30th International Conference on Lightning Protection - ICLP 2010
(Cagliari, Italy - September 13th -17th, 2010)

HIGH FREQUENCY BEHAVIOR OF SOIL IMPROVER COMPOUNDS

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ABSTRACT

The method of using soil improver compounds in order to improve the DC resistance of an earth electrode is becoming more and more known all over the world. In the past years many practical but not effective methods were used as soil improver compounds. There are still some references that one can find, which identify some compounds like salt and coal as soil improver compounds, however they may cause accelerated aging of the earth electrodes as well as environment degradation and this is completely unacceptable. In order to avoid the uncontrolled use of non acceptable improvers recently a new European Standard was issued under the series of EN 50164 (part 7) specifying testing and performance requirements of soil improver compounds. Although there are many references on the performance of soil improvers showing their effect on the DC resistance of an earth electrode, there is not much information about their behaviour under high frequencies. This paper aims to investigate the performance of various earth electrodes installed in the field with and without various soil improver compounds under high frequencies.

1 INTRODUCTION

The objective of this experimental study is to analyze how the presents of a various soil improver compounds used in a real size earth electrode system may help so as to improve also the transient behavior of the earth electrode by reducing its impedance at high frequencies. The effective length of an earth electrode when discharging high frequency currents is very important and as an example it is widely accepted that a horizontal length of about 10 m is the maximum that will contribute to the discharge of a high frequency current independent more or less of the soil that this electrode is installed. Therefore in high resistivity soils we may end up with a very poor earth electrode always considering the parameter of the effective length. As a result in such cases soil improver compounds may be a solution to improve the behavior of the earth electrode.

2 PREVIOUS AND CURRENT WORK

During past laboratory experiments performed by the authors it has been found that the transient behavior of various soil samples is influenced by the presents of soil improver compounds. This paper describes field measurements simulating real size earth electrodes, which are installed in the soil samples previously tested in the laboratory. The measurements in the field were performed by using high frequency source, which is able to simulate the transient effect of impulse current and therefore to evaluate the behavior of the impedance of the earthing system.

3 TESTING MEANS AND TESTED CONFIGURATIONS

High frequency measurements of earthings were performed by use of AES 1002 meter manufactured in France [2], [3]. It allows to measure in an entirely automatic process, by means of an integrated processor, the impedance of earthing system, within a range of frequencies from 10 Hz to 1 MHz. It uses the regular three points measurements : one injection rod (Z) and one measuring rod (Y) located at 66% of the distance between measured earth electrode (X) and injection rod. The only difference is the cables being of coaxial type and also the frequencies used for measurement. The coaxial cables limits the length of Z cable and Y cable to respectively 15 m and 10 m. low frequecny regular measurement of the earthing resistance have also been performed with a regular earth meter.

The results have been interpreted according to the result directly given by the device in terms of quality of the high frequency earthing impedance and also based on the curve Z(frequency) and especially the highest values (greater or equal to 63 kHz) and their mean value (average impedance) from 63 kHz and 1 MHz [4].

Measurements have been done :

- on galvanized steel tape conductors 10 m long in various trenches with our without earthing compounds (see figure 1). Three trenches have been made named A, B and C. A is back filled with the regular soil of the area. B is made in such a way that a compound available on the market (C1) is used around the tape and then the trench is back filled the regular soil of the area. With B two configurations have been tested. One with 10 m length of tape, the second one with a center connection so this means 2 tape of 5 m connected to the center point.

C is made in such a way that another compound available on the market (C2) is used around the tape and then the trench is back filled the regular soil of the area.

- on rods in various places based on configurations already studied in [5], see figure 2 and 3). There are 7 different configurations. Arrangement 6 is using compound C2.

Figure 1. Tape testing place.

