

Research on Calibration Method of 7kV Single Voltage Pulse for IGBT Models Test System

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To cite this article:

Liu Chong, Li Jie, Kan Jingsong. Research on Calibration Method of 7kV Single Voltage Pulse for IGBT Models Test System. *American Journal of Physics and Applications*. Vol. 5, No. 6, 2017, pp. 91-94. doi: 10.11648/j.ajpa.20170506.13

Received: August 25, 2017; **Accepted:** September 27, 2017; **Published:** October 20, 2017

Abstract: Power IGBT module is widely used in high power conversion applications in various fields because of the advantages of high voltage and high current applications. In order to avoid the influence of temperature rise to the device measurement, pulse test method is widely used to test its static and dynamic parameters, So there are single high pulse voltage source and single pulse high current source in power IGBT modules test instruments. For now in the metrology field, how to calibrate its Single High Pulse Voltage source is a difficult problem. Now the amplitude of single high pulse voltage source is above 7kV with the pulse width as 50 microseconds. Based on detailed research on the test principles of the power IGBT modules test instruments, the pulse high voltage divider and the data acquisition unit are used to setup a calibration device for Single High Pulse Voltage source to calibrate the amplitude of Single High Pulse Voltage source. Resistors are used to develop the pulse high voltage divider, and did carefully research on the pulse response time, voltage dispersion, voltage regulation of the pulse high voltage divider. Also the data acquisition unit with 20MHz bandwidth and 100MS/s acquisition rate is evaluated through tests including vertical accuracy test, bandwidth test, rise time test, comparison test and etc.. Through above relevant test results, with the comprehensive consideration of the influence of each measurement uncertainty component, It has finished that the evaluation of the uncertainties of the amplitude measurement for Single High Pulse Voltage source. The uncertainty of measurement is better than 2% with the coverage factor as 2.

Keywords: Power IGB, Single High Pulse Voltage Source, Pulse Test Method, Calibrate

1. Introduction

Power IGBT modules, which are the typical representative of semiconductor devices with the characteristics of high voltage, high current, high speed, low voltage drop, high reliability and so on, are widely used in various of important occasions, such as the UPS power supply, the switching power supply, the chopper power supply, the AC motor control and inverter circuit and etc. Now the IGBT modules can be used in the applications of 7kV high voltage and 3kA high current, the companies that produced these modules include SIEMENS, Fairchild, Toshiba, IR, ABB, Fuji and so on. [2]

Power semiconductor devices test equipments are the main instruments to do the performance evaluation for Power IGBT modules before used. In China, some kinds of semiconductor devices test equipments are used in the company of power IGBT modules production and application, The typical

equipment are the series named TRDS produced by LEMSYS SA in Switzerland, and the typical model is TRDS4070 with flexible configuration for different application. The appearance of the typical model is shown in Figure 1. [5]



Figure 1. The appearance of the typical model TRDS.

The "Pulse test method" is widely used in these equipments, and the test principles and the composition in these equipments are very complicated. In China, there are a few companies that produce these devices test equipments, and the typical model is CESI1250A-3000 power semiconductor devices DC test system produced by China Electronics Standardization Institute which is also called CESI located in Beijing China. The appearance of the equipments is shown in Figure 2. [1]



Figure 2. The appearance of the typical model CESI1250A-3000.

2. Calibration of Single High Pulse Voltage for Semiconductor Devices Test Instruments

2.1. Calibration Status of Semiconductor Device Testing Equipment

Power semiconductor device test equipments are composed of the power supply, the computer control module, the pulse high voltage source, the pulse current source, the voltage measurement unit, the current measurement unit, the test adapter and so on. It can test the specific parameters of power IGBT modules under the test conditions specified in the technical documents followed the test principle of "FVMI" or "FIMV", that is force voltage measure current or force current measure voltage.

The Partial parameter method is used to calibrate Semiconductor Devices Test Instruments and now it is easier to fulfill the calibration on the test adaptors of the power supply, the computer control module, the pulse current source, the voltage measurement unit, the current measurement unit, and so on. It is a big challenge to calibrate the pulse high voltage source, because it has the characteristics of high pulse current, narrow pulse width and instantaneous single time. Commonly for the power semiconductor device test equipment, 50 micro seconds are often used as the pulse width for the high voltage single pulse. Above all, How to realize the calibration of the pulse high voltage source of the semiconductor devices test equipments is a big technical problem. [3] [6] [7]

2.2. Calibration Method of the Amplitude of Single High Pulse Voltage

The calibration for the pulsed high voltage source is

mainly carried out by using the calibration device which is set up by the pulse high voltage divider and the digitizer. Except as provided in the equipments documents, the calibration method shall be in conformity with the test principle of equipment measurement. The calibration principle to the Semiconductor Devices Test Instruments is shown as below Figure 3.

