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Transient Impedence Characteristics of Soil and Sand

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Abstract **– This paper discussed the transient impedance characteristics of dry soil and sand. The behavior of a grounding system under high transient differs from its steady state behavior. When the value of the applied voltage exceeds the critical value, then soil ionization phenomena occur and which decrease the soil impedance. Impulse voltage test of the standard 1.2/50 µs were performed under different polarities. The applied voltage and drain current were recorded, resulting in the determination of the time variation of the transient impedance. The resultant current contains some noise. To overcome that problem, used a filter in data analysis.**

Keywords **– Breakdown Voltage, Grounding, Sand, Soil, Transient Impedance.**

I. Introduction

Earthing is an important and necessary element of any energy system. Properly designed and constructed earthing guarantees safety for both people and devices located in places where a flow of dangerous short circuit or surge current caused by a lightning discharge can occur. Therefore, the earthing resistance should be made as low as possible, and its value should meet the guidelines contained in the specified standards and regulations.

When lightning currents are discharged into earth it is important to observe the way grounding systems respond in order to establish the overvoltage control levels at the protection systems. It has been noted that this response is strongly dependent on some variables such as the type of soil, the electrical conductivity (water content), the heat capacity and thermal properties, the geometry of the electrode and the surge current magnitude.

Connections to earth in general are complex impedances, having resistive, capacitive, and inductive components, all of which affect their current-carrying capabilities. The resistance of the connection is of particular interest to those concerned with power frequencies because it is affected by the resistivity of the earth in the area of the connection. The capacitance and inductance values are of interest to those concerned with higher frequencies, such as are associated with radio communications and lightning.

II. Experimental Arrangment

Test Setup

Ten stages Marx Generator at the Uppsala University was used to supply the impulse voltage standard waveform 1.2 µs rise time and 50 decay time. The voltage and energy supply for each stage was 100 kV and 5kJ respectively. Voltage and current measurements were performed using shielded cables. Current measurements were achieved with commercially available Rogowski coil. Matlab software was used for data analysis.

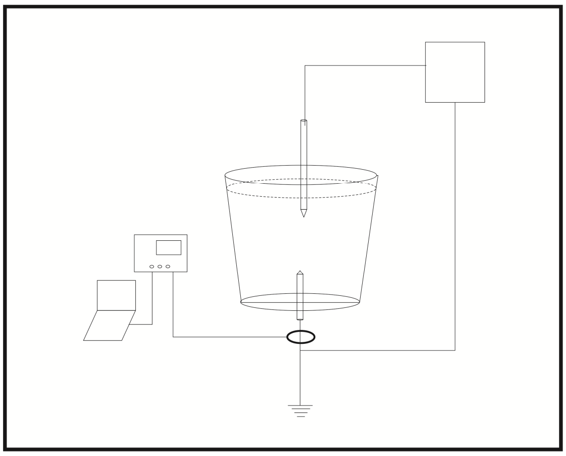

Fig. 1. Experimental set-up

Fig. 2. Experimental set-up

Test Cell

The test cell is consisted of a cylindrical container with 80 cm diameter. The gap between the electrodes was maintained 15 cm. Connection for the current was fixed on the bottom of the container. Small grain size dry sand and soil were used for the experiment. Impulse test with different voltage impulses have been conducted with both

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positive and negative polarities in order to determine the transient impedance.

III. Fundamentals

Impulse Impedance

This paper discusses the transient impedance analysis of soil and sand. Impulse impedance is basically defined as the ratio of the impulse voltage to the impulse current upon the time.

$$Z\,(t) = \frac{v\,(t)}{i\,(t)} \quad (1)$$

This impulse impedance is normally defined in four ways.

$$Z_1 = \max\,(z(t)) \quad (2)$$

$$Z_2 = \frac{v\,(t_1)}{i\,(t_1)} \quad (3)$$

$$Z_3 = \frac{v\,(t_1)}{i\,(t_2)} \quad (4)$$

$$Z_4 = \frac{v\,(t_2)}{i\,(t_2)} \quad (5)$$

Where,
Z1: The maximum value of transient impedance
Z2: the ratio of the peak value of voltage to the respective value of current, at the time that voltage reaches its peak.
Z3: the ratio of the peak value of voltage to the respective peak value of current.
Z4: the ratio of voltage, at the time that current reaches its peak value, to the respective peak value of current.