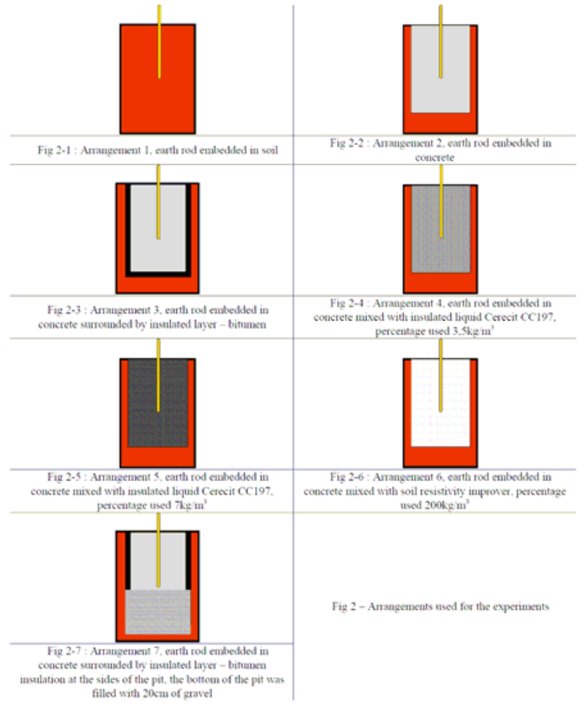

Fig 2 – Arrangements used for the experiments

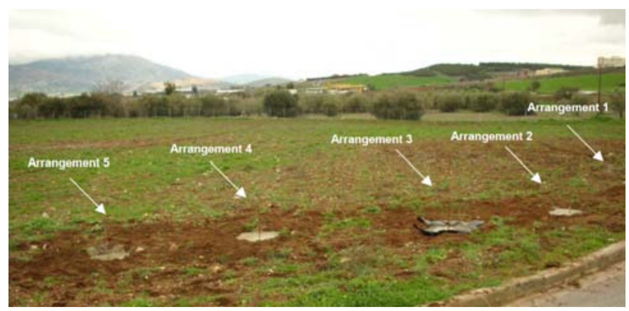

Figure 3. Original test arrangement for rods.

4 TESTING RESULTS

Results obtained for the trenches are given in Table 1.

Table 1 data obtained in 2009 for the trenches.

Electrode	10 m galvanized steel	10 m galvanized steel	10 m galvanized steel. Center connection	10 m galvanized steel
Trench	A	B	B	C
Compound	none	C1	C1	C2
Measurement N°	10	16	17	18
DC value (Ω)	29,2	10,65	10,62	8,31
High frequency device	Impedance (Ω)			
79 Hz	31	11	11	9
63 kHz	22	12	11	10
1 MHz	60	59	54	52
Average value of Z (63 kHz-1MHz)	42	31	28	28
Criterion	Bad	Acceptable	Good	Good

The results obtained at low frequency with the high frequency device are consistent with those obtained with a regular earth meter (called DC value in the table).

The resistance improvement is 64% for C1 and 72% for C2.

The average impedance with compound C1 is improved by 26% and by 33% for compound C2. Same improvement is obtained with center connection with compound C1 but in such a case, the Y and Z electrode where probably located in the area of influence of other trenches. Experience on other sites where a unique trench exists, shows that the effect of center connection is normally more noticeable than what we found in the case described above.

We can see from figure 5, that the curves are very similar for M17 and M18 and much lower than for M10. The increase at highest frequencies, show the inductive effect of the tape.

Basically the combined effect of the compound to reduce resistance and increase capacitive coupling, improves the average impedance.

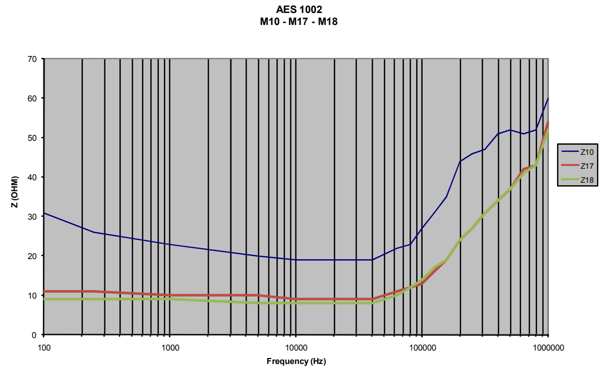

Figure 5. M10, M17 and M18 Z .vs. frequency curve.

Results obtained for rods are given in Table 2.

The results obtained at low frequency with the high frequency device are also consistent with those obtained with a regular earth meter (called DC value in the table). When the regular earth meter was not able to make the measurement (resistance > 2 000 Ω), the high frequency device was unable as well (???? shown on the device display). It should be noted that compared to previous campaign the resistance has increased typically by a ratio 6, due probably to different conditions of the soil (wet in previous campaign due to heavy rain in previous weeks/days) and dry in 2009 campaign.

