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Test specification for electrochemical energy storage system connected to power grid

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1 Scope

This Standard specifies the test conditions, test equipment, test items and methods for electrochemical energy storage system connected to power grid.

This Standard is applicable to electrochemical energy storage systems with a rated power of 100 kW and above and an energy storage time of not less than 15 min. It also applies – as a reference – to the implementation of electrochemical energy storage systems of other power levels and energy storage time.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies to this document. For undated references, the latest edition (including any amendment) applies to this document.

GB/T 12326, Power quality - Voltage fluctuation and flicker

GB/T 12706.1, Power cables with extruded insulation and their accessories for rated voltages from 1 kV (U_m = 1.2 kV) up to 35 kV (U_m = 40.5 kV) - Part 1: Cables for rated voltage of 1 kV (U_m = 1.2 kV) and 3 kV (U_m = 3.6 kV)

GB/T 12706.2, Power cables with extruded insulation and their accessories for rated voltages from 1 kV (U_m = 1.2 kV) up to 35 kV (U_m = 40.5 kV) - Part 2: Cables for rated voltages from 6 kV (U_m = 7.2 kV) up to 30 kV (U_m = 36 kV)

GB/T 13729, Remote terminal unit equipment

GB/T 14549, Quality of electric energy supply - Harmonics in public supply network

GB/T 15543, Power quality - Three-phase voltage

GB/T 21431, Technical code for inspection of lightning protection system in building

GB/T 24337, Power quality - Interharmonics in public supply network

GB/T 36547, Technical rule for electrochemical energy storage system connected to power grid

4 General principles

4.1 Before the test, a test plan shall be prepared, and corresponding safety measures shall be formulated.

4.2 The equipment of the electrochemical energy storage system can be connected to the power grid for on-site test only after the on-site debugging is completed.

4.3 The test contents of the electrochemical energy storage system include: power grid adaptability test (including frequency adaptability test, voltage adaptability test and power quality adaptability test), power control test, overload capacity test, power quality test, protection function test, charge-discharge response time test, charge-discharge adjustment time test, charge-discharge conversion time test, rated energy test, energy conversion efficiency test, etc.; the electrochemical energy storage system connected to power grid through voltage levels of 10 (6) kV and above shall also be subjected to low voltage ride through test, high voltage ride through test and communication test, etc.

4.4 During the power grid adaptability test, simulated power grid devices should be adopted for the test; during the low voltage ride through test and high voltage ride through test, power grid fault simulation devices should be used.

4.5 The test results shall meet GB/T 36547 or other relevant requirements, and a corresponding test report shall be formed.

5 Test conditions

5.1 Environmental conditions

The energy storage system shall be tested under the following environmental conditions:

a) Ambient temperature: 5 °C ~ 40 °C;

b) Ambient humidity: 15% ~ 90%;

c) Atmospheric pressure: 86 kPa ~ 106 kPa.

5.2 Basic conditions

The energy storage system shall meet the following requirements before it is connected to power grid for test:

a) The lightning protection grounding device of the energy storage system shall meet the requirements in GB/T 21431, GB 50057 and DL/T 621;

c) During the test, the steady-state voltage variation range shall not exceed 1% of the nominal voltage;

d) The voltage deviation shall be less than 0.2% of the nominal voltage;

e) The frequency deviation shall be less than 0.01 Hz;

f) The three-phase voltage unbalance shall be less than 1%, and phase deviation shall be less than 3°;

g) For a simulated power grid device whose neutral point is not grounded, the neutral point displacement voltage shall be less than 1% of the phase voltage;

h) The rated power (P_N, the same below) shall be greater than the rated power of the electrochemical energy storage system to be tested;

i) It shall be provided with the ability to adjust ±0.1% of the rated frequency f_N within one cycle;

j) It shall be provided with the ability to adjust ±1% of the rated voltage U_N within one cycle;

k) The step response adjustment time shall be less than 20 ms.

6.3 Performance of the power grid fault simulation device for testing

The power grid fault simulation device shall meet the following technical requirements:

a) The device shall be able to simulate three-phase symmetrical voltage drop, phase-to-phase voltage drop and single-phase voltage drop, and the drop amplitude shall include 0% ~ 90%;

b) The device shall be able to simulate three-phase symmetrical voltage rise, and the rise amplitude shall include 110% ~ 130%;

c) The voltage step response adjustment time shall be less than 20 ms.

