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Design and research of test platform for grounding device technology based on DSP builder

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Abstract. The grounding device is always an important problem to be solved in power network, which is directly related to the safety of people and equipment. However, the measurement of traditional grounding devices has the characteristics of instability and low reliability. Therefore, the design and research of the test platform for grounding devices based on DSP Builder was proposed in this paper. The working mechanism of grounding device was described, and the test platform of grounding device based on DSP Builder was constructed. Finally, through the test of the performance of the platform, it was concluded that the design of the platform for the grounding device based on DSP Builder is reasonable. In addition, the measured data has small difference from the actual values with good accuracy and stability.

Key words. DSP Builder, grounding device, technical test, platform design.

1. Introduction

With the continuous development of economy and science and technology, people's demand and demand for power systems are also increasing. The larger the scale of the grid, the greater the current required for ground short circuit, and the higher the grounding requirements. At the same time, the grounding is also closely related to the whole power system and the safety of people and equipment [1]. In the past power system, the power equipment was damaged because of the defects of the grounding device, which made the power plant shutdown or even serious accidents. As the complexity of the power system increasing, in order to avoid more unnecessary people and equipment property losses caused by serious accidents, the study of grounding device and grounding device testing has become the focus of research in recent years, which is of great significance.

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2. State of the art

At the beginning of people's understanding of the power grid, the measurement of the characteristic parameters of the grounding device was mainly to measure the ground resistance, and the experiment was carried out in the traditional way. An electrode was installed at a relatively far distance from the grid, and the result was the ground resistance by comparing the measurement of the auxiliary electrode resistance, the current and voltage at the two ends of the grid [2]. This traditional method was not only complicated, but also needed a lot of work. At the same time, the influence of the auxiliary electrode on the potential distribution was not considered in the process of measurement. Moreover, the auxiliary electrode was easily disturbed in the strong magnetic field and could not be effectively measured. With the development of technology, it was found that the measurement method of grounding device had many errors, and the reliability was low. Therefore, after 1960, people gradually accepted the principle of potential drop measurement. Up to now, the potential drop method can still be used in the ANSI/IEEE standard [3]. The method of potential drop measurement is the installation method of the auxiliary electrode, that is, the grounding body and the voltage potential drop curve are measured by changing the position of the constant voltage pole, and then the grounding resistance is obtained by analyzing the curve. In the same way, a lot of work is needed, and complex things such as potential drop curves are also needed. It is not easy to perform relevant operations at the scene [4]. Therefore, in the following research, some experts have proposed a relatively simple theory, in which the three-pole potential compensation method is one of the most widely used methods.

In order to reduce the interference of grounding resistance measurement, the related researchers have improved on the basis of the three-pole compensation method, and obtained a lot of advanced measurement methods, such as inverting method [5]. However, due to technical and environmental limitations, the final measurement results of these methods are inaccurate. Because the interference signal is uncertain in actual situations, the measured values are different. Therefore, in order to better remove the interference in the signal, it is necessary to ensure that the ground resistance has a more accurate measurement value [6]. Later, some scholars put forward the grounding resistance measurement method based on white noise, the phase compensation method, variable frequency and small current method.

3. Methodology

3.1. Grounding device technology and its basic principles

The grounding of the power system is to make the metal objects on the ground or some nodes in the circuit connect reliably through the wires and the earth, so that the potential of the metal objects or the nodes is consistent with the earth. In essence, in the case of normal, accident and lightning strikes, the power system can use the earth as a component of a ground current loop to hold the ground to the ground potential [7]. Therefore, the main function of grounding is to prevent damage to devices and lines in the power system when struck by lightning, and prevent electrostatic damage and personal electric shock, so as to ensure the normal operation of the power system and the personal safety [8]. According to the different purposes of electrical equipment, the grounding is divided into three kinds. The first is the protective grounding, which is mainly to protect the personal safety, avoid the damage of the insulation materials in the equipment and the risk of electric shock. The second is the working grounding, which is mainly to ensure the normal operation of the power system. The third is grounding for lightening, which is to drain the lightning into the earth to get rid of the dangerous voltage [9].

A hemispherical ground body and its potential distribution in a homogeneous soil are shown in Fig. 1. The resistance of the current to the earth after passing through the grounding body is the dispersion resistance. The contact resistance between ground and soil is much smaller than the dispersion resistance, so the grounding resistance is practically equal to the dispersion resistance [10].

