Study Transient Impedance of Spherical Electrode Buried in the Ground

Mohamed Nayel

Electric and Electronics Engineering Department
Xi'an Jiaotong Liverpool University
Suzhou, Jiangsu Province 215123, China
Mohamed.Nayel@xjtlu.edu.cn

Abstract - This paper studies the transient characteristics of a spherical electrode embedded into ground at different depths. Step-like current of different rise times is injected into the spherical electrode to investigate the domain frequency of injected current effects on the spherical electrode impedance. The results show that the spherical electrode impedance dependent on the domain frequency of the injected current and depth of the grounding spherical electrode. This explains the effect of penetration depth of the domain frequency on the wave propagation and the spherical electrode impedance.

Index Terms - Hemispherical electrode, Transient characteristic, Frequency effects

I. INTRODUCTION

The grounding electrodes main job is dissipating fault currents effectively into the ground, and to prevent damage of installations. The performance of the power system also, is influenced by proper functioning of grounding systems.

Up to now, there are no derived formulas of impedance and admittance even for a simple vertical or horizontal naked conductor buried in ground during transient. Experimental techniques are still the best method to investigate the transient characteristics of the grounding systems.

Transient characteristics of grounding systems can be investigated by numerical electromagnetic analysis [1-4]. Or, using experimental technique to investigate transient characteristics of grounding systems. There are two directions for investigating transient characteristics of grounding systems, one concerns of a frequency-dependent effect [5-11] and the other relates wave propagation [12-15].

This paper studies the transient characteristics of spherical electrode buried at different depths and different injected current rise times to understand the impedance transient characteristics.

II. EXPERIMENT SETUP

Fig. 1 shows an experimental setup to study the transient characteristics of spherical electrode. A step-like current of 7 or 308 nsec rise time is applied from a pulse generator (PG) of 500V to grounding spherical electrode via a lead wire that is supported at 4 m height above the ground surface. The grounding spherical electrode is apart from PG by 11 m. The current is measured by a CT (Pearson model 2877, bandwidth from 300Hz to 200MHz), and recorded by a digital oscilloscope (Tektronix TDS 3054m, bandwidth 500MHz). Transient voltages were measured by a voltage probe (Tektronix P6139A, bandwidth 500MHz).

The ground resistivity of experimental site is measured by means of Wenner method using a specific ground resistance tester (Yokgawa Electric Work type 3244) as a function of depth. The measured resistivity shows a decreasing of grounding resistivity with ground depth as shown in Fig. 2. The experimental site was at yard area of Doshisha University, Kyotanabe Campus, Kyoto, Japan.

A hemispherical electrode had been buried in the ground to study the effects of spherical electrode depth and injected current rise time (domain frequency). The studied injected current rise times are 7 and 308 nsec. The studied depths of the hemispherical electrodes are 0, 10, 20 and 30 cm.

II. MEASURED RESULTS

Figure 3 show the measure injected currents and hemispherical electrode voltages waveforms for the different studied cases.

The capacitive/resistive characteristics are observed in the spherical electrode voltages and currents wave forms.
Table 1 show the steady state calculated resistance and the time delay between the voltage and current waveforms. The hemispherical resistance decreases as the depth increases and as the injected current rise time increases.

The time delay between voltage and current waveforms shows that for 7 ns rise time the, time delay increases with the spherical electrode depth increases. This is coming from that the 7 ns rise time has a high frequency which penetrate near the ground surface, so as the hemispherical electrode go deeply as the current diffusion in ground take a time and increases time delay of the voltage waveform.

The time delay between voltage and current wave forms shows that for 308 ns rise time. The time delay increases with the depth decreases. This is coming from that the 308 ns injected current has a low frequency which go deeply in the ground where the ground resistivity decrease and spherical electrode capacitance decrease vise verse near the ground surface where the spherical electrode capacitance increased.

The percentage differences (R%) between 7 ns and 308 ns resistances show that this difference decrease with the depth increase. This can be explained by the effect of penetration depth which demand pass all currents near the ground surface at high frequency and this depth decreases with injected current domain frequency increases.

The impedance of spherical electrode for different cases is observed in fig. 4 to be composed dominantly of a resistance and a capacitance. The hemispherical electrode impedance decrease rapidly in the case of 7 ns injected current than that of 308 ns injected current. The impedance phase angle in case 308 ns change from 0° to -90° rapidly than that of 7 ns injected current. As the spherical electrode go deeply as the frequency response impedance decrease due to the decrease of ground resistivity with depth as shown in fig. 2.

**TABLE 1**

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Td: Time delay between voltage and current waveform
R%: Percentage difference between resistances measured at 308 ns and 7 ns

**CONCLUSIONS**

From the experimental results one can obtain the following conclusions:

- As the spherical electrode go deeply in the ground of reduced resistance with depth, as the spherical electrode impedance decreases.
- The spherical electrode impedance decreases rapidly with frequency increases.
- The spherical electrode resistance at low rise time is higher than that at high rise time due to penetration depth and both decreases when the spherical electrode goes deeply in the ground for the studied cases.
- The time delay between the current and voltage waveforms increase with the spherical electrode depth decrease.
Fig. 4 Frequency response of spherical electrode for different cases

REFERENCES
