A Novel Approach to The Grounding Testing of Sensitive Electronic Equipment

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Abstract:. The paper discusses the problems encountered in the grounding testing of sensitive electronic equipment. The paper points out the disadvantages of existing test methods. A novel method of the grounding testing is described, which can be used for periodical control of grounding systems in the wide spectrum frequencies.
Keywords: Grounding, Testing, Sensitive Electronic Equipment, High Frequency

Introduction

The primary goal of every grounding system is to ensure the safety of personal and prevent damage to equipment. The purpose of the grounding system in a sensitive electronic equipment installation is to provide a direct path to the ground for currents, while maintaining the lowest possible voltage differences between any two points in the installation. Its task is to serve, as a common voltage reference and to mitigate disturbances.

The amplitude of currents caused by power system faults and lightning strikes reaches tens of kiloamps, and the signals produced by them have frequencies between 50 Hz and several MHz. The grounding system has to keep voltage differences between any two points as low as possible in all this frequency range.

The impedance of grounding conductors should be as low as possible so that the power fault currents and the high frequency currents will be diverted without passing through the electronic equipment. Generally, protective grounding conductors alone are not able to fulfil this requirement. For high frequencies the inductive impedance along the grounding conductor will be predominant. Signal reference grids are used in electronic installations to ensure a ground reference, which will be equivipotential in high range of frequencies.

The grounding system contributes to the mitigation of disturbances by serving as the return path for currents between a source of disturbances and electronic equipment, and also by acting as a ground reference for protective devices, for example filters, surge arresters and so on. Modern electronic equipment are much more sensitive to currents and voltages than those considered in the context of personnel safety.

If grounding system is to be effective, all aspects of its design and maintenance, from the measurement of the soil resistivity to periodical testing should be taken into consideration.

Much of the information available on the subject of grounding testing of sensitive electronic equipment is lacking in detail regarding high frequency measurements. Very little guidance is available on how to measure grounding impedance at high frequencies.

This paper presents a new method for accurate and quick measurement of the grounding systems of sensitive electronic equipment. A test method has been developed to verify bonding conductors, which connect electronic equipment ground to the signal reference grid.

The paper gives some helpful hits in field measurements gained from authors' experience over the last years. The paper describes a systematic approach of testing of electronic equipment grounding system and presents results at a selected station as an example.

Test Method

General Description

Measurements of newly installed grounding systems are required to confirm the design and the integrity of the system. In addition to the designing and testing of grounding systems at new stations to meet the requirements, the adequacy of the grounding system performance at existing stations, especially at very old stations where the grid design is unknown, need to be verified periodically. Periodic measurements throughout the life of the grounding system are necessary to ensure continued satisfactory performance.

Maintenance tests are carried out at regular intervals, for example every 5 to 6 years or after any major change of the grounding system. Periodic tests are essential to monitor the grounding system condition and can help to identify deterioration in integrity, for example due to corrosion, damage or theft. The tests are generally conducted with the stations in service and minimum disturbance to their operation.

Many publication outlining design guidelines [1]. However, the traditional approach based on the electromagnetic coupling does not give us a guide to test the grounding system, though the grounding system configuration is an essential factor to improve EMC immunity, because the noise current propagates into the sensitive circuits via the grounding conductors.

A consistent measurement procedure is necessary to achieve EMC immunity. Presently, there is no any test method, which can verify the integrity of the grounding system at high frequencies. Traditionally, measurements of grounding impedance are based on the frequencies up to about 200 Hz [2,3].

This paper describes a method to analyze the relationship between the grounding system configurations and EMC immunity by concentrating on ground impedance variations. The most important parameter to be measured in the test is the grounding impedance. Its usefulness as an indicator of integrity requires that the measurements are carried out in a consistent manner, and that variations in impedance as a result of other factors are minimized. One of these factors is electrical noise, which is present in all electrical installations.

Grounding System Model

In sensitive equipment installations grounding system provides a set of interconnected paths for currents, designed to have low transfer impedance in order to keep the interference voltages at the inputs of sensitive equipment low. Bonding conductors are used to connect ground bars to reference ground and provide signal grounding to sensitive electronic equipment. Figure 1 illustrates the grounding system model for a typical set of electronic equipment enclosed by a metallic frame.

