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Semiconductor converters - Electrical test methods

半导体变流器 电气试验方法

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Semiconductor converters- Electrical test methods

1 Scope

This standard specifies general electrical test methods for semiconductor converters.

This standard applies to various ordinary converters, including rectifiers, inverters, converters with both rectification and inverter operation modes, various power electronic switches. The dedicated converter can also use it as a reference.

This standard does not apply to converters for motor vehicles and onboard converters for aviation electrical appliances.

2 Normative references

The following documents are essential to the application of this document. For the dated documents, only the versions with the dates indicated are applicable to this document; for the undated documents, only the latest version (including all the amendments) are applicable to this standard.

GB/T 2900.33-2004 Electrotechnical terminology- Power electronics (IEC60050-551:1998 and IEC60050-551-20:2001, IDT)

GB/T 3859.1-2013 Semiconductor converters- General requirements and line commutated converters- Part 1-1: Specification of basic requirements (IEC 60146-1-1:2009, MOD)

GB/T 3859.2-2013 Semiconductor converters- General requirements and line commutated converters- Part 1-2: Application guide (IEC/TR 60146-1-2:2011, MOD)

GB/T 3859.4-2004 Semiconductor converter- Self-commutated semiconductor converters including direct d.c. converters (IEC 60146-2:1999, IDT)

GB/T 17626.2-2006 Electromagnetic compatibility (EMC)- Testing and measurement techniques- Electrostatic discharge immunity test (IEC 61000-4-2:2001, IDT)

GB/T 17626.4-2008 Electromagnetic compatibility- Testing and

3.9

Inherent direct voltage regulation

DC voltage adjustment value when it is free from the influence of AC system impedance.

[GB/T 2900.33-2004, definition 551-17-22]

3.10

Steady-state output voltage deviation

Under the specified maximum and minimum input voltage and specified maximum load and minimum load (light load), the maximum steady-state difference between the output voltage and the specified voltage.

3.11

Transient output voltage deviation

When the load changes (sudden increase or decrease), the difference between the maximum instantaneous value of the output voltage and the corresponding steady-state deviation.

3.12

Voltage recovery time

The time interval from the moment of sudden increase or sudden decrease of change (load or power supply voltage change, the two do not occur at the same time) to the start instant when the output voltage change reaches and remains within the specified steady-state deviation.

4 General requirements for test

4.1 Overview

This standard gives general electrical test methods for semiconductor converters, see Appendix B for test circuits. The division of specific electrical test methods and test types not given in this standard shall be specified in the product standard.

The results of all tests shall be determined in accordance with the provisions of the product standards.

Measuring position:

- Between circuits that are not electrically connected to each other;
- Between the circuit and the case.

The insulation resistance is only used as a reference for the insulation voltage test, not as an assessment.

5.1.2 Insulation voltage test

Under normal circumstances, follow the test in 7.2.2 of GB/T 3859.1-2013.

Converters using water cooling are generally tested without water.

When it is inconvenient to apply an AC test voltage, it may apply a DC test voltage equal to the peak value of the specified AC test voltage.

The time for the test voltage to rise from zero to its specified value shall not be less than 10 s, or from 50% of the specified value, each stage is, at 5% of the specified value, gradually increased to its specified value.

During the exit-factory test, if the test voltage is enough to rise to its specified value within 1 s, it is not necessary to increase the test voltage step by step.

5.1.3 Ground resistance measurement of accessible metal parts

It can be measured by direct measurement method.

Before measurement, the converter shall be disconnected from the power supply and load; clean up the contamination (if any) at the specified measurement point.

When measuring, the terminal of the meter is connected to the ground terminal and the case, respectively (or conductive metal parts that shall be grounded).

5.1.4 Light load test

Test procedure:

- Adjust the input voltage to reach the rated value (type test shall be performed at the maximum and minimum rated input voltage);
- Adjust the output voltage to reach the rated value (the load current can meet the test requirements);
- Check whether the display instrument, trigger device, protection device, cooling device and fault detection unit can work normally.

in ampere (A);

I_M - In each parallel valve device, the average current carried by the device carrying the largest current share, in ampere (A);

n_p - The number of parallel valve components.

5.1.7 Rated current test (low-voltage current test)

If it is more convenient, the load test under rated conditions can be used instead of this test.

Test procedure:

- Connect the input terminal of the converter to a power supply capable of generating a rated continuous current through a voltage regulator or a low-voltage converter transformer; the output terminal is directly short-circuited or short-circuited through a reactor;
- Adjust the voltage through a voltage regulator or phase control (if available) so that the output current reaches the rated value;
- Check the operation of each part of the converter.

