Ground Resistance Measurement Method Based on High-Frequency Pulses

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Keywords: Measuring Device, High-Frequency Pulses, Impact Ground Impedance.

Abstract: In recent years, many substations have expanded accidents due to lightning strikes, most of which are related to unqualified grounding resistance of the ground grid, so vigorously strengthening the regular monitoring of the ground resistance of the ground grid has become an important task. At present, the common use of high and low voltage and low frequency AC, high voltage low and high frequency AC, high and low voltage variable frequency AC, high and low voltage DC, etc. flows through the measured body, testing the ground resistance, impedance, the AC or DC used, the frequency is single, and the rising and falling edges are slow, and the ground impedance is inductive impedance, capacitive impedance or pure resistance impedance can not be well reflected. In order to solve the above problems, a grounding resistance test method based on low-voltage high-frequency pulse voltage is proposed.

1 INTRODUCTION

1.1 Brief Introduction

The grounding device of the generator, substation and transmission line is the fundamental guarantee and important measure to maintain the safe and reliable operation of the power system and ensure the safety of electrical equipment and personnel [Jianwei Guo, 2008]. The grounding device not only provides a common reference ground for various electrical equipment, but also can quickly disperse the fault current or lightning current in the event of a fault or lightning strike, limit the rise of the ground potential, and ensure the safety of people and equipment [Huadong Huang, 2013]. At present, many power grounding systems are limited by technical conditions, only pay attention to the measurement of power frequency characteristics, but with the gradual development of science and technology, the stability of the power system has been greatly improved, therefore, the main accidents at this stage are mainly caused by impulse current and lightning current. When the inrush current flows into the grounding device of the generator and substation, if the grounding resistance value of the ground grid is large, it will cause the potential of the ground grid to rise abnormally, causing the local potential difference of the grounding system itself to exceed the safe value [Guanghui Song, 2016]. At this time, the inductive component of the grounding grid cannot be ignored, and the real state of the grounding grid can not be well reflected by traditional measurement methods.

In order to better reflect the real state of the grounding grid, this paper proposes a high-frequency pulse digital grounding resistance tester. Using low-voltage high-frequency pulse voltage as the test power supply, that is, 20KHz, square wave voltage with a duty cycle of 50%, input to the ground point under test, the square wave current of 20KHz flows back to the tester through the far ground loop, by testing the peak voltage of the three-point square wave, the MCU calculates the grounding resistance of the ground point under test, at the same time, through the LCD display, the voltage waveform of the measured point is displayed, and the grounding resistance of the measured point is determined whether it is capacitive, inductive or purely resistive through the change of the rising edge and falling edge of the square wave; And observe the changes of the rising edge and falling edge of the square wave, and roughly determine the size of the stray inductance or stray capacitance.

Zhang, Y. and Zhang, H.
Ground Resistance Measurement Method Based on High-Frequency Pulses.
DOI: 10.5220/0012280300003807

In *Proceedings of the 2nd International Seminar on Artificial Intelligence, Networking and Information Technology (ANIT 2023)*, pages 253-256
ISBN: 978-989-758-677-4

1.2 Current Situation at Home and Abroad

At present, there are many ways to measure grounding resistance, such as the three-pole method, the four-pole method, and the frequency conversion method, and in lightning detection, the most commonly used method is the tripolar method measurement. However, because there are many influencing factors when measuring grounding resistance, such as grounding wire resistance value, grounding body own resistance, contact resistance between grounding body and soil, etc., traditional measurement methods can not well exclude the influence of the above factors, so the following measurement methods are proposed.

Power frequency high current method: the use of injected larger current, so that it can measure the depth deeper, but also the reverse method to eliminate the power frequency interference, can more accurately measure the resistance of the ground resistance. However, it is precisely because of the introduction of a large current that it means an increase in cost and is difficult to achieve.

Heterogeneous frequency method: this method uses alternating current, can well eliminate the interference of power frequency current in the earth, compared with the large current method, the implementation degree of this method is greatly improved, and the implementation cost is also reduced, but because the current is small, the depth of current penetration into the earth is also small.

