EXPERIMENTAL EVALUATION OF A GROUNDING GRID SUBJECTED TO HIGH INTENSITY CURRENT IMPULSE

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Abstract – Grounding grids are fundamental for the safety of people and equipments in power system. Atmospheric discharges cause serious damage to the electrical system. So, it is important to study the performance of grounding grids subjected to high intensity current impulses. In order to analyze the performance of grounding grid subjected to current impulses, it was applied current impulses up to 2 kA into the soil. To produce the current impulses, it was used from 15 kV to 35 kV to charge the capacitors of an impulse generator. By using an oscilloscope it was acquired current and voltage signals applied into the soil. From these measurements, impulse impedance and transient impedance are obtained. From the results it is observed that the impedance increased when the signal amplitude increased. It was also observed that the impedance tends to the value of ground resistance at low frequency.

Keywords: current impulse, grounding grid, impulse impedance, transient impedance.

1. INTRODUCTION

Grounding grid is important to save lives and apparatus in electrical systems. Its main function is to provide a path of current from: current unbalance in industrial frequency, atmospheric discharge, switching and short circuit [1]. The elements of a grounding grid are electrodes, connectors and soil. So, electrical characteristics of soil are important to grounding grids performance.

Researches about grounding grids subjected to high intensity current impulses are not a trivial task, because electric and magnetic effects occur simultaneously [2]. However, to study the effects of high intensity current impulses on electrical systems constitutes a matter of very important role, because lightning is the leading cause of interruption of operating of electrical systems in the world.

The response of a grounding grid subjected to current impulse is significantly different from that in which the ground is subjected to low frequency signals. Researchers want to know how the dynamic performance of a ground is different from the low frequency resistance (R_{LF}).

There is no consensus on which parameters show the performace of ground grids sujected to current impulses. But according to [2,3,4,5], the most important parameters to evaluate grounding grids performance are: transient impedance, impulse impedance, impulse coefficient, electrodes effective length, transient duration and harmonic impedance.

The transient impedance ($z(t)$) is defined as (1):

$$z(t)= v(t)/i(t) \tag{1}$$

where $v(t)$ is the applied voltage in time and $i(t)$ is the related current.

Impulse impedance (Z_p) is presented in (2):

$$Z_p= V_p/I_p \tag{2}$$

where V_p – is voltage peak value and I_p is current peak value.

The impulse coefficient (A) is shown in (3):

$$A=Z_p/R_{LF} \tag{3}$$

where Z_p is the impulse impedance and R_{LF} is the low frequency resistance.

Effective length is the maximal length of the ground electrode for which the impulse coefficient is equal to one. Transient duration is the required time to the transient impedance reaches the value of the low frequency resistance [2,3,4,5].

This paper presents an experimental evaluation of grounding grid subjected to high intensity current impulse by using a high current impulse generator. The high intensity current impulses were applied to the grounding through electrodes buried in the ground and the measurements of current and voltage signals were performed by using a digital oscilloscope.

2. EXPERIMENTAL SETUP

It is presented in this section materials and methods used to achieve the objectives.

To obtain the results, high intensity current impulses were applied into the soil. These impulses were produced from an electric current impulse generator of 80 kJ/100 kV (Photo in Figure 1).

It is presented in Figure 2 a schema to explain the impulse generator operation.

(a)

(b)

Fig. 1. Electric current impulse generator of 80 kJ/100 kV (Photo) (a) Bank of capacitors; (b) Control desk.

The current impulse generator has 8 stages, each one is composed by capacitor and resistor, represented in Figure 2 by the parallel mash RC. From the power system and using a control desk, the capacitors are charged with the with the desired voltage. Then the spark gaps (SG) are approximated, when the electric arc is formed, the impulse is applied into the soil via a coaxial cable and a rod.
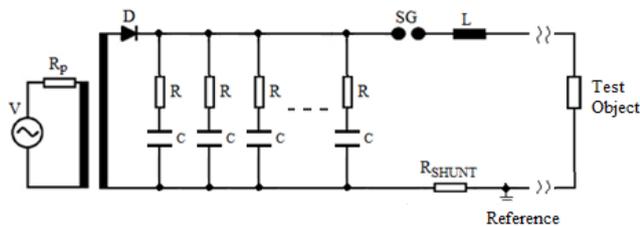

Fig. 2. Schema of current impulse generator of 80 kJ/100 kV.