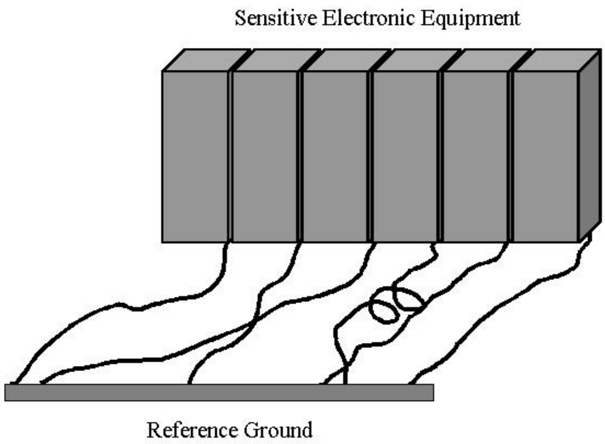

Figure 1. Bonding Conductors

At frequencies above a few hundred Hertz, inductive reactance is the major factor in determining the impedance of conductors. Resistance, including skin effect resistance is not a major factor. The total inductance is the sum of self-inductance determined by conductor size, shape and length, and mutual inductance determined by spacing and orientation of nearby conductive objects.

In order for the conductor to be effective as a bonding means, it is required to be maintained to lengths shorter than about 1/20 of the wavelength of the resonant frequency. This length restriction limits the voltage and current along the conductor to reasonable values most of the time.

Description of the Measurement Approach

The test checks the integrity of bonding conductors and associated joints between the signal reference grid and individual electronic items of installation. The theoretical principle of the test method is based on a comparison of the conductor impedance measured between any grounding system points with the value expected from the distance between the points.

The measured impedance can be compared to the previously recorded value for the bonding conductor of the same length. This is achieved using preliminary received in the laboratory condition reference set of impedance curves. A measured value significantly higher than the previously recorded one may indicate any problem, in which further investigation is necessary.

Measurements and Instrumentation

Figure 2 shows a typical measuring circuit. The measurement hardware consists of five major components: selective voltmeter, tracking generator, impedance bridge, personal computer and measuring leads.

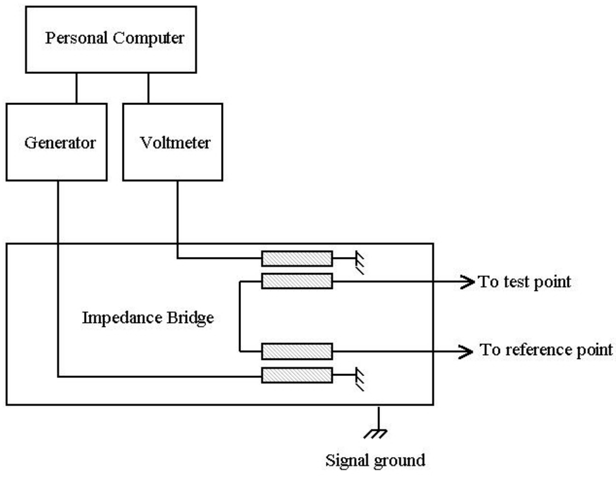

Figure 2. Measuring Circuit

The digital display is so calibrated that the impedance can be read directly. The test frequency is selected as 10 – 1000 kHz so that the all range of interest is covered. The bandwidth is typically 25 Hz allowing effective rejection of electromagnetic noise. The sampling period is about 10 s. The selective voltmeter provides an amplitude resolution of 0.1 dB in log scale or 1% in impedance linear scale. The output level of the tracking generator is +10 dBm. These parameters allow frequency response curves to be displayed and evaluated graphically.

Special software allows the measurement results to be displayed directly in ohms versus frequency. Normalization of the impedance bridge using a reference element, for example 100 ohms, detects all undesirable deviations and sets the display of the measurement receiver to the corresponding value. This normalizing level is used as the reference value for all subsequent impedance measurements. Validating test results is important as several factors can influence the accuracy of measurements.