7 Test items and methods

7.1 Grid adaptability test

7.1.1 Frequency adaptability test

The test wiring – to test the frequency adaptability of the energy storage system – is shown in Figure 1. This test item shall use a simulated power grid device to simulate changes in power grid frequency. The test steps are as follows:

a) Connect the energy storage system to the simulated power grid device.

b) Set the energy storage system to run in the charging state.

c) Adjust the frequency of the simulated power grid device to the range of 49.52 Hz ~ 50.18 Hz; select a number of points reasonably within this range (at least 3 points, and the critical point must be measured); continuously run at each point for at least 1 min, there shall be no tripping phenomenon; otherwise, stop the test.

d) Set the energy storage system to run in the discharge state, and repeat step c).

e) Connect to the energy storage system of the grid through the 380 V voltage level:

1) Set the energy storage system to run in the charging state; adjust the frequency of the simulated power grid device to the range of 49.32 Hz ~ 49.48 Hz and 50.22 Hz ~ 50.48 Hz respectively; select a number of points reasonably within the range (at least 3 points, and the critical point must be measured); continuously run at each point for at least 4 s; respectively record the operational state of the energy storage system and the corresponding operating frequency and operating time;

2) Set the energy storage system to run in the discharge state, and repeat step 1).

f) Connect to the energy storage system of the grid through the voltage level of 10(6) kV and above:

1) Set the energy storage system to run in the charging state; adjust the frequency of the simulated power grid device to the range of 48.02 Hz ~ 49.48 Hz and 50.22 Hz ~ 50.48 Hz; select a number of points reasonably within this range (at least 3 points, and the critical point must be measured); continuously run at each point for at least 4 s; respectively record the operational state of the energy storage system and the corresponding operating frequency and operating time;

2) Set the energy storage system to run in the discharge state, and repeat step 1);

3) Set the energy storage system to run in the charging state; adjust the frequency of the simulated power grid device to 50.52 Hz; run continuously for at least 4 s; record the operational state of the energy storage system and the corresponding operating frequency and operating time;

4) Set the energy storage system to run in the discharge state, and repeat step 3);

5) Set the energy storage system to run in the charging state; adjust the frequency of the simulated power grid device to 47.98 Hz; run continuously for at least 4 s; record the operational state of the energy storage system and the corresponding operating frequency and operating time;

6) Set the energy storage system to run in the discharge state, and repeat step 5).

a) Connect the energy storage system to the simulated power grid device;

b) Set the energy storage system to run in the charging state;

c) Adjust the harmonic value, three-phase voltage unbalance and inter-harmonic value at the AC side of the simulated power grid device to the maximum limits required in GB/T 14549, GB/T 15543 and GB/T 24337 respectively; run continuously for at least 1 min; record the operational state of the energy storage system and the corresponding operating time;

d) Set the energy storage system to run in the discharge state, and repeat step c).

7.2 Power control test

7.2.1 Active power adjustment capability test

7.2.1.1 Power rise test

As shown in Figure 1, connect the energy storage system to the simulated power grid device (the public supply network); adjust all parameters to normal operating conditions, to perform the active power adjustment capability test for power rise. The test steps are as follows:

a) Set the active power of the energy storage system to 0;

b) As shown in Figure 2, adjust the active power set point step by step to $-0.25P_N$, $0.25P_N$, $-0.5P_N$, $0.5P_N$, $-0.75P_N$, $0.75P_N$, $-P_N$ and P_N, and keep each power point for at least 30 s; measure the sequential power at the grid connection point of the energy storage system; take the average value of active power every 0.2 s as a point, and record the measured curve;

c) Calculate the average value of active power for 15 s in the second 15 s after each active power change;

d) Calculate the control precision, response time and adjustment time of active power at each point of b).

7.2.1.2 Power drop test

As shown in Figure 1, connect the energy storage system to the simulated power grid device (the public supply network); adjust all parameters to normal operating conditions, to perform the active power adjustment capability test for power drop. The test steps are as follows:

a) Set the active power of the energy storage system to P_N;

b) As shown in Figure 3, adjust the active power set point step by step to $-P_N$, $0.75P_N$, $-0.75P_N$, $0.5P_N$, $-0.5P_N$, $0.25P_N$, $-0.25P_N$ and 0, and keep each power point for at

Note 2: The discharge power of the energy storage system is positive, and the charging power is negative.

