vec{B} &= \mu \vec{H} \end{aligned} \tag{3}$$

where ε is the permittivity of the medium and μ its permeability these equations reduce to:

$$\begin{aligned} \varepsilon \nabla \cdot \vec{E} &= \rho \\ \nabla \cdot \vec{H} &= 0 \\ \nabla \times \vec{E} &= j\omega\mu\vec{H} \\ \nabla \times \vec{H} &= \theta \vec{E} + \vec{J}_{\text{ext}} \end{aligned} \tag{4}$$

where $\theta = \sigma + j\omega\varepsilon$ is the complex conductivity of the medium.

With a horizontally layered medium, Eqs.(3) are obeyed in each layer. The continuity of the tangential components of the electric and magnetic fields is used as a boundary condition to connect the results in the different layers [2].

Computer program HIFREQ can determine equivalent earth structure models from measured soil resistivity data by approximation. During few series of computations user can approximate soil type – figure 8. Of curse it's necessary to compare these computation results with measurements to choose right soil type – figure 7,8 (only these models can be used to analyze grounding systems in HIFREQ [4]). Every soil type brings RMS error.

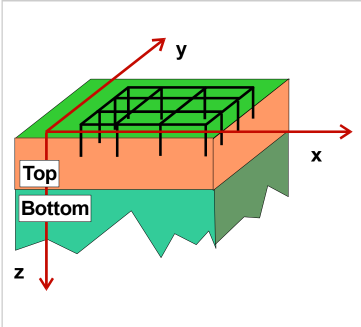

Fig. 7. Horizontal two layer soil type

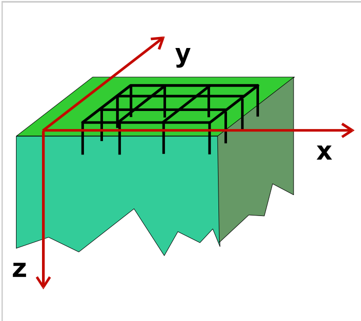

Fig. 8. Uniform soil type

5. SIMULATION AND MEASUREMENTS RESULT

The plots on Figure 9 compare the measured scalar potential with scalar potential computed from the above soil structures. As these plots show, the computed curves fit the measured data very well. The "RMS Error" column in Table 1 provides a quantitative measure of the agreement between the measurements and the proposed soil models. The RMS error ranges from about 2% to 60%, which is excellent.

Presented method can be also used to verify buried grounding system configuration. A typical 60m high GSM broadcasting station is connected to the grounding system which consists of two grounding rings connected to another grounding ring, differences between project and real GSM station can are described – see figure 9. Grounding grid in real station is shifted by 2,9m from originally projected location.

Table 1. Agreement between the measurements and the proposed soil models.

Soil Type	Ground resistivity [Ω·m]	RMS Error [%]
Two layers	910/182	-60%
Two layers	262/1056	+15%
Two layers	16/503	+2%
Uniform	807	+37%

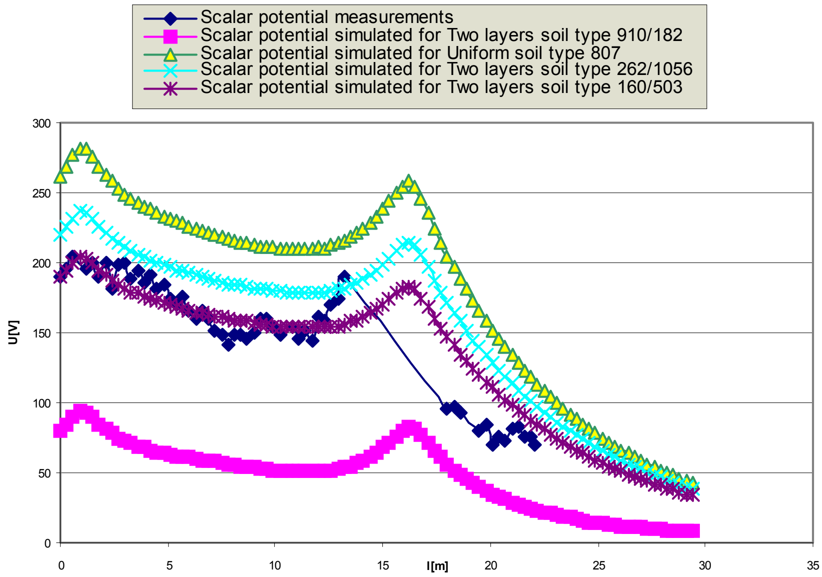

Fig. 9. Scalar potential compare between measurements and simulation

4. CONCLUSIONS

By judiciously selecting a soil types from uniform to 2 layer soil type or more, taking care to lay out the measurement leads to minimize induction, and correcting the simulated results for soil resistivity values and soil type models using computer software such as HIFREQ [4] and FFTSES [3], the scalar potential, step voltage, touch voltage of an operating GSM broadcasting station or power plant can be simulated, in isolation from the external grounding to which it may be connected. Presented method can be also used to verify buried grounding system configuration.

5. REFERENCES

1. "The TELE Greenland Modular Container System", TELE Greenland Catalog 2003.
2. "HIFREQ Theory", Safe Engineering Services & Technologies Ltd., Montreal Canada.
3. "FFTSES User's Manual: Fast Fourier Transform", Safe Engineering Services & Technologies Ltd., Montreal Canada.
4. "HIFREQ User's Manual: Frequency Domain Analysis of Buried Conductor Networks", Safe Engineering Services & Technologies Ltd., Montreal Canada.
5. ANSI/IEEE Std 80-2000.

BIOGRAPHICAL NOTES

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Graduated in power system at Electric Power System Faculty of Technical University, Bialystok in 2002. Main research area is application of computer technology in damage analysis at electric power substation during direct lightning strikes.