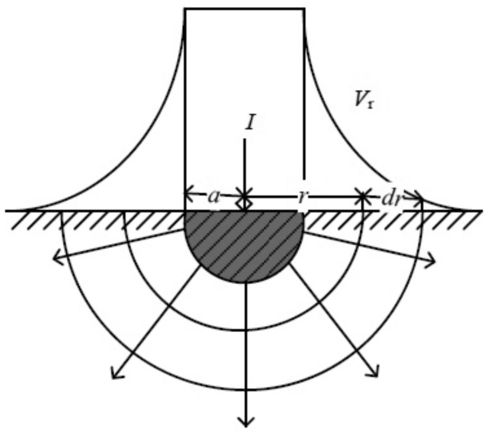

Fig. 1. Hemispherical ground body and its potential distribution in homogeneous soil

Let I be the current that from the earth electrode flows into the earth, and a is the radius of the grounding electrode. The earth is assumed to be homogeneous, and its resistivity is ρ. The current density in the soil with the center distance of r is J and the electric field corresponding to this is shown in the formula

$$E = J\rho = \frac{I\rho}{2\pi r^2} \tag{1}$$

As shown in formula (2), the resistance of hemispherical ground electrode from radius a to radius r is

$$R' = \frac{V_{ar}}{I} = \frac{\int_a^r E\,\mathrm{d}r}{I} = \int_a^r \frac{\rho\,\mathrm{d}r}{2\pi r^2} = \frac{\rho}{2\pi}\left(\frac{1}{a} - \frac{1}{r}\right) = \frac{\rho}{2\pi a}\left(1 - \frac{a}{r}\right). \tag{2}$$

When $r \to \infty$, there will be

$$R = R'_{\infty} = \frac{\rho}{2\pi a}\,.$$

3.2. Design and construction of technical test platform for grounding device based on DSP builder

In this article, the test platform for grounding device technology is designed and constructed mainly through the DSP Builder technology. Therefore, the test system for grounding device technology can achieve accurate measurement and tracking of the impact grounding resistance. In actual situation, better voltage and current signal acquisition requires the test system has a fast response speed and reliable stability. The hardware diagram of the test platform is shown in Fig. 2. As can be seen there , DSP is mainly the core of the system's control processing, including voltage divider, impact current generator, data acquisition, data preprocessing part, LCD display, keyboard and other peripheral circuits. The following describes the principle of grounding device test platform based on DSP Builder. First, after the measurement command is received by DSP, a trigger pulse is generated to control the impulse current generator, and an incident current injection grounding device is generated. The voltage divider and diverter will sample the response voltage signals and the current signals according to a certain proportion, and then send them to the AD converter after the signal conditioning to carry out the data acquisition of the two channels' signals. After the DSP's corresponding data processing and calculation, finally the operation results are displayed by the LCD.

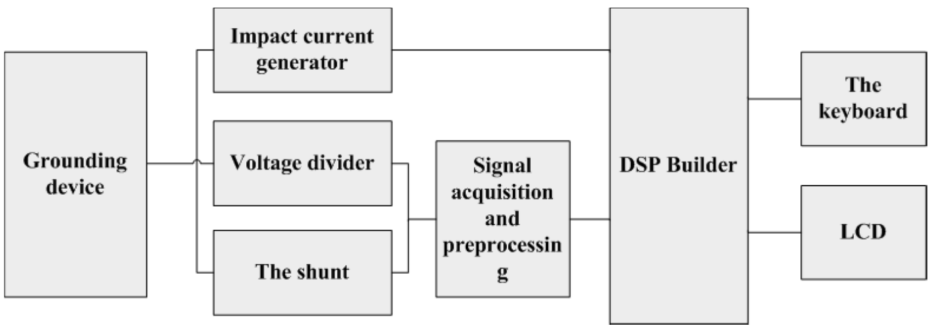

Fig. 2. Schematic diagram of test platform hardware

This paper is based on DSP Builder technology to carry out the design of testing platform for grounding device technology. The design based on DSP Builder is a fully up and down design process. Both the description of the platform system and the implementation of hardware can be completed in a complete design environment. The following is the design steps for DSP Builder. First of all, the design of the platform is mainly modeled by Simulink module and DSP Builder module. The main modeling environment is MATLAB/Simulink, and the corresponding parameters of each module are set. At the same time, through the Simulink platform, the system functions of the DSP system and the corresponding modules are simulated and verified.