During the test, the control devices (if any) and auxiliary devices are powered by an independent power supply at a rated voltage.

5.1.8 Load test

Test procedure:

- Adjust the input voltage and load current to reach the rated value;
- For converters with adjustable output, adjust the output voltage to reach the rated value;
- Check the operation of each part of the converter.

5.1.9 Temperature rise test

The test shall be carried out as far as possible under conditions equivalent to the specified load. The test can be performed simultaneously with the rated current test or the load test under rated conditions.

The temperature rise shall be measured under the harshest rated cooling conditions. If the test is carried out under the temperature lower than the specified maximum temperature, it shall be corrected.

The ambient temperature shall be measured during the last quarter of the test

- Measure the output voltage.

5.1.13 Overload test

The test is generally combined with temperature rise test and rated current test or load test.

Test procedure:

- Adjust the load current to reach the rated value;
- After the converter temperature reaches thermal equilibrium, increase the load current to the specified overload value;
- After the specified time interval, reduce the load current to the rated value. If it is carried out at the same time as the rated current test or load test, measure the output voltage according to 5.1.12;
- After overload, confirm that the measured parameters required by the temperature rise test, rated current test or load test are within the specified range; meanwhile the protection action and signal display meet the requirements.

5.1.14 Short circuit test

The test can be combined with light load test and functional test (see 7.3.1 in GB/T 3859.1-2013), rated current test or load test.

Test procedure:

- Adjust the input voltage and load current to reach the rated value;
- For a converter with adjustable output voltage, adjust the output voltage to reach the rated value and measure the current at the specified measuring point;
- Close the short-circuit switch or other short-circuit device; measure the current at the specified measuring point; check whether the fault circuit is cut off and the protection device operates normally;
- Replace the fuse or turn on the fast switch or circuit breaker; restart the converter. If it is carried out at the same time as the rated current test or load test, measure the output voltage according to 5.1.12;
- Confirm that the measurement parameters required by the rated current test or load test are within the specified range; the protection action and signal display meet the requirements.

I_N - The average value of the rated output current, in ampere (A).

5.2.5 Parallel test of rectifiers

The rectifier parallel test circuit is as shown in Figure B.4.

Test procedure (take two converters in parallel as an example):

- Adjust the input voltage of each rectifier to reach the rated value;
- For rectifiers with adjustable output voltage, adjust the output voltage to reach the rated value;
- Connect the public load, the load current shall not be less than 90% of the sum of the rated output current of the two converters;
- Measure the output current of each rectifier.

5.2.6 Measurement of inherent voltage adjustment value

It is determined by load test method or light load and rated current test method.

a) Load test method

It is determined in accordance with GB/T 3859.1-2013.

b) Light load and rated current test method

Measurement procedure:

- Determine the inductive voltage adjustment values d_{xt} and d_{xb} in accordance with 4.7 of GB/T 3859.2-2013;
- Consider the threshold voltage of the semiconductor device; calculate the inherent voltage adjustment value.

5.3 AC circuit electrical test

5.3.1 Determination of steady-state deviation of AC output voltage

It is determined by directly measuring the output voltage and then making calculation.

Measurement procedure:

- Adjust the input voltage and load current to reach the rated value; measure the output voltage U_o ;

calculation. For pulse width modulation or pulse width control converters, the method specified in the product standard can be used.

Measurement procedure:

- Adjust the input voltage and load current to reach the rated value; measure the output voltage U_o (when the setting value is adjustable, U_o shall be within the setting range);
- Step change the load current to the specified maximum value; measure the output voltage and load current;
- Step change the load current to the specified minimum value; measure the output voltage and load current;
- According to the transient voltage waveform (see Figure C.2), determine the transient deviation $+d_u$ and $-d_u$ of the AC output voltage and the voltage recovery time t_r ;
- Determine the transient deviation of the AC output voltage expressed as a percentage in accordance with 5.2.3.

If the product standard specifies otherwise, measure the output voltage and load current in accordance with the product standard.

5.3.4 Determination of AC output voltage variation range

It is determined by directly measuring the output voltage.

Measurement procedure:

- Adjust the input voltage and load current to reach the rated value;
- The output voltage regulator is placed at the maximum and minimum positions respectively; measure the corresponding output voltage;
- Take the maximum and minimum of the output voltage as the measurement result.

