Chroma

PV Inverter (PCS) Test Guide

Version 1.0

Revision History

The following lists the additions, deletions and modifications in this manual at each revision.

Date	Version	Revised Sections
Sep. 2019	1.0	Completed Guide

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Preface

Regenerative energy sources such as solar and wind power often have unstable and intermittent power supply problems that affect the power grid stability. Setting up an ESS (Energy Storage System) can offset the difference problem among power generation, distribution and utilization. Besides reducing the impact of regenerative energy in grid connection and increasing the stability of power grid operation, it can also adjust the peak load to maintain the power supply balance. With its multiple applications and benefits, the ESS plays an important role in developing smart grid and microgrid, which can be used to balance the power load, steady the power supply, and stabilize the power quality.

ESS technology has already shifted from emergency demands to economic demands. The PCS (Power Conditioning System) is one of the most important pieces to further guide the technical development of energy storage systems to creating safe, highly efficient, and reliable products. Chroma has more than 33 years of experience in the field of power testing. Combining our extensive experience with the knowledge from other major power testing companies, we defined the PCS test specifications and created this comprehensive overview.

1. Scope

This test guide covers the terminologies, definitions, and test items of energy storage inverters' PCS.

2. Terminologies and Definitions

The following definitions and testing purposes are applicable throughout this test guide.

2.1 Energy Storage System (ESS)

In this guide, ESS refers to the equipment system that uses electrochemical battery as the energy storage carrier to store and release electric energy through a converter.

2.2 Power Conversion System (PCS)

In an electrochemical energy storage system, PCS is a device that is capable of bi-directionally converting electrical energy between a battery and a power grid (and/or load).

2.3 Converter Efficiency

A power converter's efficiency is the percentage ratio of output active power and input active power of that power conversion system. When the power grid saves battery power, the ratio of active power output on the DC side to active power input on the AC side is the rectification efficiency. When the battery releases power to the grid, the ratio of output power of the AC side to active power of the DC side is the inverter efficiency.

2.4 Grid Mode

Grid mode is the mode in which the power conversion system synchronously integrates into the AC grid and operates with current source characteristics to store the grid energy in the battery (charging mode) or to feedback the battery energy to the grid (discharging mode).

2.5 Islanded Mode

Islanded mode is the mode in which the power conversion system operates with voltage source characteristics and provides a power supply for the load connected to the AC side of energy storage system.

2.6 Transfer Time between Charge and Discharge

The transfer time between charge and discharge refers to the time required for the energy storage system to switch between the state of charge and the state of discharge. Generally, it regards the average transfer time required from the rated 90% charging power state to the rated 90% discharging power state and vice versa.

2.7 Stabilized Current Precision

Stability current precision is the ratio of output current maximum fluctuation to the value before set when the DC side output current of the power conversion system changes within the rated range in CC charging state.

$$\delta_I = \frac{I_M - I_Z}{I_Z} \times 100\%$$

δ_I: Stabilized current precision
I_M: Maximum fluctuation value of output current
I_Z: Output current setting

2.8 Stabilized Voltage Precision

Stability voltage precision is the ratio of output voltage maximum fluctuation to the value before set when the DC side output current of the power conversion system changes within the rated range and remains stability in CV charging state.

$$\delta_I = \frac{V_M - V_Z}{V_Z} \times 100\%$$

δ_V: Stabilized voltage precision
V_M: Maximum fluctuation value of output voltage
V_Z: Output voltage setting

2.9 Low Voltage Ride Through

When a power system incident or disturbance occurs and causes the grid point voltage to drop, the low voltage ride through (LVRT) function ensures that the power conversion system continues operation without going off-grid, within a certain voltage drop range and time interval.

2.10 Grid Simulator

The grid simulator is a controllable AC power supply with grid output characteristic simulation (and/or AC load characteristic simulation).

3. Test Specification, Method, and Purpose

3.1 PCS Performance Tests

3.1.1 Charge/Discharge Transfer Time Test

Test Specification:

The charge and discharge transfer time of the PCS should be t<100 ms.

Test Method:

1. Connect the circuit connection diagram as shown in Figure 3-1.

2. Make the PCS run in rated power charging state for at least 3 minutes.

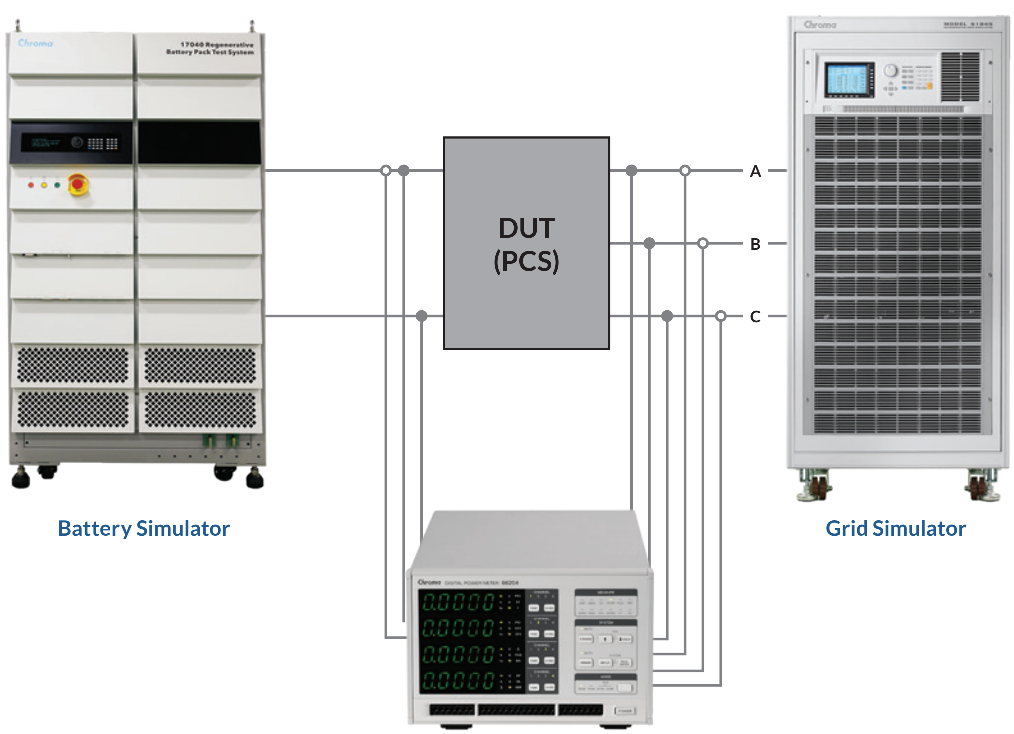
3. Send a rated power discharging command to the PCS, and measure the minimum time interval t1 of PCS when switching from 90% of power charging state to 90% rated discharging state.