Pre-ionization and post-ionization impulse resistances

During these tests, it was observed that there are two current peaks with some initial oscillations. The existence of two current peaks leads to the definition of two resistances for each tested configuration; the pre-ionization (R1) and the post-ionization resistance (R2). These resistances can be determined at the current maxima and their corresponding instantaneous voltages.

$$R_1 = \frac{V(@I_{peak\,1})}{I_{peak\,1}} \quad (6)$$

$$R_2 = \frac{V(@I_{peak\,2})}{I_{peak\,2}} \quad (7)$$

IV. Result and Discussion

Main objective of this paper is to investigate the behavior of transient impedance variation of sand and soil. For this investigation, only four current and voltage waveforms were selected among large experimental data set which was done to find the breakdown voltage of sand and soil.
The test results are summarized in Table 1.

Table 1. First breakdown voltage

Medium	Polarity of the impulse	First breakdown voltage
Soil	Positive	55 kV
	Negative	60 kV
Sand	Positive	100 kV
	Negative	90 kV

The test results are summarized in Table 2.

Table 2. Experimental results

Medium	Shot No	Z_1 (kΩ)	Z_2 (Ω)	Z_3 (Ω)	Z_4 (Ω)	Peak Current (A)	Peak Voltage (kV)	Figure No
Soil (positive imulse)	177	2162	9769	246	52	232.5	57.270	Fig 3
Soil (Negative Impulse)	215	1723	21194	183	39	342	62.610	Fig 4
Sand (positive Impulse)	142	10231	35748	158	36	668.3	105.600	Fig 1
Sand (Negative Impulse)	100	27985	9545	164	41	576.5	94.690	Fig 2

As the charging voltage was increased, higher current magnitudes were obtained. The above table shows that, Impedance is varies $Z_1>Z_2>Z_3>Z_4$.

The diagrams which show the variation of voltage, current and impedance upon the time are depicted in figure 3…6. Each figure contains three graphs, voltage and current variation, filtered voltage and current variation and impedance.

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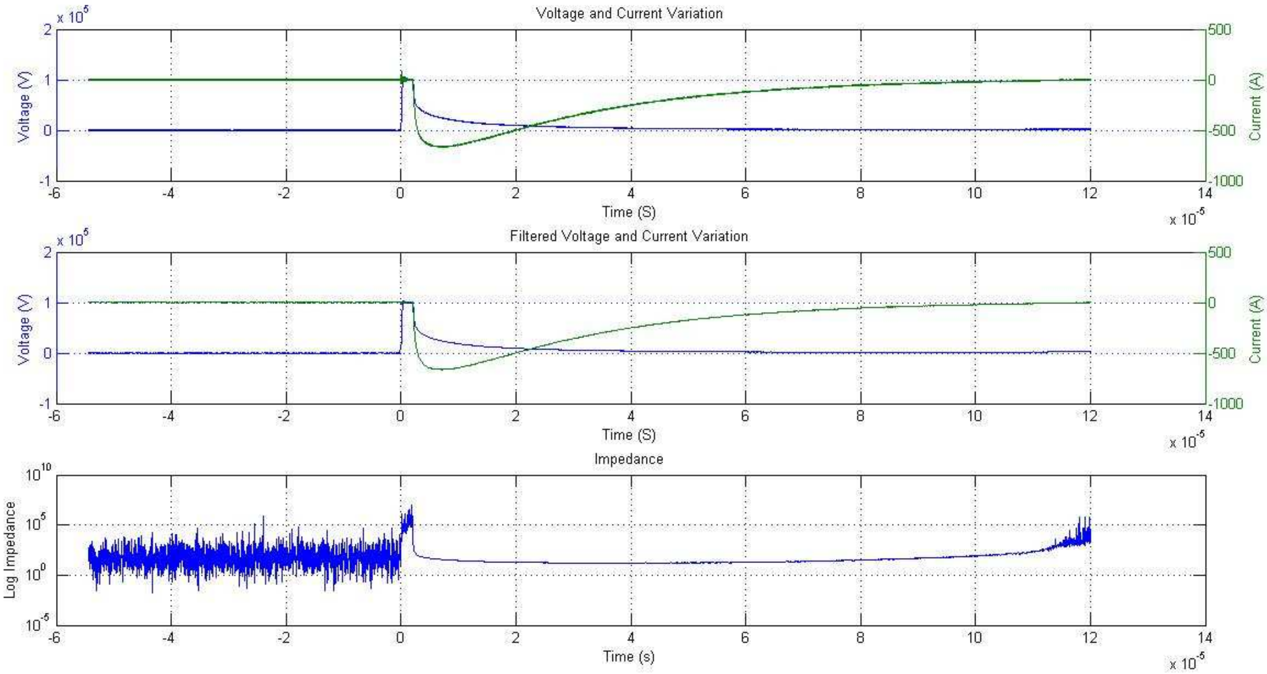