Secondly, Signal Compiler module in DSP Builder toolbox is used to compile the model which has already been built in the platform. At the same time, the Simulink file is transformed into VHDL description code, and the TCL script is used for synthesis, emulation, and compiling. After we get the VHDL file, the system will provide two options, the automated process or the manual process. An automated process is a process that can almost ignore hardware. Quartus and other EDA software can be automatically called to complete adaptation such as synthesis and netlist generation, until the FPGA configuration is downloaded from MATLAB. The manual process is basically the same as the design process of EDA standards based on the VHDL, except for design input and behavior level simulation validation.

Finally, the hardware is simulated for the VHDL generated by the previous step, and the function simulation is done by automatically generating the TCL script and the simulation of the simulation incentive file. Download the configuration files generated by the Quartus II to the target device and form the required hardware system. In the experiment of test platform for grounding device technology based on DSP Builder, it is necessary to test and calculate the grounding resistance. The formula (3) shows the mathematical expression of the impulse current signal with double exponential wave in theory.

$$i\left(t\right) = I_{\mathrm{m}}\left(\mathrm{e}^{-\frac{t}{T_2}} - \mathrm{e}^{-\frac{t}{T_1}}\ ,\right) \tag{3}$$

where I_{m} represents the peak of the impact current, T_1 represents the time at which the theoretical wave head appears and T_2 represents the time at which the theoretical coda appears. From equation (3) we can see that the amplitude and steepness of impulse current waveform formed by different parameter values are different. The amplitude of standard lightning impulse current waveform adopted by this algorithm is 5000 A, and the time of wave head and wave tail is 2.6/50 μs.

According to formula (2), the maximum values of the corresponding impulse voltage $u_2'(n)$ and standard lightning current waveform sequence $i_2(n)$ that be found by the software. The theoretical impulse grounding resistance R_{ch}' is calculated as shown in equation

$$R_{\mathrm{ch}}' = \frac{u_{2m}'(n)}{i_{2m}(n)} \tag{4}$$

where, $u_{2\mathrm{m}}'(n)$ and $i_{2\mathrm{m}}(n)$ are the maximum values of $u_2'(n)$ and $i_2(n)$, respectively.

In addition to hardware design, the grounding technology test platform based on DSP Builder still needs to design the software. The management of system measurement and control, data collection and analysis are realized by corresponding software. According to the actual demands, TMS320F2812 DSP is adopted as the core of the measurement system. According to the characteristics of TMS320F2812 DSP and the existing problems, the high-level language C is used to do the corresponding software design, so as to improve the readability and portability of the program and reduce the difficulty of software programming. As a platform software program code to edit and debug software, Code Composer Studio 2.21 (CCS) provides program code editing tools, which has painting capabilities and real-time debugging capabilities. The following is the basic idea of the master program of the platform system, that is, after the initialization of the DSP system, all commands, states, and related storage units are restored to their initial state. Upon entering the test process, the DSP system issues a capacitor charging command that causes the pulse to trigger the thyristor of the current generator. In this way, the impulse current is simulated in the grounding device. Meanwhile, the AD switch is started to collect the voltage and current signals. After the AD conversion technology, the current and voltage data will be analyzed and judged. Then the corresponding calculation of voltage and current data is carried out by measuring and calculating program. Finally, the grounding resistance value is displayed on the display. This cycle goes into the next measurement calculation process of grounding resistance.

4. Result analysis and discussion

According to the above mentioned, the construction of the grounding device technology test platform based on DSP Builder has been carried out. In order to better test the performance of the platform, the measurement platform of grounding device based on DSP Builder is simulated. The generation of impulse current and the adjustment signal and the measurement and calculation of impulse grounding resistance are tested. Fig.3 shows the analog impulse current and voltage waveform. As can be seen from the diagram, the corresponding impulse voltage waveform is collected at channel 1, and the impulse current waveform is acquired by channel 2. As can be seen from the waveform diagram, the response of the voltage signal to the wave head and wave tail is about $8/59\,\mu s$, and the current signal's wave head and wave tail is about $12/59\,\mu s$. It shows that the simulated impulse current waveform in the platform is similar to that of the previous standard lightning impulse waveform. That is to say, the design of the test platform is in line with the requirements. Based on the comparison of the data and waveform, it can be seen that the time of the wave head of the voltage waveform is faster than that of the wave head in the current waveform, and the response voltage waveform is less smooth as that of the current. This is mainly due to the fact that the load ground model contains inductance components so that the current signal lags behind the voltage signal. At the same time, inductance exists in the load ground model, which has great influence on the current waveform. The larger the inductance is, the greater the influence of the current waveform is, and the longer the wave head time lags.

