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Study on the Acceptance Test Specification of Grid-connected Micro-grid

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Abstract
According to relevant standards and specifications at home and abroad, the acceptance tests that must be performed to validate whether the grid-connection/splitting process and grid-connection operation of micro-grid meet the relevant technical requirements have been studied in this paper. Combining the technical requirements of the micro-grid, this paper gives the conditions, measuring instruments, general process and acceptance standards of the acceptance tests, and focuses on the designing of acceptance tests of key operation, operation parameters and protection functions of the micro-grid, such as grid-connection/splitting process, power quality during the grid-connection operation and reverse power and short-circuit protection and so on. The relevant test methods, specific steps and acceptance standards are proposed. This paper can provide a good foundation and basis for designing the acceptance tests specification of micro-grid.

Keywords*: micrograms, grid-connection/splitting, power quality, reverse power, acceptance test*

1. Introduction

Micro-grid has been widely researched in recent years for its flexible configuration and easy operation, it can improve the safety and reliability of power system while improving the power quality and service level of the supply to customer, thus can promote the applications of renewable energy distributed generations [1-3].

When accessed to distribution network, micro-grid will have effects on the voltage distribution, power flow, power quality, relay protection and network reliability of the distribution grid [4-6]. In order to limit these adverse impacts on the normal operation of distribution network, IEEE standards coordinating committee 21 had developed series standards about the grid-connection of distribution generations, i.e. the IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems [7-9]. More comprehensive specific technical requirements on various aspects of the operation of micro-grid were introduced in [10].

In China, a notification about constructing the standard system of energy storage, distributed generation and micro-grid technology had been issued by the State Grid Corporation recently, in which the commissioning and acceptance test specification of micro-grid accessing distribution system has been listed in engineering construction group in the system framework of micro-grid technology standard. Therefore, the development of micro-grid technical provisions and the corresponding acceptance test specification will be very necessary and has important significance.

This paper introduces the general items of the acceptance tests of micro-grid accessing firstly, which includes the pre-conditions, general process, measuring instruments and acceptance standards of the acceptance tests. Then according to the technical requirements of micro-grid, acceptance tests of key operation, operation parameters and protection functions of the micro-grid are designed, such as grid-connection/splitting process, power quality during the grid-connection operation and reverse power and short-circuit protection. The relevant test methods, specific steps and acceptance standards are proposed. This paper can provide a good foundation and basis for designing the acceptance tests specification of the micro-grid.

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2. General Items of Grid-connection Acceptance Tests

2.1. Pre-conditions

Grid-connection acceptance tests should be completed jointly by micro-grid owner and operator, equipment manufacturer, construction unit and supervision unit, grid operation and dispatching department, and testing agency with appropriate qualification, and needs to be provided with following conditions: 1) The owner of the micro-grid must submit all the supporting documents that required by grid-connection to distribution system operation department, which may include the wiring diagram of the micro-grid, the parameters, operating characteristics and operating guidelines of the main equipments of each unit of micro-grid, the configuration and parameter settings of the protections and so on; 2) Micro-grid has completed the field installation and commissioning of its own hardware equipments, monitoring and communication software system, secondary circuit wiring and secondary equipment, and submitted corresponding reports to the grid; 3) Associated auxiliary equipments (Power source, grounding, lightning protection, etc.) had been installed and tested; 4) The application reports of acceptance tests had been submitted by the installation and commissioning corporation and it had been approved by the acceptance working group; 5) the acceptance test program had been completed by the corporation of installation and commissioning together with equipment manufacturers, and it had been reviewed and confirmed by the acceptance working group; 6) safety measures of acceptance tests had been completed.

2.2. Measuring Equipment

Measuring instruments and devices installed on the equipments should not cause the changes of test indices or other characteristics of target micro-grid, and their precision should be suitable for the tests to be conducted. The error of each measurement should not exceed 0.5 times the accuracy of the test parameters.

The mainly used measuring instruments and devices in acceptance tests may include: 1) Multi-function power quality analyzer; 2) The instruments required to measure the connection status, active/reactive power, voltage, current and frequency at the point of common connection; 3) Electromagnetic interference testing instrument; 4) Withstand voltage tester; 5) Relay protection tester.