Initially, voltammetry was used for ground impedance measurement, and the experiment was very primitive. In the fifties and sixties of the last century, the former Soviet Union's E-type shaker replaced the voltammetry, and the power supply was a hand-cranked generator. In the 70s, the domestic grounding impedance meter came out, and the ZC series (such as ZC-28, ZC-29) was better than the E-type shake meter in structure, measurement range, index value, and accuracy. However, due to the hand-cranked generator, the accuracy is not high. In the 80s, the digital ground impedance meter was put into use, and the stability was far higher than that of the shake meter pointer type. The birth of clamp resistance meters in the 90s of the last century broke the traditional test method. In recent years, due to the use of computer control technology, intelligent ground impedance measuring instruments have been produced, such as the Italian HT234. So far, there have been high-current measurement methods such as current and voltage method, interference compensation method, frequency differential beat method, difference frequency compensation method, quadrupole method, as well as anti-interference grounding shake meter, oscillator-frequency selection voltmeter method, spectrum analysis method, frequency conversion method and other small current measurement methods.

In order to suppress the interference of measurement, a method based on white noise was proposed earlier, but it was not applied due to the limitations of the measurement range and error. At the end of the 90s of last century, a method based on higher-order spectroscopy was proposed, and research was carried out from the theoretical and simulation aspects. In order to eliminate the error and interference when measuring ground impedance, in the 90s of last century, Chinese scientific and technological personnel successively proposed the double potential pole lead method, the additional series resistance method, the potential pole lead midpoint grounding method, the potential difference method, and in recent years, the multi-pole method was proposed. At the same time, foreign people have also proposed the direct current method, numerical calculation method, Berent compensation method, and the Jopa-Laidi method in the operating state.

2 TEST METHODS

2.1 Working Principle

The grounding resistance test principle, as shown in Figure 1, is the equivalent circuit for a high-frequency pulse tester to test the grounding resistance.

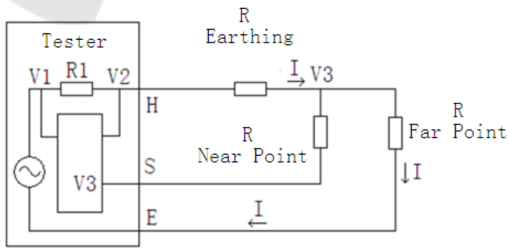

Figure 1: Tester Equivalent Circuit.

Among them, R1 is the current sampling resistance inside the tester, and H outputs a high-frequency square wave signal of 20KHz, which flows back into the tester through R grounding and R remote current loops.

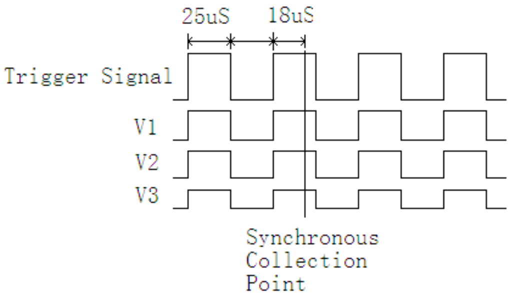

Figure 2: Test Principle.

Through the trigger signal rising edge trigger, delay 18uS, synchronously collect V1, V2, V3 voltage, and calculate the measured ground resistance value as follows.as shown in Figure 2.

$$I = \frac{V1 - V2}{R1}$$

$$R = \frac{V2 - V3}{I}$$

The delay is 18uS, synchronous acquisition, is the flat section of the acquisition at the high level of the square wave, which is equivalent to DC, so the measured resistance is DC resistance. Observe the V3 waveform, if the high level of the V3 waveform does not have a flat section, or the flat section is too short, it indicates that there is an inductance in the grounding system, and the measured ground resistance is not a pure resistance.

Through the change of the rising edge of the waveform of V3, it is possible to know whether there is an inductance in the grounding system, and inductance is the most important parameter affecting the shock response. When there is an inductance in the grounding system, the rising edge of V3's waveform slows down, as shown in Figures 3 and 4, the larger the inductance, the slower the rising edge of V3. Therefore, the response of the grounding system to the impact is judged, because the lightning signal, the harmonic component is many, and the

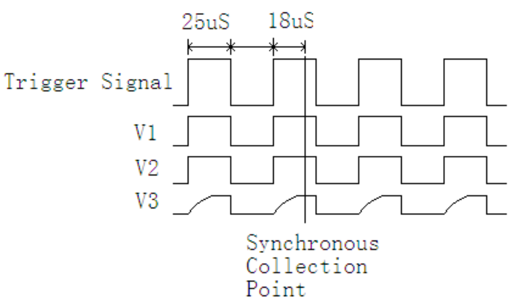

Figure 3: Grounding System Inductance 10uH.

frequency is high, and there is inductance on the grounding system, which has the greatest impact.

