

MEASUREMENT OF GROUNDING RESISTANCE IN TOWER LINES

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Abstract – This article exposes the methodologies for the resistance measurements of grounding systems in transmission lines, it summarizes the implemented procedures, describes the earth tester used and exposes a statistical analysis of results in the measurements of more than three thousand towers of high voltage.

1 - INTRODUCTION

A project of earth resistance measurement was led in 3025 towers of transmission, with voltages of 115 kV to 2500 m.o.s.l. (meter over sea level), as part of a maintenance program, it was necessary to determine the percentage of towers that were above 30 ohms (Design value), and to look for a correlation with the towers with more lightning activity.

The measurement system, the necessary personnel and the earth tester were determined keeping in mind:

- The scarce documentation and standards about the topic.
- Condition physical - environmental unfavorable.
- Instruments not well employed or without the appropriate characteristics for this kind of measurements.
- Parallel connections among grounding systems due to overhead ground wire.
- Bad implementation of the different ground resistance measurement techniques.
- Uncertainty in obtained data.

With the previous aspects tests were carried out, these tests determined that field measurements should be made under the following conditions:

- With one or two overhead ground wire connected or disconnected.
- With energized or de-energized lines.
- With earth testers with frequencies from 111Hz to 25 kHz in order to compare their results and possible coincidences.
- To implement the recommendations given by the guide IEEE - 81 of 1983 in relation with the earth tester and measurement method.
- To implement earth testers with different techniques and methodologies of application.

2 - SYSTEM OF MEASUREMENT

In a simple way, the objective of a measurement system is to present a qualitative or quantitative result of a measured variable. However, in a specific relation with the numbers, the measured value is not specifically similar to the true value, this in reason of all the elements that involves a measurement system.

A measurement system is conformed basically by four elements: the object to measure, the measurement earth tester, the measurement method and finally the

observer. Although not all the measurements systems are the same, some qualities can be named, that can affect the development of the measurement system. Such qualities can be systemic as the environmental effects, the error is the uncertainty and that they can be static as the calibration.

3 - STANDARDS

The guide IEEE 81 - 1983 in their numeral 12,6 suggests that the transmission lines measurement should be implemented with a high - frequency ground resistance meter, which operates to 25 kHz

4 - MEASUREMENT METHODS

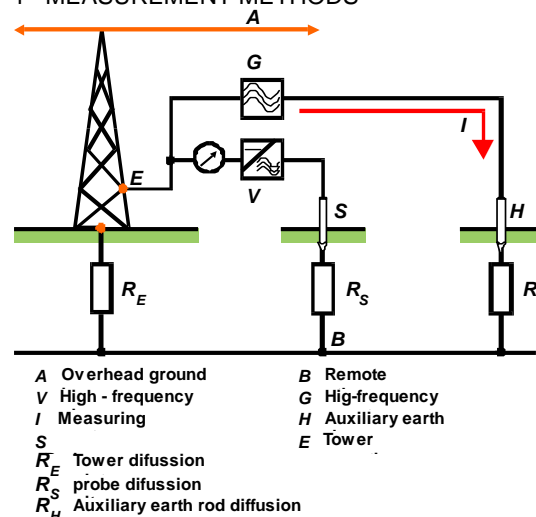


Fig. 1

The fig. 1 shows the method suggested by the IEEE 81 - 1983 with a high frequency ground resistance meter (25 kHz) and the application of the rule of 61,8%. This method requires two auxiliary electrodes that have to be placed and buried at 90° of the overhead wires. This recommendation is given in order to avoid a coupling with the grounding system under test. The earth tester injects current in one of the electrodes, it is considered as "current electrode", that electrode is placed far from the grounding system, the intermediate electrode is placed at 61.8% of the distance between the grounding system and the current electrode, this electrode measures the potential elevation and its named "probe electrode". The precision is given by the non interaction of both electrodes (guaranteed using a far earth) and the place of the intermediate electrode in the valley of the curve, the number of measures (minimum three) and the characteristics of the earth tester.

Other measurements were made with a low frequency earth tester, using the fall-of-potential method and with the overhead earth wires connected or disconnected.