The advantage of this method is that the bonding under test does not need to be disconnected from the signal reference grid. It provides a quick and simple test and avoid operational and safety issues associated with the disconnection of grounding components. This is especially important in some installations, for example substations and plants.

Grounding Tests at High Voltage Substations

Test and Measurement Procedure

Verification of the grounding system values was needed in view of the extensive grounding interconnections, especially due to uncertainties in the inductive and conductive components involved.

The test method, procedure and instrumentation were as explained in above sections. Measurements were performed under several test conditions involving various combinations of equipment under test and reference ground.

The results are then compared with the permissible limits received for the station in order to evaluate the adequacy of the grounding system performance.

Measured Results

The testing procedure has been successfully used at many IEC's substations and communication towers. Some stations are tested when problems occur or inspection reveals deterioration. Measurements were often needed to evaluate the adequacy of the station grounding system performance and verify design values.

The test data are analyzed in detail for measured results taking into account a distance between the test points. Tests at some stations have indicated that signal grounding of sensitive electronic equipment is connected to the signal reference grid by wound bonding conductors with large impedance.

Results obtained at one substation are presented as an example. Only two selected measured results received for different test conditions are presented here in figures 3 and 4 for simplicity. In these figures measured impedance curves are marked by a triangle and reference curves are bold.

Discussion of Results

Several experiments in high voltage substations up to 400 kV show the correctness of our approach. The measured results give grounding system performance for a wide frequency range.

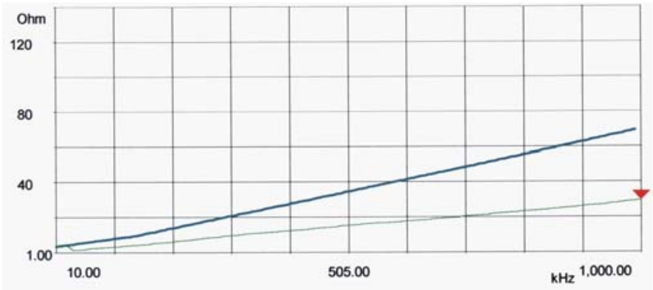

Figure 3. Measurement result for the proper bonding conductor

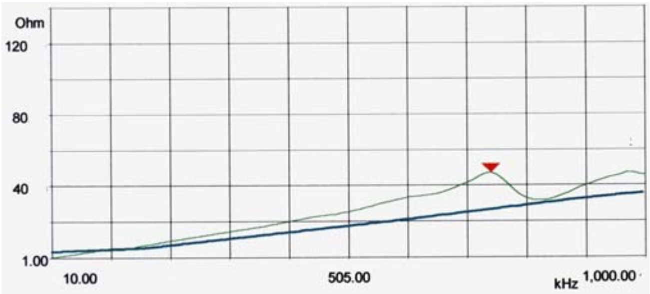

Figure 4. Measurement result for the wound bonding conductor

Although the comparison of a series of ground impedance measurements can provide a useful information on grounding integrity, there are a number of factors, which can influence the measured impedance and could misinterpreted as a loss of integrity. Coupling between test leads and other current carrying conductors was found playing an important role.

Conclusion

Extensive interconnections and possible uncertainties in a grounding installation sometimes make evaluation of grounding system performance difficult and necessitate field testing to evaluate the adequacy of the grounding system.

This paper describes a systematic approach of testing and evaluating grounding system performance at high frequencies. The test procedure and instrumentation presented here have proved adequate for all practical grounding system measurements.

The proposed method is very effective to analyze the dependency of ground conditions on EMC immunity and to improve EMC immunity in sensitive electronic equipment design. The method enables to carry out quick and accurate measurement of the grounding systems of sensitive electronic equipment.

References

[1] IEEE Recommended Practice for Powering and Grounding Electronic Equipment, IEEE Standard 1100-1999.

[2] IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System Part 1: Normal Measurements, IEEE Standard 81-1983.

[3] IEEE Guide for Measurement of Impedance and Safety Characteristics of Large, Extended or Interconnected Grounding Systems, IEEE Standard 81.2-1991