Figure 3 – Power drop test curve

7.2.2 Reactive power adjustment capability test

7.2.2.1 Charging mode test

As shown in Figure 1, connect the energy storage system to the simulated power grid device (the public supply network); adjust all parameters to normal operating conditions, to perform the reactive power adjustment capability charging mode test. The test steps are as follows:

a) Set the charging active power of the energy storage system to P_N;

b) Adjust the energy storage system to operate in the operating mode of outputting the maximum inductive reactive power;

c) Measure the sequential power at the grid connection point of the energy storage system; record the active power and reactive power for at least 30 s; take the average value of power every 0.2 s as a point; calculate the average value of active power and reactive power in the second 15 s;

d) Adjust the charging active power of the energy storage system to $0.9P_N$, $0.8P_N$, $0.7P_N$, $0.6P_N$, $0.5P_N$, $0.4P_N$, $0.3P_N$, $0.2P_N$, $0.1P_N$ and 0 respectively; repeat steps b) ~ c);

e) Adjust the energy storage system to operate in the operating mode of outputting the maximum capacitive reactive power; repeat steps c) ~ d);

f) Take the active power as the abscissa and the reactive power as the ordinate, to draw the power envelope diagram of the energy storage system.

7.2.2.2 Discharge mode test

As shown in Figure 1, connect the energy storage system to the simulated power grid device (the public supply network); adjust all parameters to normal operating conditions, to perform the reactive power adjustment capability discharge mode test. The test steps are as follows:

a) Set the discharge active power of the energy storage system to P_N;

b) Adjust the energy storage system to operate in the operating mode of outputting the maximum inductive reactive power;

c) Measure the sequential power at the grid connection point of the energy storage system; record the active power and reactive power for at least 30 s; take the

average value of power every 0.2 s as a point; calculate the average value of active power and reactive power in the second 15 s;

d) Adjust the discharge active power of the energy storage system to $0.9P_N$, $0.8P_N$, $0.7P_N$, $0.6P_N$, $0.5P_N$, $0.4P_N$, $0.3P_N$, $0.2P_N$, $0.1P_N$ and 0 respectively; repeat steps b) ~ c);

e) Adjust the energy storage system to operate in the operating mode of outputting the maximum capacitive reactive power; repeat steps c) ~ d);

f) Take the active power as the abscissa and the reactive power as the ordinate, to draw the power envelope diagram of the energy storage system.

Note 1: The positive value of reactive power represents inductive reactive power, and the negative value of reactive power represents capacitive reactive power.

Note 2: When the active power is within ±2% P_N, it is considered that the active power is adjusted to 0.

7.2.3 Power factor adjustment capability test

As shown in Figure 1, connect the energy storage system to the simulated power grid device (the public supply network); adjust all parameters to normal working conditions, to perform the power factor adjustment capability test. The test steps are as follows:

a) Adjust the discharge active power of the energy storage system to four points of $0.25P_N$, $0.5P_N$, $0.75P_N$, and P_N respectively;

b) Adjust the power factor of the energy storage system from the lead of 0.95, continuously to the lag of 0.95, and the adjustment range shall not be greater than 0.01; measure and record the actual output power factor of the energy storage system;

c) Adjust the charging active power of the energy storage system to four points of $0.25P_N$, $0.5P_N$, $0.75P_N$, and P_N respectively;

d) Adjust the power factor of the energy storage system from the lead of 0.95, continuously to the lag of 0.95, and the adjustment range shall not be greater than 0.01; measure and record the actual output power factor of the energy storage system.

7.3 Overload capability test

The steps to test the overload capacity of the energy storage system are as follows:

a) Adjust the energy storage system to the hot stand-by state; set the charging active power set point of the energy storage system to $1.1P_N$; run continuously for 10 minutes; measure the sequential power at the grid connection point of the energy

simulation device shall be consistent with that of the no-load test. The test steps are as follows:

a) Connect the energy storage system disconnected during the no-load test to the grid for operation;

b) Adjust the output power of the energy storage system to $0.1P_N \sim 0.3P_N$;

c) Control the power grid fault simulation device to perform three-phase symmetrical voltage drop;

d) Record the waveforms of the voltage and current at the grid connection point of the energy storage system; at least record the data between 10 s before the voltage drops and 6 s after the voltage returns to normal;

e) Control the power grid fault simulation device to perform asymmetrical voltage drop;

f) Record the waveforms of the voltage and current at the grid connection point of the energy storage system; at least record the data between 10 s before the voltage drops and 6 s after the voltage returns to normal;

g) Adjust the output power of the energy storage system to the rated power P_N;

h) Repeat c) ~ f).