If the product standard specifies otherwise, measure the output voltage in accordance with the product standard.

5.3.5 Determination of the frequency of AC output voltage and its steady-state deviation

It is determined by the method of directly measuring the output voltage frequency and then making calculation.

output voltage and frequency in accordance with the product standard.

5.3.8 Harmonic measurement

5.3.8.1 AC output voltage harmonics

It is determined by directly measuring the root mean square value of the output harmonic components.

Measurement procedure:

- Adjust the input voltage and load current to reach the rated value; the output voltage shall be within the specified value range. Measure the root mean square value of the fundamental and harmonic components of the output voltage;
- Adjust the load current to reach the specified maximum and minimum values respectively; measure the corresponding root-mean-square value of the fundamental and harmonic components of the output voltage under the rated input voltage;
- Adjust the input voltage to reach the specified maximum and minimum values respectively; measure the corresponding root-mean-square values of the fundamental and harmonic components of the output voltage under the rated load current.

5.3.8.2 Current harmonics injected by the converter into the grid

It is determined by directly measuring the root mean square value of the current harmonic components at the input end of the converter. For rectifiers, it can also be determined in accordance with 6.3.1 of GB/T 3859.1-2013 on the basis of measuring inductive DC voltage.

Measurement procedure:

- Adjust the output voltage to reach the specified minimum value;
- Adjust the load current to reach the rated value; measure the root mean square value of the current harmonic components.

If necessary, measure the root-mean-square value of current harmonic components under light load.

5.3.9 Measurement of AC voltage distortion factor

5.3.9.1 AC output voltage distortion factor

Use direct measurement method to determine.

U_p - The positive sequence component of the output voltage.

5.3.11 Power factor measurement

It can be determined by load test method, light load test and rated current test.

During the test, the converter is connected to an AC power supply with a specified internal resistance.

a) Load test method

The power factor is determined by directly measuring the input parameters and then making calculation.

Measurement procedure:

- Adjust the input voltage and load current to reach the rated value;
- For converters with adjustable output voltage, adjust the output voltage to reach the rated value;
- Measure the input voltage U_A , U_B , U_C , the current I_A , I_B , I_C and the active power P_{in} at the input end of the converter;
- Calculate the power factor λ according to formula (29):

$$\lambda = P_{in} / (I_A \times U_A + I_B \times U_B + I_C \times U_C) \dots\dots\dots (29)$$

Where:

P_{in} - The input active power of the converter, in watts (W);

I_A , I_B , I_C - The phase current at the input of the converter, in amperes (A);

U_A , U_B , U_C - The phase voltage at the input of the converter, in volts (V).

b) Light load and rated current test method

When the light load and rated current test method is used to determine the power factor of the rectifier, the measured reactance or DC voltage adjustment value U_{dPN} and the magnetizing current of the transformer can be calculated according to 4.6 of GB/T 3859.2-2013.

The light load power loss's measurement can be combined with the light load test.

If feasible, the power loss shall be measured when the converter is rectified. The measurement procedure is as follows:

- See 5.1.4 for the light load test procedure. Connect a resistive load on the DC side. The current flowing through the converter shall not be lower than the transition current when the light load voltage of the converter starts to rise;
- Measure the input power;
- Measure the power consumed by auxiliary devices and triggering device (if any), as well as other power losses that do not depend on the load of the converter;
- Measure the output power. For converters with a pulse number of 6 and above, it is allowed to use a DC ammeter and a DC voltmeter to measure the output power, but it shall be explained, so as not to be confused with the DC power.

The light load power loss is equal to the measured input power of the converter minus the output power.

No-load power loss is equal to the input power at no-load.

A.3 Determination of short-circuit power loss

A.3.1 Uncontrolled rectifier

It is determined in accordance with 6.2 of GB/T 3859.2-2013.

A.3.2 Controllable converter

When the user and the manufacturer reach an agreement, or when there is no significant difference between the operating conditions of the controllable converter and the uncontrollable rectifier in terms of short-circuit loss. The short-circuit power loss can be determined in accordance with A.3.1.

During the test, the converter shall be short-circuited in the rectification state. The short circuit shall include an inductor, whose value is sufficient to make the ripple current superimposed on the DC current roughly equal to the expected ripple current under actual load conditions. Auxiliary devices and triggering devices are powered by independent power sources at rated voltage; the power they consume is not included in the short-circuit power loss.

If the short-circuit power loss is measured under specified operating conditions,

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