4. Make the PCS run in rated discharging power state for at least 3 minutes.

5. Send rated power charging command to PCS, and measure the minimum time interval t2 of the PCS when switching from 90% of power discharging state to 90% rated charging state.

6. Calculate the average charge and discharge minimum transfer time t = (t1+t2) / 2.

Fig. 3-1 PCS Structure for Performance Test



Purpose and Impact:

It ensures that the PCS charge/discharge transfer time can react quickly when the grid load changes by reaching grid voltage regulation, peak clipping, valley fillling, in order to maintain power balance.

3.1.2 Active Grid Mode and Islanded Mode Switching Test

Test Specification:

Check whether the switching function of grid mode and islanded mode on PCS runs normal.

Note: This test is only applicable to a PCS that has both grid and islanded modes.

Test Method:

1. Set the load power to 100% of rated power for the PCS to be tested.

2. Adjust the PCS to the running conditions for on-grid mode.

3. When the PCS is running stably, send an off-grid command.

4. Make sure the PCS is switched to off-grid mode.

5. When the PCS is running stably, send an on-grid command.

6. Make sure the PCS is switched to on-grid mode.

7. Check the inductive and capacitive loads (PF = 0.8) via steps 1-6.

Purpose and Impact:

It confirms whether the grid mode and islanded mode switching function on the PCS operates normal.

3.1.3 Low Voltage Ride Through Capability

Test Specification:

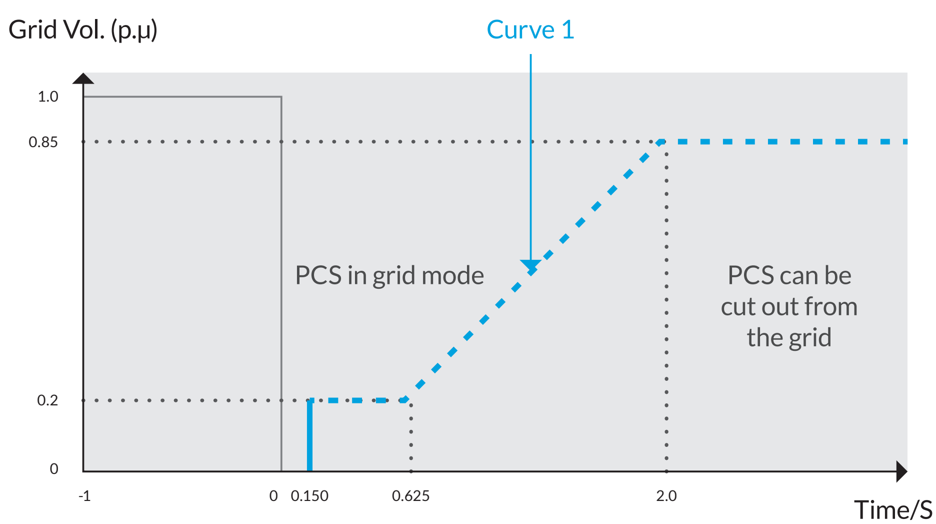
When the power system fails and the PCS grid voltage is still within or above the voltage outline area (as specified in Figure 3-2), the PCS should be able to run normally without switching to islanded mode.

1. When the PCS grid voltage point drops to 0V, the PCS system should be able to run normally for 0.15 second without switching to islanded mode.

2. When the PCS grid voltage point drops to beneath curve 1, the PCS can be cut off from the grid.

3. A PCS that is not cut off during power system failure should be able, after troubleshooting, to automatically and rapidly recover to the rated power before failure.

Fig. 3-2 Low Voltage Ride Through Testing Diagram



(Reference Source: GB/T 34120-2017)

Test Method:

Follow the low voltage ride through outline shown in Figure 3-2. Select at least 5 voltage drop points including the 0% V_n point and the 20% V_n point, and with the rest of them located in the following three areas: (20%-50%) V_n, (20%-50%) V_n and (50%-75%) V_n. Also select the mapping drop time.

V_n: The nominal voltage at the grid point when the PCS is running normally.

Purpose and Impact:

It validates the low voltage ride through capability of the PCS.

3.1.4 Power Grid Voltage Distortion Waveform Adaptability Test

Test Specification:

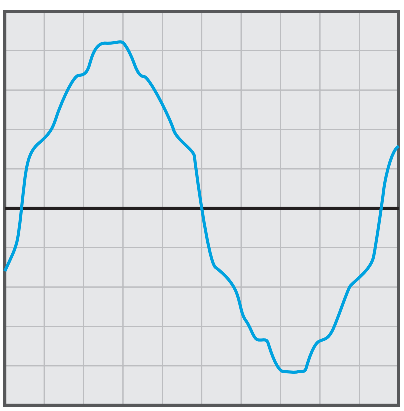
When the power system is having a voltage distortion, the PCS should be able to continue to run in grid mode.

Test Method:

1. Adjust the PCS to the running conditions in grid mode.

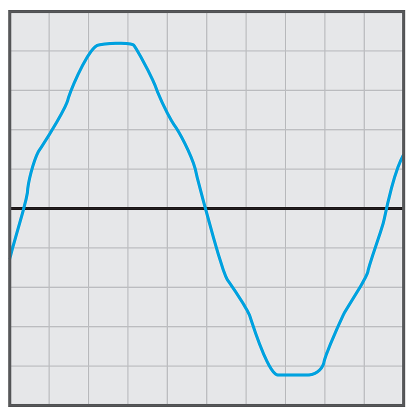
2. Follow the EN60204-1 standard to setup the power grid simulator for output voltage distortion waveform (or refer to Appendix B in Chroma 61800 User's Manual.)