2.3. General Process

The general process of acceptance tests includes: 1) The acceptance program can start when all the conditions listed in 1.2 are satisfied; 2) An acceptance working group must be established by the organization department of the acceptance tests; 3) The installation and commissioning corporation submits the project completion report, equipments technical documents, test reports, acceptance test program and field application report to the acceptance working group for review; 4) The acceptance working group test each item listed in the test program approved, and record the results; 5) The problems found in acceptance test must be re-inspected by the working group after it had been treated; 6) the acceptance test report must be written after the acceptance test had been completed and reported to the working group to determine the acceptance conclusion.

2.4. Standards of Acceptance Test

The acceptance test report must be signed jointly by the acceptance working group and the installation and commissioning cooperation after the acceptance tests had completed. The requirement for and deadline of the left over problems in acceptance test must be recorded in test report, and these problems must be handled by the installation and commissioning corporation together with the equipment manufacturers.

Acceptance test report shall contain the contents as following: 1) The records of the defects and deviations in acceptance test; 2) The records of acceptance tests and analysis reports; 3) The conclusions of the acceptance test; 4) The memo of the problems left over in the acceptance test (should contain the descriptions of the phenomenon, solutions and expected resolution time); 5) Acceptance test program.

Acceptance tests can be considered to pass when the following requirements had been met: 1) The system files, relevant drawings and materials are all ready and complete; 2) The type, quantity and configuration of all the equipments meet the requirements in technical agreement; 3) The result of each of the acceptance test must meet the requirement proposed in this paper; 4) No defective items；5) The number of deviation items does not exceed 5% of the total number of tests.

3. Acceptance Test of Grid-connection/splitting Operation

3.1. Acceptance Test of Grid-connection Equipment

The purpose of this test is to verify that the installed grid-connection equipment possesses the performances as declared by the manufacturers. Note that this test is not a composition of field acceptance test, but instead it is a prerequisite condition. The tests listed here should be used as part of the equipment type test or factory acceptance test, and may be completed in laboratory, factory or in the field. Some of these tests may be selected to perform in the field acceptance test if needed. The main relevant tests and methods are: 1) Test of the synchronization function of the grid-connection device. The test method is mainly according to that given in JB/T3950-1999 Automatic synchronizing device , and the test results must meet the requirements of this standard; 2) Electromagnetic compatibility emission level test of the grid-connection device. The test method can adopt that prescribed in GB/T 17799.3-2001 Electromagnetic compatibility: Generic standards- Emission standard for residential, commercial and light-industrial environments or GB/T 17799.4 Electromagnetic compatibility: Generic standards- Emission standard for industrial environments for residential, commercial and light-industrial or industrial environments respectively, and the test results must meet the requirements of these standards; 3) Electromagnetic compatibility immunity level test of the grid-connection device. The electrostatic discharge immunity, RF electromagnetic field immunity, surge immunity, immunity to conducted disturbances, induced by radio-frequency fields, and voltage dips, short interruptions and voltage variations immunity of the grid-connection device can be tested by adopting the methods proposed in GB/T 17626 Electromagnetic compatibility: Testing and measurement techniques series standards respectively, and the test results must meet the requirements of these standards; 4) Dielectric withstand voltage test. This test can be performed to the dielectric withstand voltage level between the input circuit and ground, output circuit and ground and input circuit and output circuit respectively according to the method given in GB50150-2006 The guide of electrical equipment installation engineering electrical equipment , and the test results must meet the requirements of this standard; 5) Temperature stability test. This test can be performed in low temperature, high temperature and steady damp heat conditions respectively according to the methods given in GB/T 2423 Environmental testing for electric and electronic products series standards, and the test results must meet the requirements of these standards;

3.2. Acceptance Test of Grid Connection Function

3.2.1. Technical Requirements of Grid-connection

The impacts of grid-connection operation of charged micro-grid on the distribution power system must limited to an acceptable level. Micro-grid in this circumstance can be seen as an equivalent generator, so the requirement to the technical parameters and grid-connection process may refer to the corresponding regulations for generator inter-connection. In 5.7 in JB/T 3950-1999 automatic synchronizing device , it states that: “The device detects the frequency difference between the power system and the system to be paralleled, and frequency difference tuning range of allowing to issue the closing pulse should be selected between 1/16 (1/10)~1/2Hz”. In 5.8 in the same standard, it also provides that: “The device detects the voltage amplitude difference between the power system and the system to be paralleled, and the voltage amplitude difference tuning range of allowing to issue the closing pulse should be selected between ± 3%~± 10% (or ±5%~±10%) of rated voltage.”

