P31: Characterization of Horizontal Earth Electrodes: Variable Frequency and Impulse Responses

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Introduction: Earting systems such as vertical and horizontal electrodes, and grids are installed in the soil to mitigate against the effects of system faults and lightning surges.
In this study,

- Soil resistivity measurements near the test electrode area have been carried out.
- The performance of a 24m horizontal earth rod is investigated under different low voltage energization conditions, DC, variable frequency AC and impulse.
- The test results were compared with simulated responses using a numerical earthing software HIFREQ-CDEGS.

SOIL RESISTIVITY SURVEY

- An understanding of the soil resistivity and how it varies with depth, moisture content, and temperature is necessary because it helps to provide insight into the desired earth resistance, how it can be achieved and maintained over the life of the installation with minimum cost and effort.
- Soil resistivity measurements were taken along a 240m profile using a multi-electrode multi-channel array using the Wenner configuration.
- The results indicate that the soil is nonhomogeneous, with significant variation both laterally and with depth, and they suggest a 3-layer soil model.

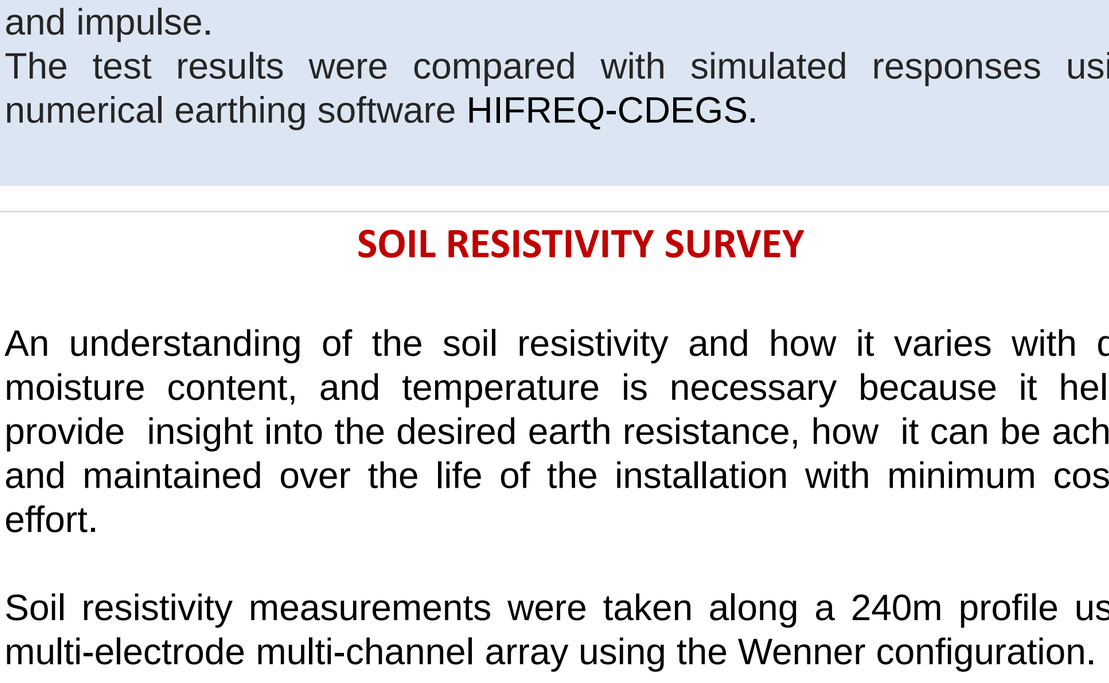


Fig (1) 2-D Resistivity model for profile near to the test location

Approximate soil models

3-layer model	Top		Middle		Lower	
	Resistivity (Ωm)	Depth (m)	Resistivity (Ωm)	Depth (m)	Resistivity (Ωm)	Depth (m)
	200	10	30	15	50	∞
2-layer model	Upper			Lower		
	Resistivity (Ωm)	Depth (m)		Resistivity (Ωm)		Depth (m)
	150	10		65		∞
Uniform model	Resistivity (Ωm)					
	150					

[1] IEEE *Std 81.2-1991,* "IEEE Guide for Measurement of Impedance and Safety Characteristics of Large, Extended or Interconnected Grounding Systems", 1992.

[2] S. Visacro, R. Alipio, M. H. Murta Vale, and C. Pereira, "The Response of Grounding Electrodes to Lightning Currents: The Effect of Frequency-Dependent Soil Resistivity and Permittivity", *IEEE Transactions on Electromagnetic Compatibility,* vol.53, pp.401-406, 2011.

[3] A. Elmghairbi, M. Ahmeda, N. Harid, H. Griffiths, and A. Haddad, "A technique to increase the effective length of horizontal earth electrodes and its application to a practical earth electrode syste", *7th Asia-Pacific International Conference on Lightning (APL),* pp.690-693, Chengdu(China), 2011.