Comparison of various configuration is made with a reference being the rod embedded in the local soil, which was the worst case for low frequency except for the two configurations isolated by bitumen (3 and 7).

The concrete by itself brings an improvement of 50% on resistance. Compound C2 mixed in concrete (200 kg/m^3) brings more improvement on resistance : 65%. This is to be compared to tape embedded in compound C2 which gave improvement of 72%. This is explained by lower quantity of C2 in the concrete-C2 mixture compared to product C2 directly in contact with the tape along its whole surface.

In the same way, high frequency behavior is improved both by concrete (37% improvement on average impedance) and compound C2 (55% improvement on average impedance).

We can see from figure 6 that the impedance tends to be almost constant over the range of measured frequencies for mixture concrete/C2 when it was decreasing with frequency for the bare rod in soil.

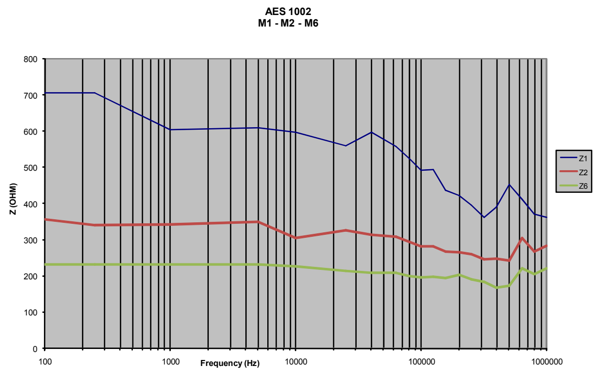

Figure 6. M1, M2 and M6 Z .vs. frequency curve.

Efficiency of compounds (including concrete) is bigger in that experiment for rods than for tapes.

Resistance without any treatment is larger for rods (short length, 1 m only) compare to tapes (10 m long). High resistance is sign of bad soil (high resistivity) as well as bad area of contact between electrode and soil (due to soil composition and size of elementary elements from one side, and due to length of electrode). By using a compound one doesn't change soil resistivity of surrounding soil but improve contact between electrode and soil as well as increase the apparent diameter of the electrode thus increasing surface of contact and decrease resistance.

A similar phenomenon occurs at high frequency : the capacitive coupling increases between electrode and soil. The inductive effect, mainly related to length of conductor is probably not influenced so much by the compound.

The improvement for compound C2 on tape (inductive behavior) is only of 13% at 1MHz when for the average impedance it was 33%. In the same way for the rods (capacitive behavior), the maximum improvement is 39% for concrete/C2 when it was 55% for the average impedance. The benefit is obtained over the whole frequency range by using compounds (concrete beinga compound).

Table 2 data obtained in 2009 for the rods.

Electrode	1 m copper coated steel	1 m copper coated steel	1 m copper coated steel	1 m copper coated steel	1 m copper coated steel	1 m copper coated steel	1 m copper coated steel
Surrounding material	none	Concrete	concrete	concrete	concrete	concrete	concrete
In addition			isolated by bitumen	insulated liquid Cerecit CC197, percentage used 3,5 kg/m3	insulated liquid Cerecit CC197, percentage used 7 kg/m3	compound C2 mixed in concrete	isolated by bitumen + gravel
Arrangement (see [5])	1	2	3	4	5	6	7
Measurement N°	1	2	3	4	5	6	7
DC value (Ω)	692	349	> 2000	341	264	245	> 2000
High frequency device	Impedance (Ω)						
79 Hz	707	358	????	361	264	233	????
63 kHz	558	309	944	306	235	209	????
1 MHz	362	284	267	276	275	222	324
Mean value of Z (63 kHz-1MHz)	437	274	640	282	237	198	676
Criterion	Bad	Bad	Bad	Bad	Bad	Bad	Bad

???? : means that the device was not able to measure the impedance at this frequency

5 CONCLUSIONS

From the results one can see that the use of soil improver compounds may improve not only the DC resistance but also to contribute to the reduction of the average impedance of the earth electrodes. Based on these findings, new characteristics may be checked in future in EN 50164-7 to characterize efficiency of these compounds over a large frequency range. New measurements after a certain time in soil with rain possibly washing the compound should be performed. Additionally, measurements made in various soil conditions (dry summer time, cold winter, rainy spring and autumn) should be performed to give an idea of long term efficiency of such product

6 REFERENCES

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