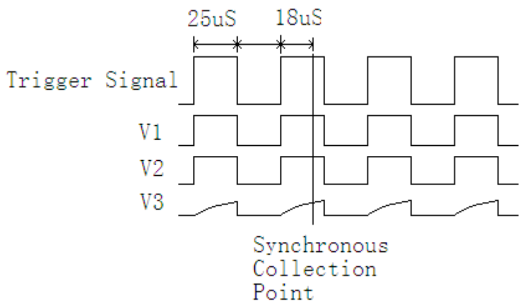

Figure 4: Grounding System Inductance 1mH.

Shock response testing of grounding systems requires a lightning current waveform with a steep wave head and a large amplitude, as well as extremely high voltages. Such devices are generally bulky and bulky, making them impractical in field testing. Through the rising edge change of the square wave signal of the high-frequency pulse tester, to observe whether there is inductance in the grounding system under test, you can roughly understand the impact response of the grounding system, without quantitative testing.

2.2 Results and Simulations

For multi-point grounding systems, the test grounding resistance can be unbroken by the grounding wire. For example, transmission towers, each tower must be grounded, and the top shielded wire between the tower and the tower, that is, the grounding wire, is equivalent to that each tower is connected to the ground. When testing the grounding resistance of a tower, existing testing techniques require untying the grounding wire. Using a high-frequency pulse grounding resistance tester, you can do without untying the wires. as shown in Figure 5. Transmission Tower Grounding Equivalent Circuit.

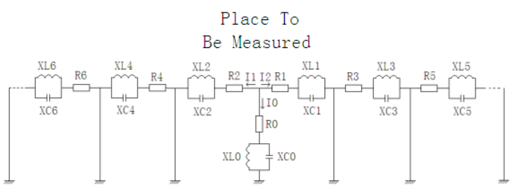

Figure 5: Transmission Tower Grounding Equivalent Circuit.

I0 is the current flowing through the ground resistance of the tower under test, and I1 and I2 are the current flowing through the parallel tower.

$$Z = R + jX$$

It can be seen that the inductive reactance is proportional to the frequency, and the capacitive reactance is inversely proportional to the frequency; Transmission line, taking model IJ-70 as an example, the unit length resistance is: 4.6*10^(-4)Ω/m, inductance is: L=1.27uH/m, capacitance is: 0.118uF/m.

The distance between the tower and the tower is calculated in 500 meters, 50Hz power frequency signal.

The inductive reactance is:

XL=2πfL=2*3.14*50*1.27*500*10^(-6)=0.2Ω;

The capacitive reactance is:

XC=1/2πFC=1/(2*3.14*50*0.118*500*10^(-6)) =53.98Ω

20KHz square wave signal

The inductive reactance is:

XL=2πfL=2*3.14*20*10^3*1.27*500*10^(-6)= 79.8Ω

The capacitive reactance is:

XC=1/2πFC=1/(2*3.14*20*10^3*0.118*500*10 ^(-6))=0.13Ω

Due to the existence of the grounding wire inductance, the impedance of the square wave signal of the 20KHz test is large, the current flowing through I1 and I2 is small, most of the current flows through I0, and the grounding of the parallel pole tower has little impact on the grounding resistance test of the tower under test and can be ignored, so the grounding wire can be solved when testing multi-point grounding.

REFERENCES

Jianwei Guo. Research and fault diagnosis analysis of grounding network of substation[D]. *Shanghai Jiao Tong University*, 2008.

Huadong Huang, An Jun. Operation and maintenance of electrical equipment and its grounding device[J]. *Science and Technology Communication*, 2013(19):2.

Guanghui Song. Research on unqualified analysis and treatment of grounding resistance of substation ground grid[J]. *Architectural Engineering Technology and Design*, 2016(24).

Baba Y, Ishii M. Numerical electromagnetic field analysis on measuring methods of tower surge impedance[J]. *IEEE Transactions on Power Delivery*, 1999, 14(2): 630-635

Ishii M, Baba Y. Numerical electromagnetic field analysis of tower surge response[J]. *IEEE Transactions on Power Delivery*, 1997, 12(1): 483-488