TESTS RESULTS

1) low voltage DC and variable frequency AC.

- Current dependence of measured resistance is significant in low voltage tests and, particularly so, over a low current range at low switched DC frequencies, Fig (2).
- AC variable frequency test implemented and compared with numerical simulation, Fig (3), and the resultts illustrate:
  - The sensitivity of the result to changes in soil resistivity, Fig (4).
  - Simulated earth impedance was not sensitive to changes in ε_r over the range 1 to 30, Fig (5).

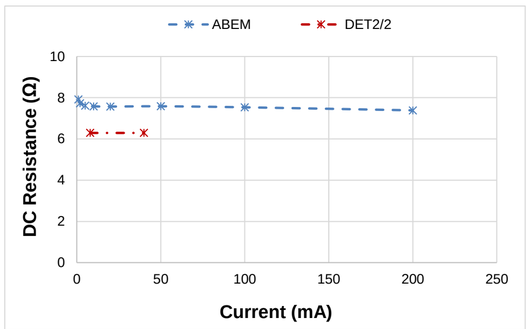
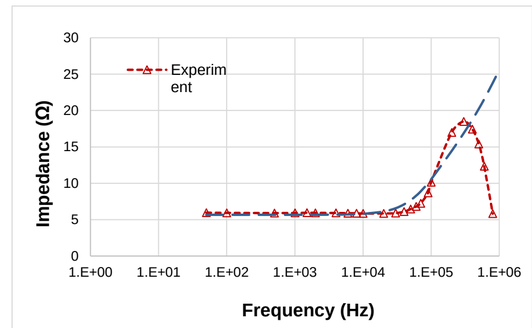


Fig (2)



Fig(3)

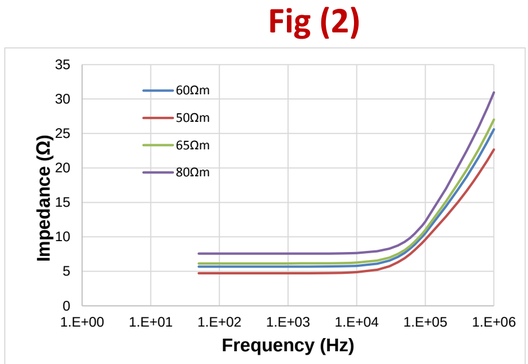


Fig (4)

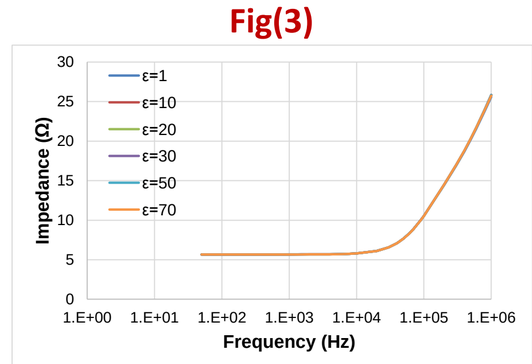


Fig (5)

2) Impulse tests low voltage.

Low voltage impulse tests carried out on a 24m earth electrode show that

- At low voltage impulse current and voltage occur in the same time with small oscillation in wave forms, Fig (6).
- Both tests show good agreement with numerical simulation results.

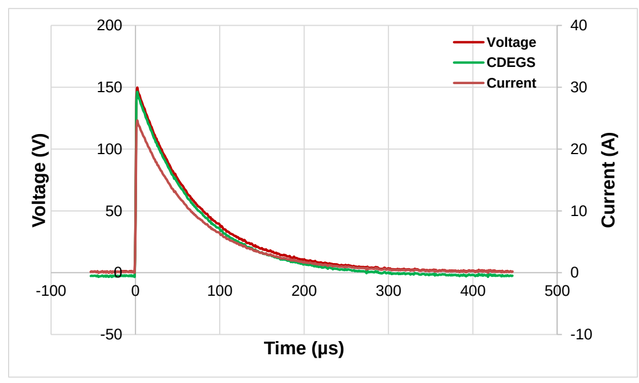


Fig (7)

Conclusions / Future Work:

- Preliminary tests were carried out on a 24m earthing horizontal electrode at the Cardiff University earthing test facility. The tests showed good agreement between low voltage AC, DC and impulse resistance values.
- The earth electrode DC resistance exhibited significant current dependence when measured with a low switching-frequency test meter.
- With AC tests, good agreement was obtained between the measured and simulated values of electrode earth impedance up to 100kHz. However, above this frequency, there was a significant difference in the frequency responses.
- Impulse tests showed resistive behaviour of of the earth electrode.
- Further tests and more detailed computer simulations with refined soil models will be carried out.