To apply the current impulse into the soil it was used an injection rod made in steel and copper coated. The rod was 1.20 m length and 13 ± 2 mm in diameter. And it was buried at a depth of 1.0 m in the ground.

A digital oscilloscope with acquisition rate of 2 GHz was used to acquire data from voltage and current signals, applied to the soil. Experimental setup is presented in Figure 3.
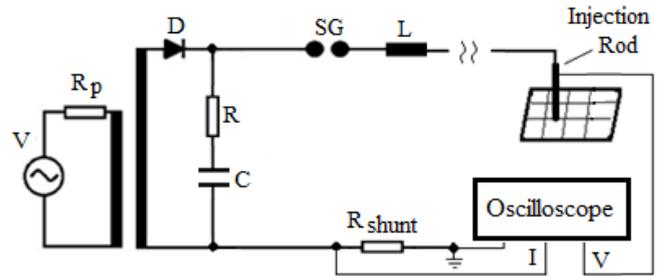

Fig. 3. Experimental setup.

Voltage signal applied to the soil is acquired using by high intensity test probe up to 40 kV and multiplication factor 1000.

To avoid the mutual effect they were used shielded cables.

The signal of current injected into the soil was obtained using the Shunt Method. A shunt resistor is connected in serie in the circuit (Rshunt in Figure 3). The current signal is obtained from the voltage signal between its terminals divided to the known resistor value.

The impulses were produced from capacitors charging in 15 kV, 20 kV, 25 kV, 30 kV and 35 kV. For each charging voltage, it was performed five measurements and the mean value was used.

The low frequency resistance was obtained according to the Wenner method, in accordance with Brazilian standard ABNT NBR 7117 [6]. This enables one to verifiy the dynamic behavior of the ground in relation to this resistance.

The soil used to perform the experiments is rocky and was not subjected to chemical treatment.

3. RESULTS

The results are presented in three sections: voltage and current signals obtained, impulse impedance and transient impedance.

The low frequency resistance obtained according to the Wenner method, in accordance with Brazilian standard ABNT NBR 7117 was 26.1 Ω.

Each charging voltage (15 kV, 20 kV, 25 kV, 30 kV and 35 kV) produces a current impulse. To each charging voltage they were repeat 5 measurements. Each signal presented in next sections are the average signal obtained from these 5 measurements. Routines MatLab were used to compute and plot the curves.

3.1. Voltage and current signals

They are displayed in Figure 4 the signal of voltage applied in the soil. Similar curves are obtained by others researches among them [7,8,9,10]. One notes that as the voltage rises the signal decay is more accentuated.
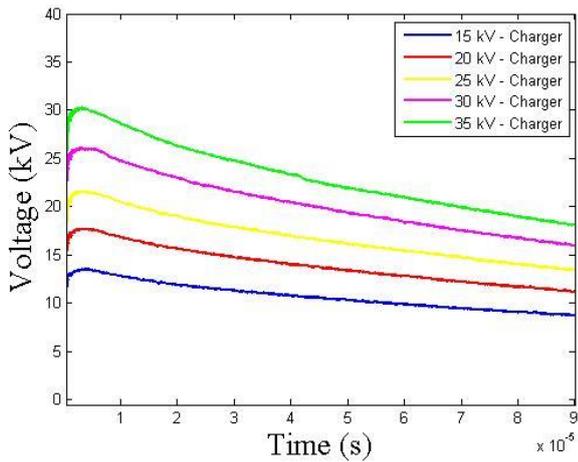
Fig. 4. Signal of voltage applied in the soil