Waveform A = DST 07



N	%	D
3	2.20	0
5	5.60	0
7	2.80	0
9	4.60	0
11	3.00	0
15	1.40	0
21	1.00	0

Waveform A = DST 16



N	%	D
5	2.45	0
7	3.95	0

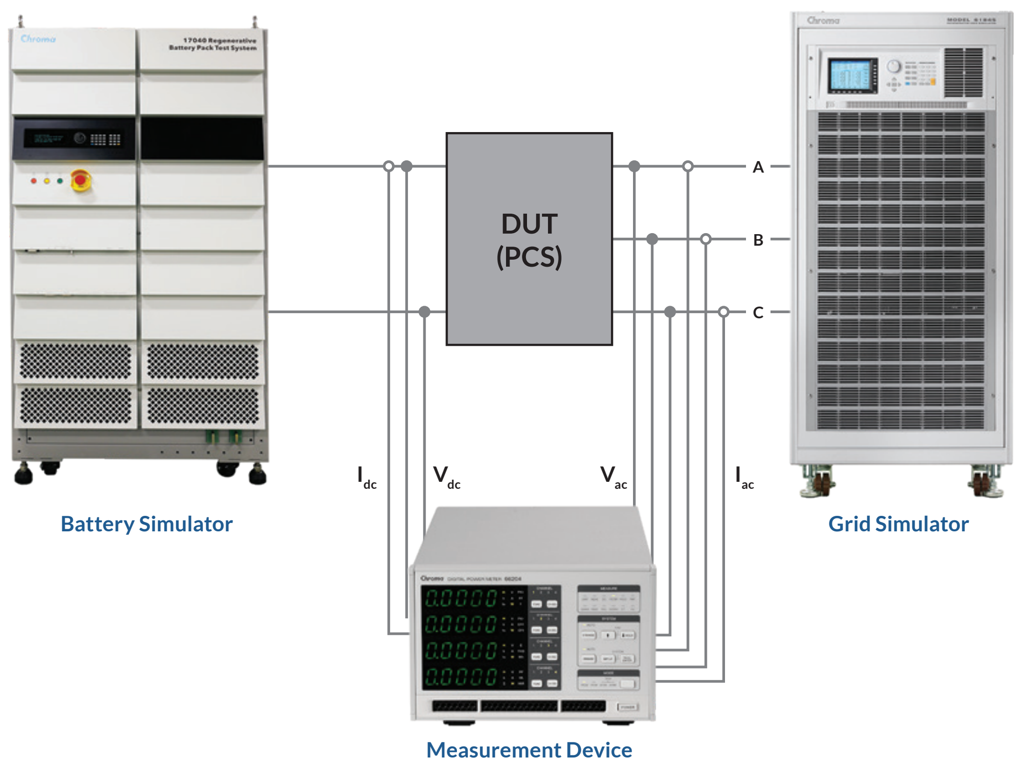
3.2 PCS Input and Output Characteristics Tests

3.2.1 Rectification Charging Efficiency Test

Test Specification:

The rectification charging efficiency of the PCS should be no less than 94% (without isolation transformer loss) when operating under the rated conditions.

Fig. 3-3 PCS Structure for Efficiency Test



Test Method:

1. Connect the rectification charging efficiency test circuit as shown in Figure 3-3.
2. Setup the PCS to grid mode and work in rectified charging state.
3. Adjust the DC side voltage of the PCS to the upper, middle, and lower limit respectively.
4. Adjust the battery simulator by the PCS rated charging power for loading every 10%.
5. Use a measurement device to record the active power on both the AC side and the DC side.
6. Use the following formula to calculate the PCS rectification charging efficiency:

$$\eta = \frac{P_{dc}}{P_{ac}} \times 100\%$$

3.2.2 PCS Efficiency Test in Grid Mode

Test Specification:

The PCS efficiency should be no less than 94% when operating under the rated conditions.

Test Method:

1. Connect the PCS for the efficiency test as shown in Figure 3-3.
2. Set the grid mode discharging state according to the PCS running mode and follow the steps below to test the efficiency.
3. Adjust the grid simulator output voltage to the PCS rated AC nominal voltage.
4. Enable the PCS to operate with output rated power.
5. Use a measurement device to record the active power on both the AC side and the DC side
6. Use the following formula to calculate the PCS discharging efficiency in grid mode:

$$\eta = \frac{P_{ac}}{P_{dc}} \times 100\%$$

3.2.3 PCS Efficiency Test in Islanded Mode

Test Specification:

The PCS efficiency should not be less than 94% when running in islanded mode under rated condition.

Note: This test is only applicable to a PCS that has both grid and islanded modes.

Test Method:

1. Connect the PCS for the efficiency test as shown in Figure 3-3.
2. Set the islanded mode according to the PCS running mode and follow the steps below to test the efficiency.
3. Set the grid simulator to AC load and adjust the load for PCS to operate with output rated power.
4. Use a measurement device to record the active power on both the AC side and the DC side.
5. Use the following formula to calculate the PCS discharging efficiency in islanded mode:

$$\eta = \frac{P_{ac}}{P_{dc}} \times 100\%$$

3.2.4 Standby Loss Test

Test Specification:

The standby loss of PCS should not exceed 0.5% of rated power (without isolation transformer loss).

Note: The standby state means that the PCS is warmed up and ready for use.

Test Method:

1. Connect the PCS for testing as shown in Figure 3-3.

2. Setup the PCS to standby state.

3. Measure the voltage and current on both the AC side and the DC side and use the following formula to calculate the standby loss:

$$P_{standby} = V_{ac} \times I_{ac} + V_{dc} \times I_{dc}$$

3.2.5 No-load Loss Test

Test Specification:

The no-load loss of PCS should not exceed 0.8% of rated power (without isolation transformer loss).

Note: The no-load state means that the PCS is in islanded mode without any load on it.

Test Method:

1. Connect the PCS for testing as shown in Figure 3-3.

2. Setup the PCS to no-load state.

3. Measure the voltage and current on both the AC side and the DC side and use the following formula to calculate the no-load loss:

$$P_{noload} = V_{dc} \times I_{dc}$$

3.2.6 Power Factor Test

Test Specification:

1. The average power factor should not be less than 0.98 when the output is larger than 50% of rated power for the PCS to run in grid mode.

2. The power factor should not be less than 0.95 when the power is 20%~50%.

Test Method:

1. Connect the PCS for testing as shown in Figure 3-3.

2. Setup the PCS to grid mode, and set the PCS output active power to 50% and 100% respectively.

3. Set the test time to 150S and record the power factor using a power measurement device.

3.2.7 DC Component Measurement

Test Specification:

When the PCS runs in grid mode under rated power, the DC component feeds to grid should not exceed the rated 0.5% or 5mA (whichever is larger).