According to test principle of the internal measurement of the power semiconductor devices test equipments, the calibrating area should be the 1/3 to 2/3 part, that is between 20 micro seconds to 30 micro seconds when the pulse width of the pulse high voltage source is 50 micro seconds. The average value of the calibrating area should be the calibration result. When the calibration is carried out, the working mode of the semiconductor devices test equipments should be the FVMI mode. Thus the output of the internal high pulse voltage source is marked as V , and the ration of the pulse high voltage divider is marked as k . The digitizer can acquire all the data that going through the pulse high voltage divider. The average value of the calibrating area is calculated out and marked as V_1 , and the calibration value marked as V_0 is calculated out through (1).

$$V_0 = V_1 \times k \tag{1}$$

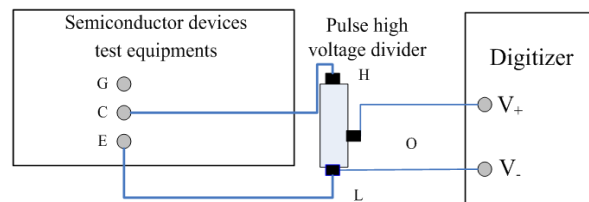


Figure 3. The calibration principle to the Semiconductor Devices Test Instruments.

2.3. Technical Requirements of the Pulse High Voltage Divider

Suitable Digitizer with proper specifications including bandwidth, amplitude measurement, response time and so on is selected to do the calibration, and the typical model is NI PXI 5122. But for the pulsed high voltage dividers, there are certain technical requirements in the time constant, technical specifications and dispersion characteristics. The detailed requirements include as followed.

Firstly, To reduce the influence of the pulsed high voltage divider on the calibration results, the Time Constant of the pulse high voltage divider should be controlled within 20µs because the calibrating area should be the 1/3 to 2/3 part, that is between 20 micro seconds to 30 micro seconds when the pulse width of the pulse high voltage source is 50 micro seconds.

Secondly, the Dispersion of pulse high voltage divider should be verified. The relative standard deviation of the voltage amplitude in the calibrating area from 20 micro seconds to 30 micro seconds should be considered as a component in the uncertainty evaluation. [8] [9]

Thirdly, to determine the Ratio Coefficient of the pulse high voltage divider. Under the specification calibration in

National Institute of Metrology China, 200 volts step wave source is used as the main metrology standard to determine the voltage ratio, and also the voltage coefficient of the pulse high voltage divider is given. [10]

Fourthly, Power demands for the pulse high voltage divider should be considered. The power of the pulse high voltage divider is controlled at least 10 Watts, which is 3 times more than the DC value 3 Watts. The typical DC state is 3000V simultaneously with 1 mA.

The Fifth point, to assess the Voltage Coefficients of pulse high voltage divider. Here different load conditions is setup to do these experiments. Through the test results, the voltage ration can be achieved under different load conditions.

2.4. Design and Processing of the Pulse High Voltage Divider

The thick-film process is chosen to processing according to the specification requirements for the pulse high voltage divider. As it is known, although use the thick-film resistors can efficiently controls internal inductance much better than other process, the wave response cannot be neglected for its high value in resistance. Now the response time of the thick-film processing can be controlled lower than 10 micro seconds with the proper technological conditions. Thus the measurement influence on the pulse voltage amplitude to the calibrating area from 20 micro seconds to 30 micro seconds can be negligible with 50 micro seconds pulse width.

The high voltage pulse divider box is developed through the thick-film process according the load conditions of the semiconductors devices test equipments. There are two pulse high voltage dividers in the box to calibrate the different pulse high voltage sources. If the pulse high voltage source provides 3kV voltage simultaneously with 0.1A to 0.5A current, the high voltage pulse divider with voltage ratio 200 is recommended. If the pulse high voltage source provides 7kV voltage simultaneously with less than 0.01A current, the high voltage pulse divider with voltage ratio 1000 is recommended. For all the two high voltage pulse dividers, the response time is less than 3 micro seconds and the specifications are better than 1%.