The allowable ranges of the parameters during synchronous interconnection of distributed generation given in IEEE Std. 1547-2003 are shown in Table 1, and this standard also provides that: “All the three parameters listed in this table must be in the given range at the instance of the closing of the grid-connected device. If any of these parameters is out of the range described in this table, the parallel device can’t be closed.”

Table 1. Synchronization Parameters Limits for DG Paralleling

DR unit Total Capacity (kVA)	Frequency difference (Δf, Hz)	Voltage difference (ΔV, %)	Phase angle difference ($\Delta \Phi$,°)
0~500	0.3	10	20
>500~1500	0.2	5	15
>1500~10000	0.1	3	10

The selection of the allowable range of these three technical parameters can take into account the national standards and the requirements of IEEE Std. 1547 comprehensively.

3.2.2. Field Simulation Acceptance Test of Grid-connection/splitting Function

The purpose of this test is to verify that the grid-connection device can perform the grid-connection operation reliably and accurately while all the technical parameters are in their allowable range respectively at the instance of paralleling by simulating the grid-connection process, and to verify that the grid-connection device can perform the splitting operation according to the splitting order reliably and accurately

The test procedure is as following:

a) Complete the system connection according to the test scheme, disconnect any one of the switches between micro-grid and power system, and perform visual inspection to ensure that this switch is in the off position. Inspect the rating, phase and connection of the current and voltage transducer used in the test;

b) Connect the test equipment, and monitor the grid-connection order, the phase relationship between the micro-grid side and system side of the paralleling device, the frequency of the voltage of micro-grid and power system, and all the phase voltages of both sides;

c) Disable the grid-connection function, and adjust the frequency difference and voltage amplitude difference between micro-grid and system are within the allowable ranges at least 3 minutes;

d) Verify that the paralleling device has not initiated grid-connection operation;

e) Enable the grid-connection function. Verify that the paralleling device has completed the grid-connection operation, and record the paralleling time. Record the waveforms of all the phase voltages of the micro-grid and power system during paralleling process, and record the frequency difference, voltage amplitude difference and phase angle difference between the micro-gird side and system side of the paralleling device at the moment of closing;

f) Record the setting values of all the parameters during the test;

g) Issue splitting command and verify that the paralleling device has completed the splitting operation. Record the splitting time;

i) Regulate the voltage and frequency of micro-gird to change the frequency difference and voltage amplitude difference, but still in the allowable range of these parameters, repeat step c) to g) 1-2 times.

The acceptance criteria of this test are that in any of the above tests, the paralleling device can perform the grid-connection operation correctly, and all the parameters at the moment of closing are well within their allowable range. In any of the above tests, the paralleling device can perform the splitting operation correctly, and the splitting time must meet the design specification.

It should be noted that the setting value limits of relevant protections of micro-grid must be considered during the tests, for the adjustment of voltage and frequency of micro-grid should not active these protections (such as over-voltage, under-voltage, low-frequency or high-frequency protection). These protections may be out of service when necessary.

3.2.3. Acceptance Test with Frequency/voltage Changes

The purpose of this test is to verify that the grid-connection device can perform the grid-connection operation reliably and accurately after the voltage/ frequency deviation changes from outside the allowable range to inside the allowable range.

The test procedure is as following:

a) Complete the system connection according to the test scheme, disconnect any one of the switches between micro-grid and power system, and perform visual inspection to ensure that this switch is in the off position. Inspect the rating, phase and connection of the current and voltage transducer used in the test;

b) Connect the test equipment, and monitor the grid-connection order, the phase relationship between the micro-grid side and system side of the paralleling device, the frequency of the voltage of micro-grid and power system, and all the phase voltages of both sides;

c) Disable the grid-connection function. Adjust the frequency/voltage of micro-gird to ensure that the frequency/voltage difference between micro-grid and power system is within the allowable range and keep constant. Adjust the phase angel difference to be within the allowable range and keep constant. Adjust and maintain the voltage/frequency of micro-gird to be higher than that of power system and the voltage/frequency difference is out of the allowable range;

d) Enable the grid-connection function and verify that the paralleling device has not initiated grid-connection operation in at least 3 minutes;

e) Reduce the voltage/frequency difference between micro-grid and power system gradually to be within the allowable range. Verify that the paralleling device has completed the grid-connection operation and record the paralleling time.

f) Record the setting values of all the parameters during the test;

g) Adjust and maintain the voltage/frequency of micro-gird to be lower than that of power system, repeat step c) to f).