Signals of current impulse injected into the soil is displayed in Figure 5. Excepted to 15 kV signal, it is observed a break in the signals from 10 to 20 µs, of course this will reflect in impedance
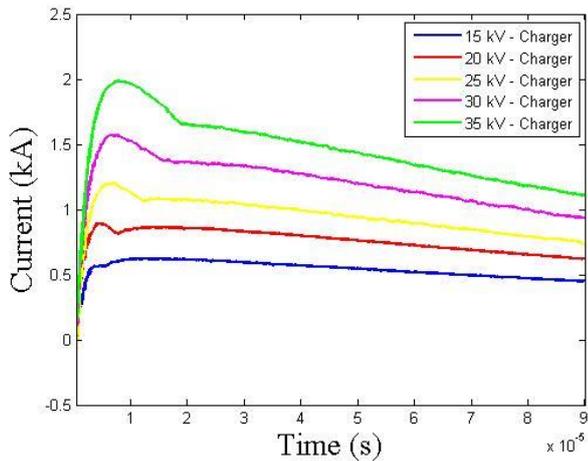

Fig. 5. Signal of current injected into the soil.

One possible justification for this current behavior is the ionization of the soil, however this topic has not been the object of study of this work.

3.2. Impulse Impedance

They are presented in Table 1 impulse impedance for different charging voltage. These values were computed using (2), the ratio voltage peak by current peak values. In Table 1, impulse impedance is higher for higher values of current applied to the soil, but they are smaller than the low frequency resistance (R_{LF}=26.1 Ω).

Table 1. Impulse impedance in different charging voltage.

Charging voltage (kV)	Impulse Impedance (Ω)	Deviation (%)
15	15.62	2.51
20	16.54	3.60
25	18.21	1.90
30	19.78	2.15
35	21.29	4.17

From these results one can say the behavoir of a grounding grid subjected to current impulse is no linear.

3.3. Transient Impedance

Transient impedance curves are shown in Figure 6. The curves are obtained using (1), a division between voltage and current signals.

As already mentioned, the impedance has a break in the signal related to 20 kV, 25 kV, 30 kV and 35 kV. As [1,11] soil ionization causes a similar effect to increase the diameter of the ground electrode, as a result has a decreased impedance. The occurrence of soil ionisation from 20 kV charging voltage could be the cause of the break in the signal presented transient impedance, however, further investigation is required to evaluate it.
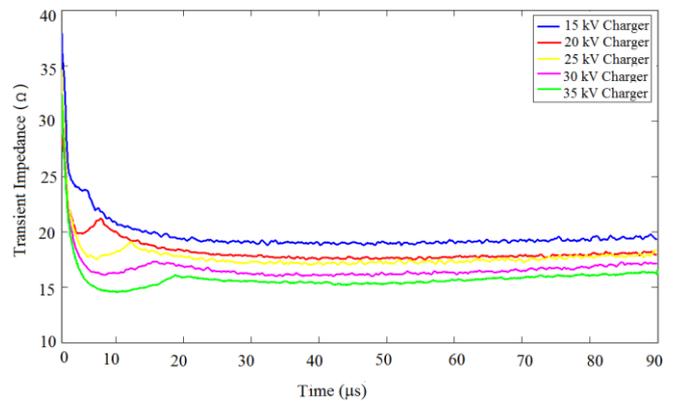

Fig. 6. Transient impedance changing the intensity of applied current.

Time acquisition was 90 µs, but one notes that the impedance value tends to low frequency resistance in a long time.

4. CONCLUSIONS

It was presented in this paper a methodology for measuring and evaluating grounding systems subjected to high intensity electric current impulses. From results it was observed that the impedance increased when the signal amplitude increased. So, the performance of a grounding grid subjected to current impulses is not linear. It was also observed that the impulse impedance tends to the value of ground resistance at low frequency.

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