The appearance of the high voltage pulse divider box is shown as Figure 4.



Figure 4. the appearance of the high voltage pulse divider box.

3. Calibrating Results

Based on the calibration method of the amplitude of single high pulse voltage, using the pulse high voltage divider, the calibration system is setup to calibrate the 7kV Single Voltage Pulse source of the IGBT Models Test System. Calibrating results of the typical model TRDS4070 series is shown as Table 1.

Table 1. Calibrating Results.

Setting value	Calibrating results	Error	k	U
1kV	1004V	-4V	2	1.5%
2kV	2005V	-5V	2	1.5%
3kV	3007V	-7V	2	1.5%
4kV	4005V	-5V	2	1.5%
5kV	5006V	-6V	2	1.5%
6kV	6005V	-5V	2	1.5%
7kV	7007V	-7V	2	1.5%

4. Discussion About the Uncertainty Evaluation

Digitizer and The high voltage pulse divider box are used to calibrate the amplitude of specified calibrating area for the high pulse voltage source, so the type B and type A uncertainty factors should be considered. A lot of experiments have been done to evaluated the components of the uncertainties. The uncertainty evaluation result is shown as Table 2.

Table 2. Uncertainty Evaluation Result.

Factors	Description	Type	Distribution	k	Result
u_{B1}	The measurement uncertainty of digital meter	B	Uniformity	$\sqrt{3}$	0.18%
u_{B2}	The measurement uncertainty of the voltage ratio for the pulse high voltage divider	B	Normal	2	0.65%
u_{B3}	The temperature coefficient of pulse high voltage divider	B	Uniformity	$\sqrt{3}$	0
u_{B4}	The voltage coefficient of pulse high voltage divider	B	Uniformity	$\sqrt{3}$	0.03%
u_{B5}	The time instant of pulse high voltage divider	B	Uniformity	$\sqrt{3}$	0
u_{B6}	The dispersion from 20 micro seconds to 30 micro seconds of pulse high voltage divider	B	Uniformity	$\sqrt{3}$	0.11%
u_{A1}	The measurement repeatability and other random factors	A	/	/	0.06%

Through the experiments, all the components of the uncertainties are independently and not related, so the synthetic standard uncertainty can be calculated through Formula 2 as followed.

$$u_c = \sqrt{(u_{B1})^2 + (u_{B2})^2 + (u_{B3})^2 + (u_{B4})^2 + (u_{B5})^2 + (u_{B6})^2 + (u_{A1})^2} \quad (2)$$

And the synthetic standard uncertainty is 0.68% through

calculation. The ISO Guide to the Expression of Uncertainty in Measurement presented two methods to choose a coverage factor: the Welch-Satterthwaite formula method and a simpler approach. After related argument, the Extended uncertainty can be 1.4% with the coverage factor k as 2.

5. Conclusion

In this paper, calibration method of 7kV single voltage pulse for IGBT models test system have been proposed by using the proper digitizer and the pulse high voltage divider box. Based on the calibration method of the amplitude of single high pulse voltage, using the pulse high voltage divider, the calibration system is setup to calibrate the 7kV Single Voltage Pulse source of the IGBT Models Test System and the calibrating results of the typical model TRDS4070 series is also shown in this paper. Finally the uncertainty of the measurement is 1.4% with the coverage factor as 2. The calibration method proposed in this paper can be widely used to calibrate the single high voltage single pulse with micro seconds rise time, and also this method can be extended to nanosecond high voltage pulse measurement.

Acknowledgements

Thanks to the hard work of our team members on participating in the research, including senior engineers Yu Lihong, Chen Lianqi, Xu Yingchun, Zhang Yufeng, Xue Jianzhen, Wu Ying, etc.

Many thanks to Professors Shao Haiming, Huang Pan, Sun Zhi, Yao Xueling, Cao Yufeng, etc in the National Institute of Metrology in China, the Electrical Metrology Center for National Defense Science and Technology Industry, Wuhan High Voltage Research Institute, Xi'an Jiaotong University, Beijing Radio Instrument Factory that provided selfless technical helps to our work.

Finally, thanks to the Professors Kan Jinsong, Wang Wenfeng for their strong support for the process of the

research.

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