The acceptance criteria of this test is that in any of the above tests, the paralleling device will perform the grid-connection operation when and only when all the parameters meet the technical requirements.

3.2.4. Field Acceptance Test of Grid-connection Function

The purpose of this test is to verify that the energized micro-grid can grid-connect to power system reliably and accurately through the paralleling device in accordance with the technical requirements.

The test procedure is as following:

a) Complete the system connection according to the test scheme. Inspect the rating, phase and connection of the current and voltage transducer used in the test;

b) Connect the test equipment, and monitor the grid-connection order, the phase relationship between the micro-grid side and system side of the paralleling device, the frequency of the voltage of micro-grid and power system, and all the phase voltages of both sides;

c) Disable the grid-connection function, and adjust the frequency difference and voltage amplitude difference between micro-grid and system are within the allowable ranges at least 3 minutes;

d) Verify that the paralleling device has not initiated grid-connection operation;

e) Enable the grid-connection function. Verify that the paralleling device has completed the grid-connection operation, and record the paralleling time. Record the waveforms of all the phase voltages of the micro-grid and power system during paralleling process, and record the frequency difference, voltage amplitude difference and phase angle difference between the micro-gird side and system side of the paralleling device at the moment of closing;

f) Record the setting values of all the parameters during the test;

The acceptance criteria of this test is that in the above test, the paralleling device can perform the grid-connection operation correctly, and all the parameters at the moment of closing are well within allowable range. This test only needs to be performed once if no special requirement.

3.2.5. Field Acceptance Test of Splitting Function

The purpose of this test is to verify that the micro-grid can disconnect from power system reliably and safely through paralleling device in accordance with the technical requirements.

The splitting process may perform automatically or manually. The acceptance test procedure of automatic splitting function is as following:

a) Complete the system connection according to the test scheme. Inspect the rating, phase and connection of the current and voltage transducer used in the test;

b) Connect the test equipments, and monitor the splitting order. Ensure that micro-grid is grid-connected.

c) Issue splitting command, measure and record the splitting time.

The acceptance test procedure of manual splitting function is as following:

a) Complete the system connection according to the test scheme. Inspect the rating, phase and connection of the current and voltage transducer used in the test;

b) Connect the test equipments, and monitor the splitting order. Ensure that micro-grid is grid-connected;

c) Disconnect the micro-power and major electrical equipments in micro-grid gradually, and shedding the loads in micro-grid gradually;

d) Confirm that the current of paralleling device approaches zero, and then disconnect the paralleling device manually.

This test is only aimed at the process from splitting order issued to splitting operation completed without considering the reasons causing splitting. This test only needs to be performed once if no special requirement.

4. Integrated Acceptance Test of Power Quality of Grid-connection Operation

The purpose of this test is to verify that all the power quality indicators at PCC meet corresponding technical requirements during the gird-connection operation of micro-grid. The power quality indicators may include current/voltage harmonics, voltage fluctuation and flicker, voltage unbalance and power factor.

The test procedure is as following:

a) Complete the system wiring according to the test scheme. Inspect the rating, phase and connection of the current and voltage transducer used in the test, and inspect the connection of the power quality analyzer used in test;

b) Ensure that micro-grid operates in grid-connection mode and without any micro-power in service. Monitor and record all the power quality indicators continuously at least 24 hours;

c) Collect monitoring data and analysis statistically.

The integrated acceptance test procedure of power quality is relatively simple. The technical requirements, measurement methods and acceptance criteria of all the power quality indicators are given below.

4.1. Harmonics

The voltage/current harmonic characteristics at PCC invoked by micro-grid are determined by the characteristic of power system, the composition and characteristics of the micro-power in micro-gird, and the connected load and equipment. The current harmonic injected to PCC by paralleling micro-grid should meet the relevant requirements proposed in GB14549-1993 Quality of electric energy supply: Harmonics in public supply network . The particular requirement of the indicator of harmonic test can be resolved according to the method given in this standard.

The 95% probability values of three phase current harmonics are calculated based on the record data, and the maximum value of three phases is chosen as the base to determine whether the current harmonic exceeds the tolerance or not.