Test Method:

1. Connect the PCS for testing as shown in Figure 3-3, and use the power analyzer to measure the DC component in the AC component.

2. Measure it for 5 times to get the average.

3.2.8 Stabilized Current Precision and Current Ripple during CC Charging

Test Specification:

When the PCS is in constant current charging mode, the stabilized current precision of output current should not exceed +/- 5% and the current ripple should not exceed 5%.

Test Method:

1. Connect the PCS for testing as shown in Figure 3-1 and setup the PCS to work in constant current charging mode.

2. Set the PCS DC side current consecutively to 100%, 50%, and 10% of rated current.

3. Adjust the battery simulator making the PCS DC side voltage to be within the maximum, middle, and minimum range. Each voltage should remain at least 10s.

4. Use an oscilloscope to record the DC current data during charging to get the DC maximum current fluctuation I_M.

5. Use the formula below to calculate the stabilized current precision.

6. Repeat step 1-3, and use an oscilloscope to measure the current ripple RMS and peak of DC side.

$$\delta_I = \frac{I_M - I_Z}{I_Z} \times 100\%$$

δ_I: Stabilized current precision
I_M: Maximum fluctuation value of output current
I_Z: Set value of output current

3.2.9 Stabilized Voltage Precision and Voltage Ripple during CV Charging

Test Specification:
When the PCS is in constant voltage charging mode, the stabilized voltage precision of output current should not exceed +/-2% and the voltage ripple should not exceed 2%.

Test Method:
1. Connect the PCS for testing as shown in Figure 3-1 and setup the PCS to work in constant voltage charging mode.

2. Set the PCS DC side voltage to the maximum, middle and minimum within the DC voltage range respectively.

3. Adjust the battery simulator to take steps with a step length of 20% rated current, going from 0% to 100% on the PCS DC side current. Each step length should remain 10s at least.

4. Use an oscilloscope to record the DC voltage data to get the DC maximum voltage fluctuation V_M.

5. Use the formula below to calculate the stabilized voltage precision.

6. Repeat step 1~3, and use an oscilloscope to measure the voltage ripple RMS and peak of DC side.

$$\delta_V = \frac{V_M - V_Z}{V_Z} \times 100\%$$

δ_V: Stabilized voltage precision
V_M: Maximum fluctuation value of output voltage
V_Z: Set value of output voltage

3.2.10 Current Harmonic Test in Grid Mode

Test Specification:
When the PCS runs in grid mode, the current total harmonic distortion rate is limited to 5% for AC side current to power grid. Table 3-1 lists the odd harmonic limits while Table 3-2 lists the even harmonic limits.

Table 3-1 Odd Current Harmonic Limits

Odd Harmonic Order	Harmonic Limit (%)
3rd~9th	4.0
11th~15th	2.0
17th~21st	1.5
23rd~33rd	0.6
35th and above	0.3

Table 3-2 Even Current Harmonic Limits

Even Harmonic Order	Harmonic Limit (%)
2nd~10th	1.0
12th~16th	0.5
18th~22nd	0.375
24th~34th	0.15
36th and above	0.075

(Referenced from China General Certification Center Technical Specifications CGC/GF004:2011)

Test Method:
1. Connect the PCS for testing as shown in Figure 3-1 and setup the PCS to work in grid mode.

2. Start from the minimum power under which the PCS can run normally. Set 10% of rated power as an interval on the PCS, and test 150 seconds for each interval. Use a power meter to read the current harmonic components consecutively and then use the ATS software to calculate the average.

3.2.11 Voltage Total Harmonic Distortion Test in Islanded Mode

Test Specification:

1. The PCS is working in islanded mode.

2. The PCS AC side output voltage total harmonic distortion should not exceed 3% under no-load and rated resistive load balancing condition.

Test Method:

1. Setup the PCS to work in islanded discharge mode.

2. Operate the PCS in no-load and rated resistive load respectively, and use a power meter to measure and read the voltage total harmonic distortion.

3.3 PCS Protection Characteristics Tests

3.3.1 Over Load Test in Grid Mode

Test Specification:

When the PCS AC side current is 110% of rated current, it should switch to islanded mode and stop running within 0.5 second. *(Reference source: SGSF-04-2012-07 7.2.6)*

Test Method:

1. Connect the PCS for testing as shown in Figure 3-1.

2. Set the PCS output over current protection to 90% or lower of the rated output current, set it to grid mode.

3. View the AC current waveform on the oscilloscope, and measure the time from the PCS rated output to stop running.

3.3.2 Over Load Test in Islanded Mode

Test Specification:

The PCS should continue to run >10 min when the AC side current is 110% of rated current and >1 min when in 120% of rated current.

Note: This test is only applicable to a PCS that has both grid and islanded modes.

Test Method:

1. Connect the PCS for testing as shown in Figure 3-1 and setup the PCS in islanded mode.

2. Set the grid simulator to AC load mode, and adjust the PCS load consecutively to 110% and 120% rated current.

3. View the AC current waveform on the oscilloscope, and measure the time from the PCS rated output to stop running.

3.3.3 Output Short Circuit Protection in Grid Mode

Test Specification:

The PCS should stop running with 0.5 second without damaging any part of it when the AC side detects a short circuit failure. *(Reference source: SGSF-04-2012-07 7.3.1)*

Test Method:

1. Connect the PCS for testing as shown in Figure 3-1.

2. Set the PCS to run in grid mode under the rated output specification.

3. Adjust the grid simulator output voltage to 0V in order to simulate the 0V output short circuit voltage on the PCS.

4. View the AC current waveform on the oscilloscope, and measure the time from the PCS rated output to stop running.

3.3.4 Frequency Adaptability Test

Test Specification:

The PCS allowed grid frequency range and required actions are shown in the table below.

Table 3-3 Frequency Response Time Requirements

PCS Mode	Frequency Range (Hz)	Required Action
Charge/Discharge Mode	49.55 ~ 50.15	Normal charge or discharge
Charge/Discharge Mode	48.05 ~ 49.54	Keep at least 4s, record PCS running status and operating time
Charge/Discharge Mode	50.16 ~ 50.45	Keep at least 4s, record PCS running status and operating time

Test Method:

1. Setup the PCS to run in charging and discharging state, adjust the output voltage frequency of the grid simulator to vary continuously in between 49.55Hz and 50.15Hz. The PCS should keep in grid mode.