Fig. 3. Impedance characteristics of Sand Positive voltage impulse

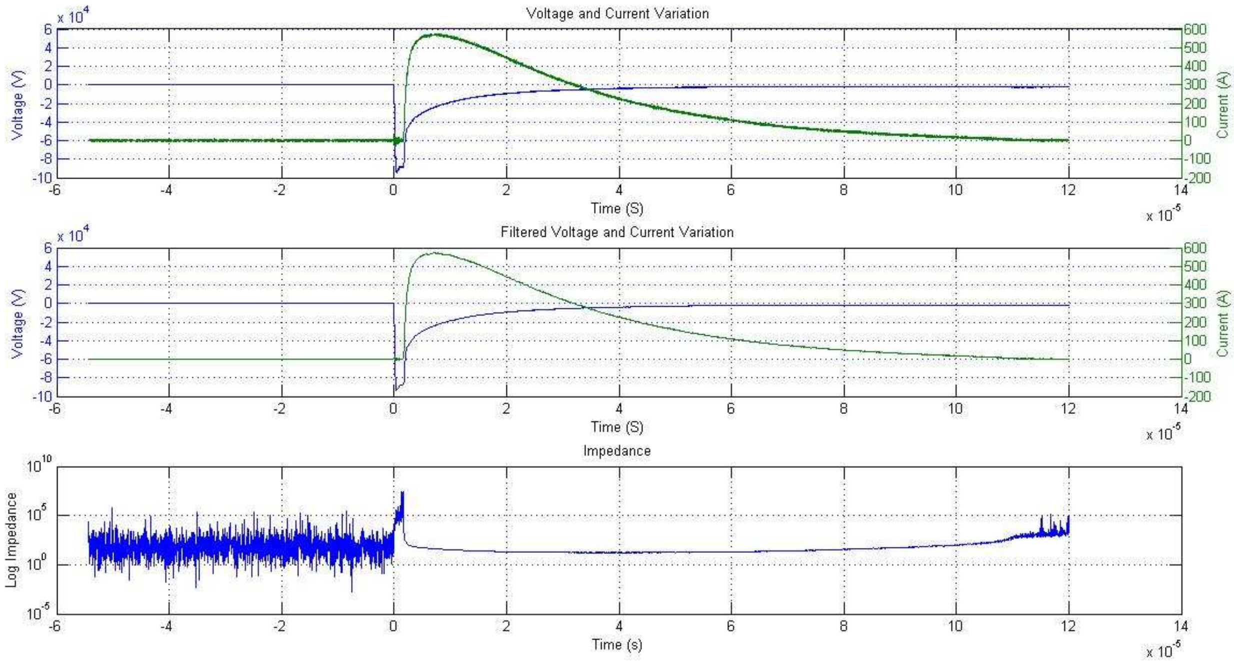

Fig. 4. Impedance characteristics of Sand Negative voltage impulse

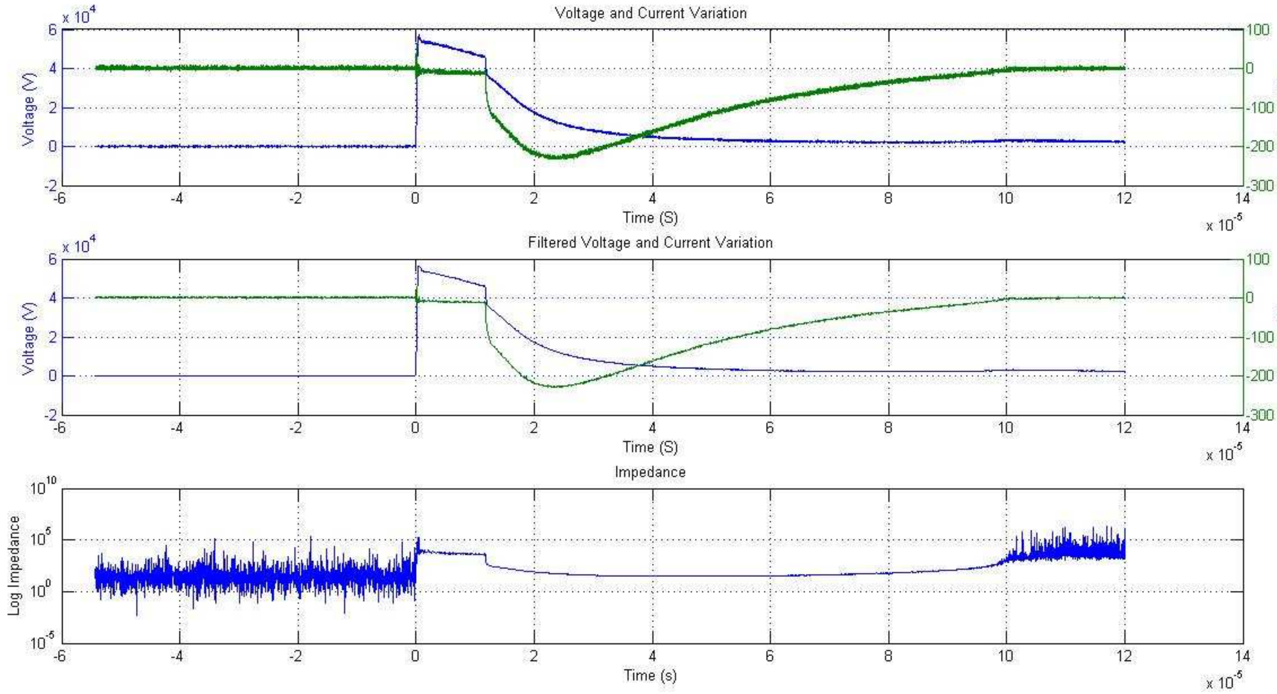

Fig. 5. Impedance characteristics of Soil Positive voltage impulse

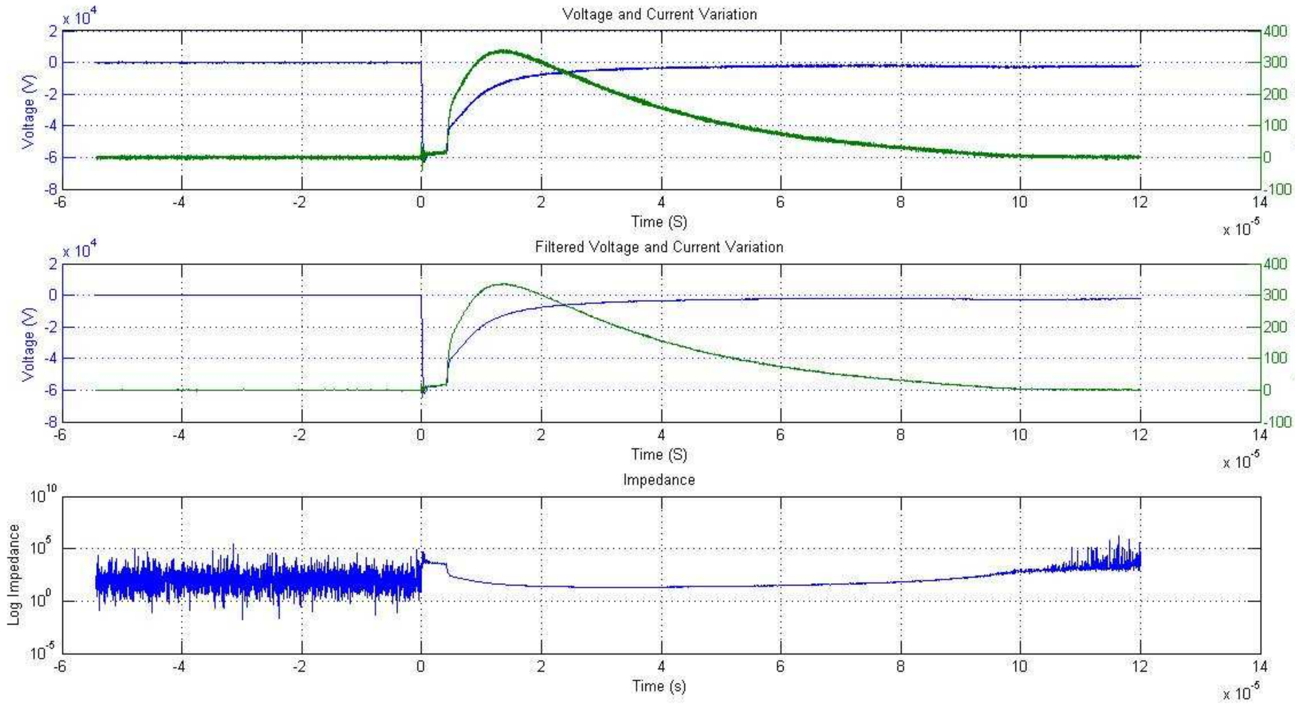

Fig. 6. Impedance characteristics of Soil Negative voltage impulse

In sand breakdown, the current impulse shape showed a fast rise time with some initial oscillations (figure 3 & 4). These initial oscillations are attributed to capacitance effects. From the above graphs, it can be observed that breakdown process of soil takes comparatively more time than sand.

V. Conclution

Grounding systems are used to dissipate high currents into the earth, in to the shortest time possible. In this case ground imedance should be maintained very low level. It will keep the ground potential rise at relatively low levels and consequently the developing step voltages and touch voltages below the permitted limits.

Impulse test were conducted on dry sand and soil under different polarities to investigate the impedance variation in soil and sand. Ionization to be the main process involved in dry soil and sand, since there is no water path that can enhance any thermal process. Because of its high resistivity, breakdown voltage of sand is higher than the soil.

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