Note that the background of current harmonic at PCC before the interaction of micro-grid must be obtained to ensure that the measured current harmonic that exceeds the tolerance is not caused by power system. The voltage harmonic THD at PCC before micro-grid paralleled should be less than 2.5%. Due to the fact that the current harmonic injected by micro-grid at PCC is greatly affected by the operation mode of micro-grid, the harmonic characteristics of micro-power and loads in micro-grid, additional tests can be performed depend on actual situation.

4.2. Voltage Fluctuation and Flicker

The voltage fluctuation and flicker at PCC caused by micro-grid paralleled should meet the requirement of clause 4 and 5 in GB12326-2008 Quality of electric energy supply: Voltage fluctuation and flicker respectively.

The tolerance of voltage flicker caused by micro-grid separately can be determined depend on the load of micro-grid, the ratio of capacity on agreement to total electricity capacity and the condition of PCC according to the method specified in GB12326-2008.

All the long term voltage flicker severity measured at PCC under the minimum operating plan of micro-grid during the integrated power quality test should be within the given limit.

The long term voltage flicker severity caused by micro-grid separately can be solved as:

$$P_{lt2} = \sqrt[3]{P_{lt1}^3 - P_{lt0}^3} \quad (1)$$

Where P_{lt1} is the measurement of the long term voltage flicker severity with micro-grid interconnected; P_{lt0} is the measurement of the long term voltage flicker severity with micro-grid disconnected, and P_{lt2} is the long term voltage flicker severity caused by micro-grid separately

It should be noted that additional test must be performed to obtain the background voltage flicker severity with micro-grid disconnected before this test. As for there is no generally accepted test method and no sophisticated test device for voltage fluctuation at present, the voltage fluctuation could be estimated according to the method provided in GB12326-2008, and only the acceptance test for voltage flicker measurement results is needed.

4.3. Voltage Unbalance

The three-phase voltage unbalance at PCC when micro-grid interconnected (only for three-phase micro-grid) must meet: 1) The requirements provided in clause 4 in GB15543 Quality of electric energy supply: Three-phase voltage unbalance , i.e. the allowable value is 2%, and the short-term value may not exceed 4%; 2) The allowable limit of negative sequence voltage unbalance at PCC caused by each consumer accessed to this point is 1.3% in general, but the short-term value may not exceed 2.6%.

The 95% probability values of RMS of the measured negative-sequence voltage unbalance in 10 minutes is chosen as the basis for determining whether the voltage unbalance exceeds the tolerance or not.

Note that the degree of voltage unbalance at PCC is normally judged by the degree of negative sequence voltage unbalance, and there is usually no requirement to zero-sequence voltage unbalance in low voltage system. The degree of voltage unbalance caused by micro-grid is greatly affected by the operation mode of micro-grid and the characteristics of micro-power and loads in micro-grid, additional test can be performed depend on actual situation if necessary. The background of voltage unbalance degree at PCC before the interaction of micro-grid must be obtained to ensure that the measured voltage unbalance that exceeds the tolerance is not caused by power system.

4.4. Power Factor

The power factor at PCC must meet the requirement in Power system voltage and reactive power control regulations 2004 when micro-grid absorbs inductive reactive power. That is: “In 35kV~ 220kV substation, the power factor of primary side of main transformer with maximum load should be less than 0.95, while should not exceed 0.95 with valley load”, “The requirement of the power factor of electricity consumers with 35kV and above can refer to the same provision; The power factor of 10kV consumers with 100kVA and above should be above 0.95, and the power factor of other users should be above 0.9”.

The power factor of micro-grid at PCC measured in integrated power quality test must meet the requirements listed above.

The power factor can be calculated as below:

$$\cos\varphi = \frac{W_P}{\sqrt{W_P^2 + W_Q^2}} \quad (2)$$

Where cosφ is the average power factor during test period; W_P and W_Q is the measured active and reactive energy during the test period respectively.

Note that the power factor of micro-grid at PCC is greatly affected by the operation mode of micro-grid and the characteristics of micro-power and loads in micro-grid, additional test can be performed depend on actual situation if necessary. This test should be performed with reactive power compensation devices in service when micro-grid contains this kind of device.