An alternating measurement method, suggested by LEM, was rehearsed and it is denominated "Selective". For its application the fall-of-potential method should be implemented with the application of the rule of 61,8% and the utilization of a clamp-on current transformer for the measurement of the current in each one of the four legs of the tower. The total resistance of an individual tower is the parallel sum of all grounds resistance values.

5 - PREVIOUS REHEARSALS

In the measurements group was necessary to carry out activities to ensure and trust the observers, earth testers and measurements methods.

The results of the measurements and the realization conditions are presented:

Date 05.08.99
Dispositive Tower 14
Voltage 115 kV

Frequency (Hz)	Method	Characteristics	No. of Measu.	Place of current electrode (m)	Resistance (Ω)
1470	Fall of potential	Without overhead ground wire	1	100	324,00
160	Fall of potential	Without overhead ground wire	1	100	330,00
800	Fall of potential	Without overhead ground wire	1	100	340,00
111	Fall of potential	Without overhead ground wire	1	100	343,00

Date 31.01.00
Dispositive Tower100
Voltage 230 kV

Frequency (Hz)	Method	Characteristics	No. of Measu.	Place of current electrode (m)	Resistance (Ω)
1470	Rule of 61,8%	With overhead ground wire	1	100	2,52
		Without overhead ground wire	2	100	7,80
111	Rule of 61,8%	With overhead ground wire	1	100	1,43
		Without overhead ground wire	2	100	7,90
111	Selective	With overhead ground wire	1	100	13,00
		Without overhead ground wire	2	100	8,10

Date: 07.02.00
Dispositive: Tower 100
Voltage 230 kV

Frequency (Hz)	Method	Characteristics	No. of Measu.	Place of current electrode (m)	Resistance (Ω)
25000	Rule of 61,8%	1 overhead ground wire	1	100	5,70
		Without overhead ground wire	2	100	6,00
1470	Rule of 61,8%	1 overhead ground wire	1	100	1,50
		Without overhead ground wire	2	100	7,30
111	Rule of 61,8%	1 overhead ground wire	1	100	0,88
		Without overhead ground wire	2	100	7,50
111	Rule of 61,8%	1 overhead ground wire	1	100	8,20
		Without overhead ground wire	2	100	7,80

Date: 23.02.00
Dispositive: Tower 105
Voltage 230 kV

Frequency (Hz)	Method	Characteristics	No. of Measu.	Place of current electrode (m)	Resistance (Ω)
1470	Fall of potential	1 overhead ground wire	1	100	11,39
25000	Fall of potential	1 overhead ground wire	1	100	27,00
111	Fall of potential	2 overhead ground wire	1	100	9,93
111	Fall of potential	Without overhead ground wire	1	100	34,50
111	Fall of potential	Without overhead ground wire	1	150	32,60

From the analysis of the results without overhead ground wire and with a frequency of 111 Hz, and combining the

results for the two rehearsal methods we obtained a standard deviation, this indicates that the dispersion among the values is small and therefore the half value can be accepted with a high grade of trust from the statistical point of view, and also the data of high frequency tester is 20% lower.

In the case of the tower 100, with overhead ground wire, to 111 Hz and combining the results of the 2 rehearsal methods, it gives a value of half 5.88 ohms, but a deviation of 5,02 that shows the great dispersion of the results, so the methods for this case are not comparable. When they are analysed individually its found that with the rule of 61.8% the half result is 1.1, the deviation is 0,2 and for the "selective" method 10,6 and deviation of 2,4. Keeping in mind that with the rule of 61.8% the deviation is lower, this method is the most reliable.

6 - IMPLEMENTED METHODOLOGIES

Based on the previous data, it was determined:

- To use the high frequency-meter (25 kHz), in measurements with overhead ground wire connected.
- To use low-frequency meters (111 Hz or 1470 Hz) with the overhead ground wire disconnected
- Not to use the low-frequency meter specifically of 800 Hz, in this kind of measurements.
- To implement the fall-of-potential method with the application of the rule of 61,8% as measurement method.