Table 1 shows the resistance values measured under different model parameter conditions. From the data in the table can be seen, the measured values of the resistance of test platform for grounding device technology based on the DSP Builder are relatively stable. Moreover, there is little error between the actual measured values and the theoretical values. This shows that the calculation and measurement algorithm based on the DSP Builder grounding device technology's test platform is correct, and the principles of the clipping algorithm are feasible to measure the impulse grounding resistance.

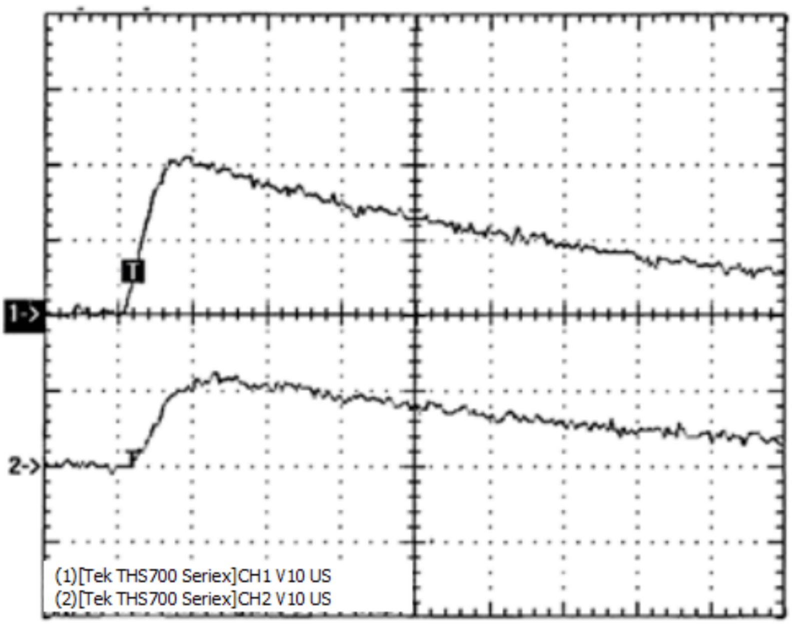

Fig. 3. Analog impulse current and voltage waveform

Table 1. Resistance values measured under different model parameters

R (Ω)	L (μH)	Measured impulse grounding resistance (Ω)			Calculated value (Ω)
49	125	18.08	18.21	17.95	16.25
25	125	14.2l	13.88	14.35	13.02
15	125	10.12	10.50	10.67	9.52
10	125	7.77	7.94	7.88	7.14
49	220	26.56	26.16	26.79	24.21
25	220	17.55	17.40	17.07	16.15
15	220	11.90	11.78	12.13	11.13
10	220	8.64	8.85	8.95	8.03
49	350	32.03	31.77	32.26	28.88
25	350	19.82	20.09	19.68	18.11
15	350	13.21 1	13.05	13.28	12.04
10	350	9.27	9.38	9.16	8.45

In summary, the experimental process of simulating shock current generation, conditioning signals, and calculating impulse grounding resistance shows that the design of test platform for grounding device technology based on DSP Builder is reasonable and feasible. It can capture the impact current and resistance signal and present the corresponding waveform more accurately. Compared with the previous testing technology, it has better stability and accuracy, and has higher practical value. However, there are some deficiencies in the test platform for grounding technology based on DSP Builder. For example, the hardware and software design of the platform's system needs to be further optimized, and more testing environments need to be considered. All of these need further research and improvement.

5. Conclusion

With the expansion of power grid scale, the requirement of docking device technology is increasing day by day. In order to better protect the safety of people and equipment, and avoid unnecessary accidents and property losses, the measurement of grounding device technology has become the focus of research in recent years. In this paper, the problems existing in the traditional grounding device and the mechanism of the grounding device were expounded. On the basis of grounding device mechanism and DSP Builder, the design and construction of the test platform for the grounding device technology were carried out. Finally, for the test platform for the grounding device technology based on DSP Builder, the simulated generation of impact current, conditioning signals as well as measurement and calculation of impulse ground resistance were tested. The results analysis shows that the simulated impulse current waveform in the platform is consistent with the previous standard lightning impulse waveform, that is, the design of the platform is reasonable. At the same time, the measured values of the resistance measurement based on DSP Builder grounding device test platform are relatively stable, and the errors between the actual measured values and the theoretical calculated values are not large. Therefore, the test platform measurement of grounding device technology based on DSP Builder is accurate and stable. However, there are still some problems in the design of the test platform for the grounding technology based on DSP Builder, which need further research and improvement.

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