2. Set the PCS to charging mode, adjust the grid simulator output voltage frequency to at least 3 frequency points for testing: 48.05Hz, 49.54Hz, and the middle of 48.05~49.54Hz. The PCS should keep running each time for 4 seconds at least.

3. Set the PCS to discharging mode and repeat step 2.

4. Set the PCS to discharging mode, adjust the grid simulator output voltage frequency to at least 3 frequency points for testing: 50.16Hz, 50.45Hz, and the middle of 50.16~50.45Hz. The PCS should keep running each time for 4 seconds at least.

5. Set the PCS to charging mode and repeat step 4.

Table 3-4 Frequency Adaptability Test Log Table

Set Frequency in Grid Mode (Hz)	Actual Measured Frequency in Grid Mode (Hz)	PCS Running Time (Sec.)	Specification (Sec.)
48.05			4s
48.05<___<49.45			4s
49.54			4s
49.55			Keep running
49.55<___<50.15			Keep running
50.15			Keep running
50.16			4s
50.16<___<50.45			4s
50.45			4s

(Source: GB/T 34133-2017)

3.3.5 AC Voltage Adaptability Test

Test Specification:

When the PCS is abnormal in grid mode, it should disconnect from the grid electricity. The power grid abnormal range and requirements of action response time are shown in the table below.

Table 3-5 Voltage Response Time Requirements

PCS Mode	Grid Mode Voltage (V)	Requirements
Charge/Discharge Mode	$V < 50\%V_n$	The maximum disconnection time does not exceed 0.2s.
Charge/Discharge Mode	$50\%V_n \le V < 85\% V_n$	The maximum disconnection time does not exceed 4s.
Charge/Discharge Mode	$85\%V_n \le V < 110\% V_n$	Continuous running
Charge/Discharge Mode	$110\%V_n \le V < 120\% V_n$	The maximum disconnection time does not exceed 4s.
Charge/Discharge Mode	$120\% V_n \le V$	The maximum disconnection time does not exceed 0.2s.

Test Method:

1. Setup the PCS to run consecutively in charging and discharging state, adjust the grid simulator output voltage to continuously vary in between 86%~109% of V_n. The PCS should stay in grid mode.

2. Setup the PCS to run consecutively in charging and discharging state, adjust the grid simulator output voltage to at least 3 voltage points for testing: 111% ~119% of V_n and 51% ~84% of V_n. The PCS should keep running each time for 4 seconds at least.

3. Setup the PCS to run consecutively in charging and discharging state, adjust the grid simulator output voltage points for testing: 49% of V_n and 121% of V_n. The PCS should keep running each time for 0.2 second at least.

Table 3-6 Voltage Adaptability Test Log Table

Set Voltage in Grid Mode (V)	Actual Measured Voltage in Grid Mode (V)	PCS Running Time (Sec.)	Specification (Sec.)
$49\% V_n$			0.2s
$51\% V_n$			4s
$51\%V_n$ <___<$84\% V_n$			4s
$84\% V_n$			4s
$86\%V_n$			Keep running
$86\%V_n$ <___<$109\% V_n$			Keep running
$109\% V_n$			Keep running
$111\% V_n$			4s
$111\% V_n$ <___<$119\% V_n$			4s
$119\% V_n$			4s
$121\% V_n$			0.2s

(Source: GB/T 34133-2017)

3.3.6 DC Side Over/Under Voltage Protection Test

Test Specification:
Perform the DC side over and under voltage protection tests according to the PCS manufacturer.

Test Method:
1. Connect the PCS for testing as shown in Figure 3-1.

2. Set the battery simulator voltage to the PCS DC rated voltage.

3. Setup the PCS to work in discharging mode and output rated power.

4. Adjust the battery simulator voltage up to the over voltage protection value for DC input.

5. View the DC voltage/current waveform on the oscilloscope and measure the DC over voltage value as well as the PCS protection time.

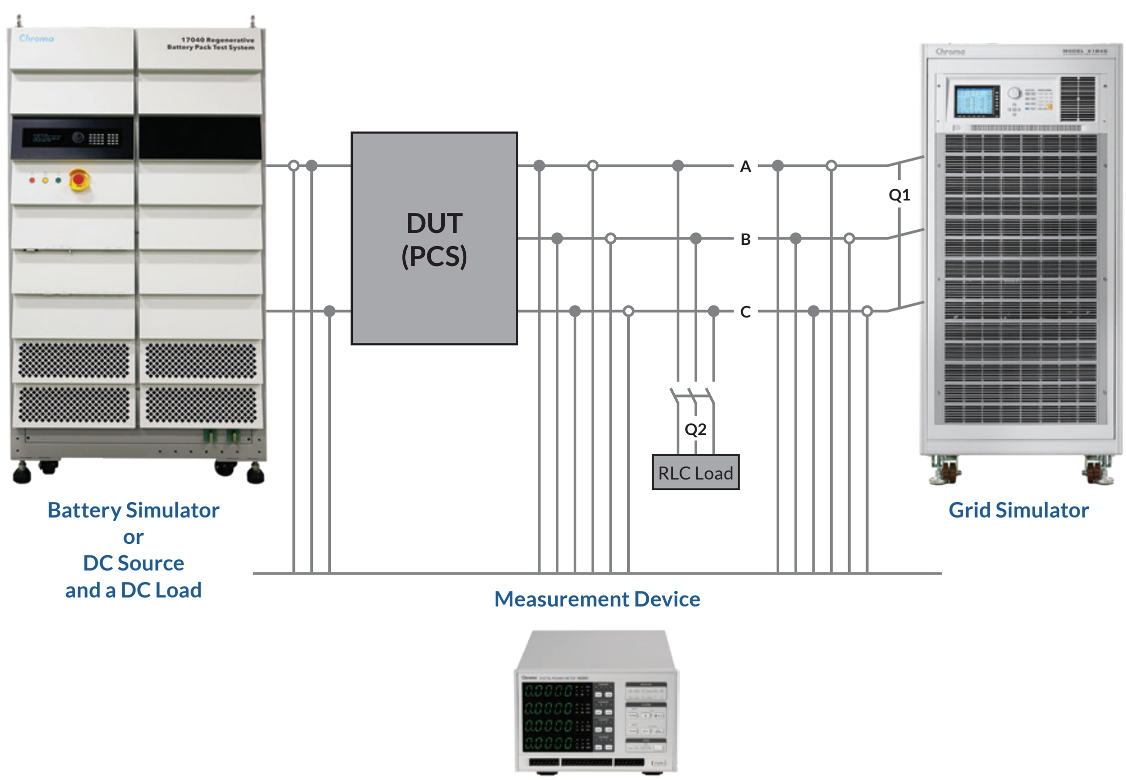
6. Repeat step 2-5 to perform a DC side under voltage protection test.