Keeping in mind that when measurements of this kind are carried out not only the obtained data is important, but it is necessary to mention that the personnel's security is also important. Among all the security recommendations, for this kind of case is important to remark that:

- Before proceeding to the resistance measurement, its necessary the measurement of the voltage originated by spurious currents. If that voltage overcomes the 25 volts, do not practice any measure and determine the origin of the problem.
- Field measurements should not be scheduled during periods of storms or lightning activity.
- Connections or disconnections of transmission lines during a period of electric storms should not be done.
- In the event that an electric storm suddenly appears on the tested area, work must be stopped, disconnecting all connections among the measurement earth testers and the tested ground, isolating temporarily the connectors.
- Any bridge or continuity between the body between and the measurement earth tester or among the measurement implements must be avoided.
- The cable rolls that are used during the measurement are isolated or at least mounted on a clean or insulating platform.
- The grounding systems must be connected (determine in case of fall) to every metallic frame of the earth testers.

7 - RESULTS

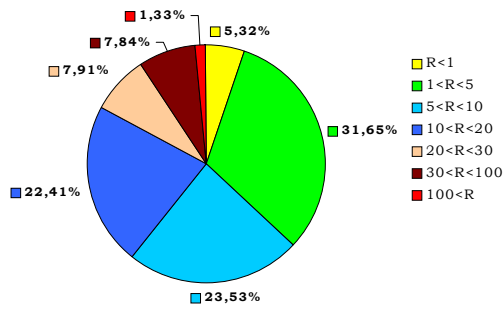


Fig. 2. 1428 Towers measured with earth tester of 111 Hz

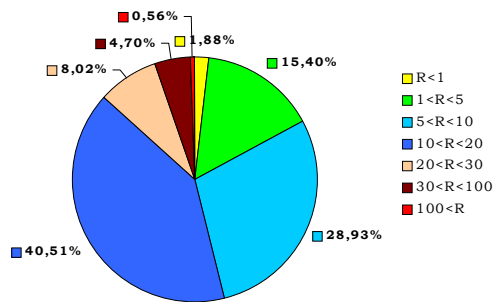


Fig. 3. 1597 Towers measured with high-frequency earth tester (25 kHz)

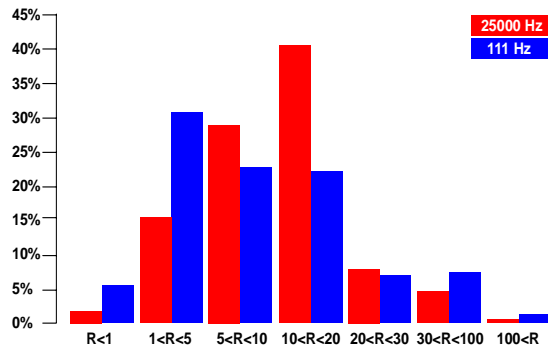


Fig. 4. Comparison between both earth testers

9 - CONCLUSIONS

9.1 - 168 (5%) of the 3025 transmission towers measured, need a corrective maintenance of their grounding system. Only 60 (2%) of towers need an urgent maintenance keeping in mind the high incidence of lightning.

9.2 - The sample measured was of 100% of the towers, its considered that the results are 100% reliable.

9.3 - All the activities were made in order to trust in the earth tester and the method of measurement, however and being strict, the results do not correspond with a calibration and a properly uncertainty analysis.

9.4 - Measurements with a high frequency tester gives 20% lower than the other measurements, its equivalent

to a measurement with a low frequency earth tester with the overhead ground wires disconnected and be carried out by two people, while with low frequency earth tester frequency 6 people are necessary.

9.5 - The measurements with low frequency tester will be with the over head ground wire disconnected.

9.7 - All measurements will be in perpendicular way to the line.

9.8 - The results of the project showed that due to the training of the people and the clarification of the all procedure, the percentage of accidents and loss of information was 0%.

9.9 - with the expressed reference to the measurement of grounding systems, the calibration presents the difficulty of emulating the real conditions of operation easily so that the variables can be really analyzed.

9.10 - In these cases, an alternative option can be the realization of a repetitive analysis that would allow to trust in the earth tester, however, earth resistance measurements are influenced by environmental changes, mainly in the moisture of the land, so that an analysis should be executed under very planned conditions in order to consider the test as applicable.

10 - REFERENCES

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