7.5 High voltage ride through test

7.5.1 Test preparation

Before the high voltage ride through test of the energy storage system connected to power grid through a voltage level of 10(6) kV and above, the following preparations shall be made:

a) Before the high voltage ride through test, the energy storage system shall work in the same control mode as that when it is actually put into operation. Connect the energy storage system, power grid fault simulation device, data acquisition device and other related equipment according to Figure 1;

b) At least 2 points shall be selected for the high voltage ride through test, and they shall be distributed in the two ranges of $110\%U_N < U < 120\%U_N$ and $120\%U_N < U < 130\%U_N$; the rise time shall be selected according to the requirements of the high voltage ride through curve in Figure 5.

7.6 Power quality test

7.6.1 Three-phase voltage unbalance test

Test the energy storage system separately in charging and discharge state, and carry out the three-phase voltage unbalance test of the system according to the relevant provisions of GB/T 15543.

7.6.2 Harmonic test

Test the energy storage system separately in charging and discharge state; perform the harmonic test of the system according to the relevant provisions of GB/T 14549; carry out the inter-harmonic test of the system according to the relevant provisions of GB/T 24337.

7.6.3 DC component test

7.6.3.1 Test the DC component of the energy storage system in the discharge state, of which the steps are as follows:

a) Connect the energy storage system to the simulated power grid device (the public supply network); adjust all parameters to normal working conditions, and the power factor to 1;

b) Adjust the output current of the energy storage system to 33% of the rated current, and keep for 1 min;

c) Measure the voltage of each phase at the output end of the energy storage system, the effective value of the current and the DC component of the current (it is DC if the frequency is less than 1 Hz); test for 5 minutes under the same sampling rate and time window;

d) When the error between the average value of the RMS voltage of each phase and the rated voltage is less than 5%, and the deviation between the average value of the RMS value of each phase current and the set value of the test current is less than 5%, use the absolute value of each measurement point to calculate the average value of the DC component amplitude of each phase current;

e) Adjust the output current of the energy storage system to 66% and 100% of the rated output current respectively, and keep it for 1 min; repeat steps c) ~ d).

7.6.3.2 Test the DC component of the energy storage system in the charging state, of which the steps are as follows:

a) Connect the energy storage system to the simulated power grid device (the public supply network); adjust all parameters to normal working conditions, and the power factor to 1;

c) Set the voltage of the simulated power grid device (public supply network) as the nominal voltage of the energy storage system, and the frequency as the rated frequency of the energy storage system; adjust the load quality factor Q to be 1.0±0.05;

d) Close switches S_1, S_2, and S_3, until the energy storage system reaches the specified value of b);

e) Adjust the load so that the fundamental current of each phase passing through switch S_3 is less than 2% of the steady-state rated current of each phase of the energy storage system;

f) Disconnect S_3, and record the time interval from disconnecting S_3 to when the energy storage system stops supplying power to the load, that is, the disconnection time;

g) Within the range of 95% ~ 105% of the initial balanced load, increase the reactive load by 1% (or increase the reactive power of the energy storage system by 1%). If the disconnection time of the energy storage system increases, an additional 1% reactive load (or reactive power) needs to be added until the disconnection time no longer increases;

h) At 95% or 105% of the initial balanced load, if the disconnection time still increases, an additional reduction or increase of 1% of the reactive load (or reactive power) is required until the disconnection time does not increase;

i) In the test results, the test points with the three longest disconnection times shall be subjected to 2 additional repeated tests; when the three longest disconnection times appear on the discontinuous 1% load increase value, all test points between the three longest disconnect times shall be subjected to 2 additional repetitions;

j) Adjust the output power of the energy storage system to 66% and 33% of the rated power, respectively, and repeat steps c) ~ i).

Note: For a three-phase four-wire energy storage system, L is the phase wire and N is the neutral wire; for a three-phase three-wire energy storage system, L and N are both phase wires.

7.8 Charging and discharge response time test

7.8.1 Charging response time test

Under the condition of charging and discharging at rated power, adjust the energy storage system to the hot stand-by state, and test the charging response time. The test steps are as follows:

a) Record the moment when the energy storage system receives the control signal, as t_{C1};

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