3.3.7 Anti-islanding Protection Test

Test Specification:
1. When the PCS is running in grid mode, it needs to be capable of islanding testing and immediate power grid disconnection. The anti-islanding protection time should be less than 2 seconds.

2. For the PCS with grid and islanded mode switching function, it should switch to islanded mode within 2 seconds and generate a stable AC voltage.

Fig. 3-4 Structure for Anti-islanding Protection Test



Test Method:

1. Close Q1, disconnect Q2 and start the PCS to run in grid mode. Adjust the battery simulator so that the PCS output power is (P_{EUT})= rated AC power, and measure the reactive power (Q_{EUT}).

2. Shutdown and disconnect Q1.

3. Use the following steps to adjust the RLC Load and make the Qf=1.0 ±0.05

3-1 $Q_L=Q_f*P_{EUT}=1.0*P_{EUT}$
3-2 Connect inductance to make the consumption reactive =Q_L
3-3 Merge capacitance to make the consumable capacity reactive: $Q_C+Q_L=-Q_{EUT}$
3-4 Merge resistance at last to make the consumption active =P_{EUT}

4. Close Q2, connect RLC Load, close Q1 and start the PLC. Make sure the output power is synchronized with step 1. Adjust the R, L, and C to output current until the Q1 current is <1%.

5. Disconnect Q1 and measure the time to when the output current reaches <1%.

6. Follow Table 3-7 to adjust the active load (R) and any reactive load (L & C) in the brackets. The simulated load does not match. A positive number indicates that the power goes from the PCS to the grid. Record each time that Q1 is disconnected and measure the time to when the output current reaches <1%.

Table 3-7 Conditions Table for Anti-islanding Protection Test

Item	PCS Output Power	Loaded Reactive	Active Deviation	Reactive Deviation
1	100%	100%	0	0
2	100%	100%	0	-5
3	100%	100%	0	+5
4	100%	100%	-5	-5
5	100%	100%	-5	0
6	100%	100%	-5	+5
7	100%	100%	+5	-5
8	100%	100%	+5	0
9	100%	100%	+5	+5
10	66% / 33%	66% / 33%	0	0
11	66% / 33%	66% / 33%	0	0
12	66% / 33%	66% / 33%	0	-5
13	66% / 33%	66% / 33%	0	-4
14	66% / 33%	66% / 33%	0	-3
15	66% / 33%	66% / 33%	0	-2
16	66% / 33%	66% / 33%	0	-1
17	66% / 33%	66% / 33%	0	1
18	66% / 33%	66% / 33%	0	2
19	66% / 33%	66% / 33%	0	3
20	66% / 33%	66% / 33%	0	4
21	66% / 33%	66% / 33%	0	5

(Source: GB/T 34133-2017)

3.3.8 Anti-Discharge Protection Test

Test Specification:

When the DC side voltage of the PCS is lower than the working range or is shutdown, there should be no reverse current flowing by.

Test Method:

1. Use a power meter to measure the current between DC input source and PCS.

2. Adjust the DC side voltage to make it lower than the operating voltage. The PCS must be turned off or in ready state with no current flowing by.

3.4 Photovoltaic (PV) Characteristics Tests

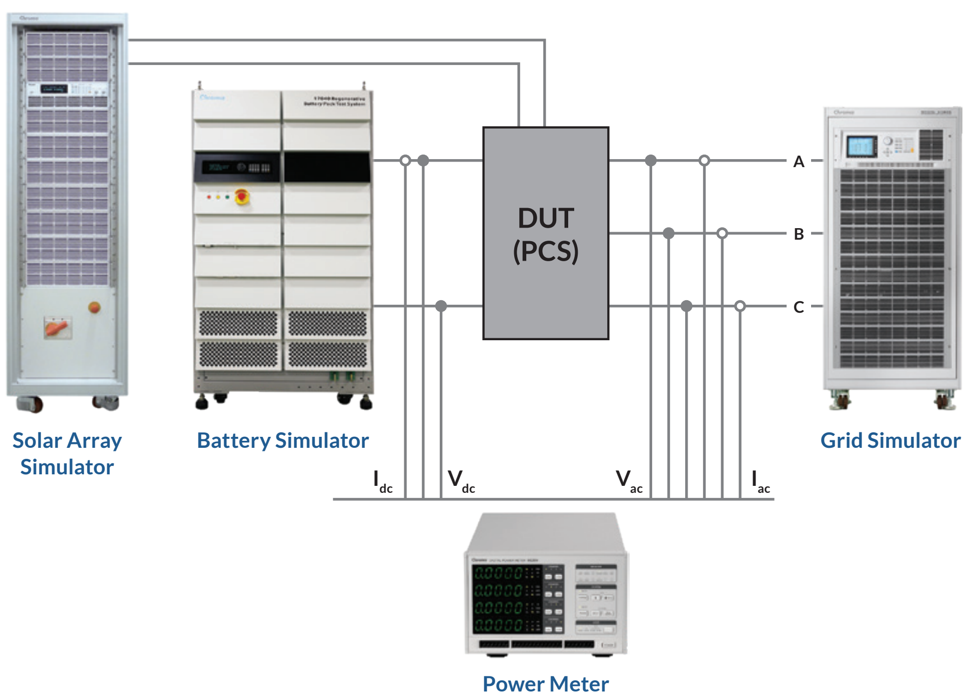
3.4.1 MPPT Efficiency Test

Test Specification:

1. This test is only applicable to a hybrid PV PCS with PV energy conversion.

2. The maximum power point tracking (MPPT) efficiency of PV PCS should be no less than 99%.

Fig. 3-5 Structure for PV PCS MPPT Efficiency Test



Test Method:

1. Use the solar array simulator to simulate the MPPT V/I curve following the PCS PV MPPT input voltage/current specification.

2. Read the measured power from power meter or SAS that is the PV PCS input power.

3. Divide the readings of step 2 by the SAS MPPT set value to get the MPPT efficiency.

3.4.2 PV Conversion Efficiency Test

Test Specification:

1. The conversion efficiency cannot be lower than the one listed in Table 3-8

2. Calculate the CEC and European efficiency following the power weight distribution formula in the table below.

Table 3-8 PV Inverter Conversion Efficiency

Item	AC Rated Power	Efficiency (η)
1	100%	97.4%
2	75%	98.27%
3	50%	98.8%
4	30%	98.67%
5	25%	98.4%
6	20%	97.5%
7	10%	93%
8	5%	84%

(Source: EN50530 Table E.2)

$$\eta_{CEC} = 0.04 \times \eta_{10\%} + 0.05 \times \eta_{20\%} + 0.12 \times \eta_{30\%} + 0.21 \times \eta_{50\%} + 0.53 \times \eta_{75\%} + 0.05 \times \eta_{100\%}$$

$$\eta_{EUR} = 0.03 \times \eta_{5\%} + 0.06 \times \eta_{10\%} + 0.13 \times \eta_{20\%} + 0.1 \times \eta_{30\%} + 0.48 \times \eta_{50\%} + 0.2 \times \eta_{100\%}$$

Test Method:

1. Set the PV PCS power input , following Table 3-8, consecutively at 5%, 10%, 20%,25%,30%, 50%,75%, and 100% to setup the solar array simulator test conditions. Then measure the inverter P_{AC_OUT}, $P_{SAS\_DC\_IN}$ and calculate the efficiency.

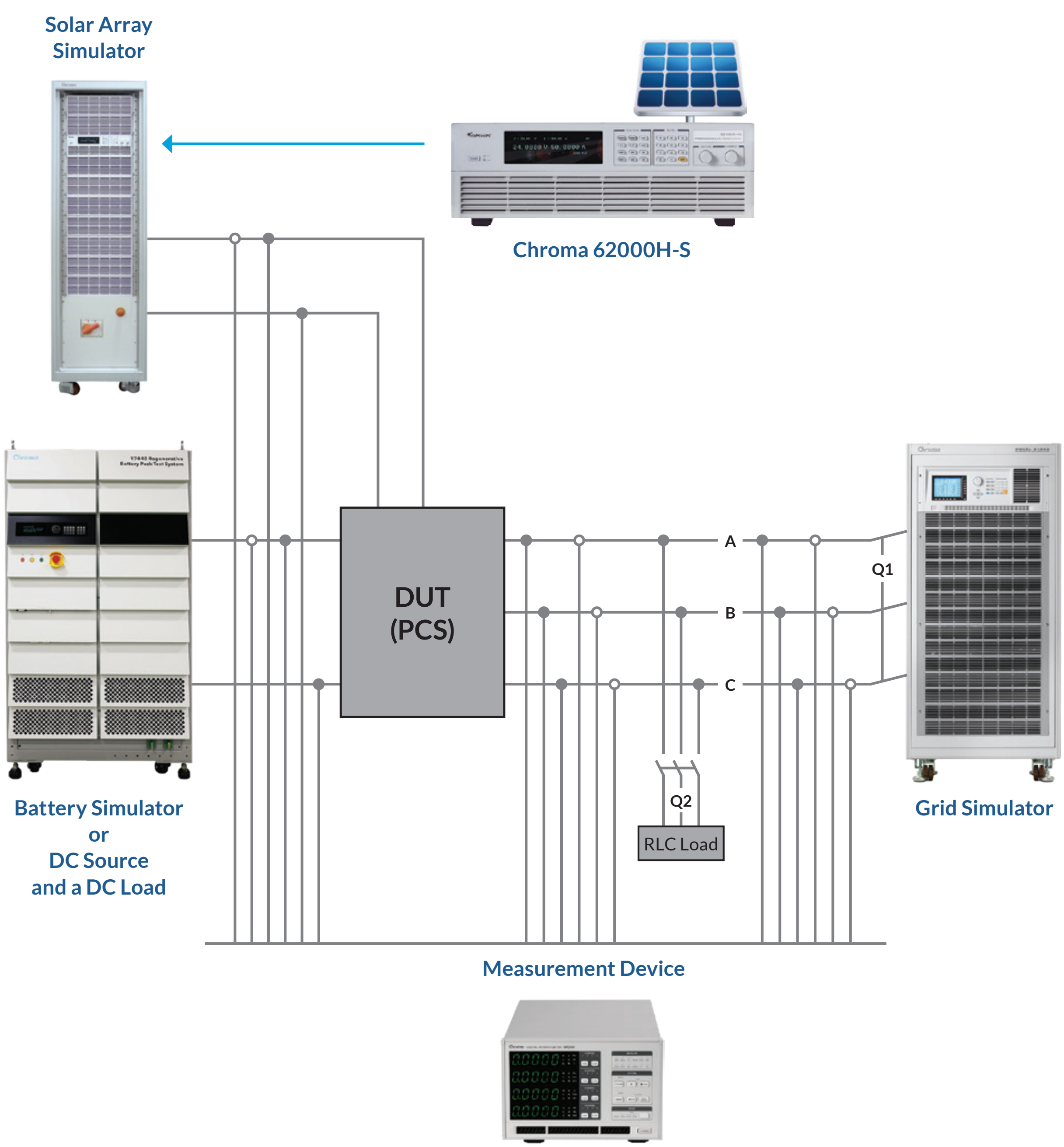
2. Calculate the CEC and European conversion efficiency following the above weight distribution formula.

4. Test Device Setup

The definitions and test purposes described below are applicable throughout this test guide.

4.1 Test Devices Configuration Diagram

The test equipment required for PCS testing mainly include Grid Simulator, Solar Array Simulator, multichannel Power Meter, Battery Simulator, Oscilloscope, and RLC Load.

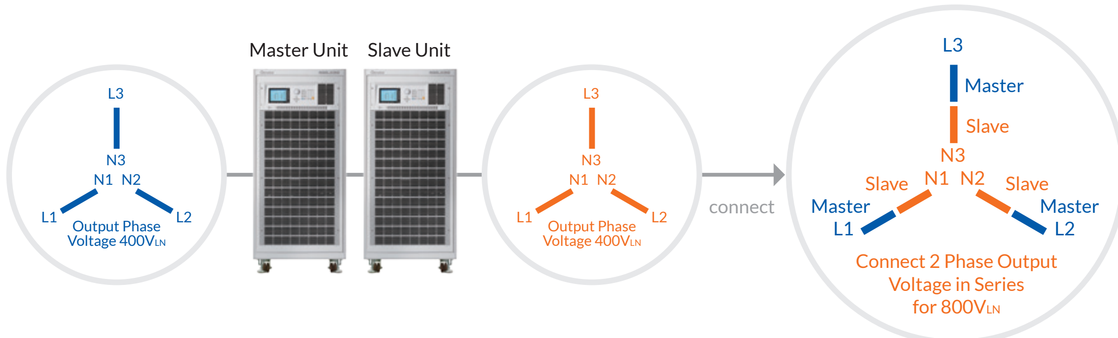


4.2 Recommended Instrument Functions and Specifications

Chroma 61800 Regenerative Grid Simulator

Functions

1. Fully regenerative up to 100% of output current rating
2. Regenerative AC load function (option)
3. Power line distortion waveform editing
4. 3-phase voltage drop and unbalance simulation
5. Voltage transient simulation that can simulate low voltage ride through (LVRT) test conditions of different regions
6. Embedded with harmonic synthesis function to simulate the voltage traceability of inverter for the grid voltage harmonic component
7. Expandable high voltage grid simulation solution to output voltage up to 1385V_{LL} (800V_{LN}) without using the step-up transformer.



Specifications	
AC Output Rating	
Output Phase	1 or 3 selectable
Power	30~300kVA
Voltage	
Range	0~300V_{LN}, HV: 400V_{LN} (option)
Resolution	0.1V
Accuracy	0.1%+0.2% F.S.
Distortion	<0.5% @ 50/60Hz <0.8% @ 30~100Hz
Line Regulation	0.1%
Load Regulation	0.2%
Maximum Current (1-Phase Mode)	
RMS	150~300A (for parallel mode only 3-phase output is supported)
Maximum Current (each phase in 3-Phase Mode)	
RMS	50~500A
Frequency	
Range	DC, 30~100Hz
Accuracy	0.01%

Chroma 62000H-S (Solar Array Simulator)

Functions

1. Solar array I-V simulation function with built-in EN50530 & Sandia I-V curve mathematic forms
2. Able to simulate various solar cell output characteristics (fill factor)
3. Able to simulate I-V curve of different temperature and different illuminance
4. Able to simulate I-V curve under solar panel mask
5. Able to test Static & Dynamic MPPT efficiency
6. Equipped with EN50530, Sandia, CGC/GF004, CGC/GF035, and NB/T 32004 dynamic MPPT test procedures

Specifications

Power	
Range	15KW up to 1500KW (10 racks), 18KW up to 720KW (40 units)
Voltage	
Range	600V, 1000V, 1800V
Output Ripple	650~1950mV
Voltage Measurement Accuracy	0.05% + 0.05% F.S.
Current Measurement Accuracy	0.1% + 0.1% F.S.
Line Regulation	Voltage 0.01% F.S. Current 0.05% F.S.
Load Regulation	Voltage 0.05% F.S. Current 0.1%~0.2 F.S.

Chroma 66200 Digital Power Meter

Functions

Able to measure the following:

1. Vrms
2. Vpk
3. Irms
4. Power, W
5. Apparent Power, VA
6. VAR
7. Power Factor, PF
8. Crest Factor of Current, CF_I
9. Frequency
10. Total Harmonic Distortion of Voltage, THD_V
11. Total Harmonic Distortion of Current, THD_I
12. Energy

Specifications

Voltage	
Range	15/30/60/150/300/600Vrms (CF=2)
Accuracy	DC, 10 to 1kHz 0.1% of reading + 0.08% of range 1k to 10kHz (0.1+0.05×kHz)% of reading + 0.08% of range
Input Resistance	2MΩ
Current	
Range	5mA/20mA/50mA/200mA/500mA/2A/5A/20Arms (CF=4)
Accuracy	DC, 10 to 1kHz 0.1% of reading + 0.1% of range 1k to 10kHz (0.1+0.05×kHz)% of reading + 0.1% of range

Chroma 66200 Digital Power Meter (*Continued*)	
Power	
Range(W)=Vrms×Irms	75mW ~ 12kW
Accuracy	DC, 47~63Hz: 0.1% of reading + 0.1% of range
Power Factor Accuracy	0.001+(15ppm/PF)×Hz
Range	DC, 10Hz ~ 10kHz
Condition	Voltage (10~100% of the voltage range)
Others	
Display Resolution	5 Digits
Refresh Rate	0.25 ~ 2 sec
Operating Temperature	0~40°C
Storage Temperature	-40~85°C

Chroma 17040 Regenerative Battery Pack Test System (Battery Simulator)

Why is the battery analog power supply required?

1. Different battery types such as sodium-sulfur battery, lithium battery, etc. have different charge and discharge characteristics, making it difficult to have them all available at the same time.
2. Battery nonlinear characteristics are temperature, charging/discharging speed, aging level, and efficiency.
3. Charging or discharging a battery requires time, which makes it challenging to test the limits of power converter.
4. Large-capacity batteries take up a large space and could be damaged or become hazardous when aging, making them inconvenient for some types of labs.

Specifications	
Power Range	60~300KW
Voltage	80~500V, 80~750V, 80~1000V
Current	150~750A
CV Mode	
Voltage Range	80~500V, 80~750V, 80~1000V
Resolution	10~20mV
Accuracy	0.1% F.S.
CP Mode	
Resolution	100mW~1W
Accuracy	0.2% F.S.
Battery Simulator Mode	
Voltage Range	80~500V, 80~750V, 80~1000V
Voltage Accuracy	0.1% F.S.
Voltage Ripple (rms)	< 1% F.S.

5. Reference Documents

This technical file is completed with reference to the following documents:

1. SGSF-04-2012-07: General Performance requirements of PCS (Power Conditioning System) for energy storage systems
2. GB/T 34120-2017: Technical specification for power conversion system of electrochemical energy storage system
3. GB/T 34133-2017: Testing code for power converter of electrochemical energy storage system
4. IEC62933-2-1 2017-12: Electrical Energy Storage(EES) Systems-
5. Part 2-1: Unit parameters and testing methods – General specification
6. China General Certification Center - Technical Specification of Grid-connected PV Inverter
7. CGC/GF004 Technical Specification of Grid-Connected PV inverter
8. BS EN 50530:2010+A1:2013