5. Acceptance Test of Reverse Power Protection

Reverse power protection may be configured when micro-grid operates in non-reverse power mode. But in the reversible power mode, there is normally a limit on the power delivered from micro-grid to power system. The principle of protecting the transmission power from exceeding the limit is the same as that of the reverse power protection. So the acceptance test for the transmission power limit protection can be carried out with reference to this test.

The method adopted in the following tests is signal injection testing method.

5.1. Acceptance Test of Magnitude Setting

This test aims to confirm the accuracy characteristic of the magnitude setting of non-reverse power protection. The accuracy of the magnitude setting must be given before test.

The test procedure is as following:

a) Complete the system wiring according to the test scheme. Inspect the rating, phase and connection of the current and voltage transducer used in the test, and inspect the connection of the relay tester used in test;

b) Adjust the voltage of micro-grid and power system to rated value and keep constant during the test. Adjust the current flows from power system to micro-grid to rated value and in phase with the power system voltage, thus the power delivered from power system to micro-gird is of rated value;

c) Set the time delay of reverse power protection to 0s;

d) Step the current amplitude close to zero, and step the phase angle between the current and the power system voltage from 0° to 180°. Keep the amplitude and phase of current steady in a certain period of time. At the end of this period, increase the current amplitude gradually;

e) Record the current amplitude measured by relay tester;

f) Restore the current amplitude to rated value and the phase angle to 0°;

g) Repeat step c) to e) three times.

In all the above tests, the measured magnitude of the current must satisfy the requirement of the given amplitude accuracy.

5.2. Acceptance Test of Time Delay Setting

This test aims to confirm the accuracy characteristic of the time delay setting of non-reverse power protection. The accuracy of the time delay setting must be given before test.

The test procedure is as following:

a) Complete the system wiring according to the test scheme. Inspect the rating, phase and connection of the current and voltage transducer used in the test, and inspect the connection of the relay tester used in test;

b) Adjust the voltage of micro-grid and power system to rated value and keep constant during the test. Adjust the current flows from power system to micro-grid to rated value and in phase with the power system voltage, thus the power delivered from power system to micro-gird is of rated value;

c) Step the current amplitude close to zero, and step the phase angle between the current and the power system voltage from 0° to 180°. Keep the amplitude and phase of current steady in a certain period of time. At the end of this period, step the current amplitude to 1.2 times the rated value;

d) Record the time delay measured by relay tester;

e) Restore the current amplitude to rated value and the phase angle to 0°, repeat step c) to d) three times.

In all the above tests, the measured time delay of reverse power protection must satisfy the requirement of the given accuracy.

6. Acceptance Tests of Short-circuit Protection

6.1. Acceptance Test of Magnitude Setting

This test aims to confirm the accuracy characteristic of the magnitude setting of short-circuit protection. The accuracy of the magnitude setting must be given before test.

The test procedure is as following:

a) Complete the system wiring according to the test scheme. Inspect the rating, phase and connection of the current and voltage transducer used in the test, and inspect the connection of the relay tester used in test;

b) Set the time delay of short circuit protection to 0s;

c) Adjust the voltage of micro-grid and power system to rated value and keep constant during the test. Adjust the current flows from power system to micro-grid to rated value and keep it constant during a certain period of time. At the end of this period, increase the current amplitude gradually;

d) Record the current amplitude measured by relay tester;

e) Restore the current amplitude to rated value, repeat step c) to d) three times;

f) Repeat this test for each phase individually or for all the three phase simultaneously.

In all the above tests, the measured magnitude of the current must satisfy the requirement of the given amplitude accuracy.

6.2. Acceptance Test of Time Delay Setting

This test aims to confirm the accuracy characteristic of the time delay setting of short-circuit protection. The accuracy of the time delay setting must be given before test.

The test procedure is as following:

a) Complete the system wiring according to the test scheme. Inspect the rating, phase and connection of the current and voltage transducer used in the test, and inspect the connection of the relay tester used in test;

b) Adjust the voltage of micro-grid and power system to rated value and keep constant during the test. Adjust the current flows from power system to micro-grid to rated value and keep it constant during a certain period of time. At the end of this period, step the current amplitude to 1.2 times the rated value;

c) Record the time delay measured by relay tester;

d) Restore the current amplitude to rated value, repeat step b) to c) three times.

e) Repeat this test for each phase individually or for all the three phase simultaneously.

In all the above tests, the measured time delay of short-circuit protection must satisfy the requirement of the given accuracy.

7. Conclusion

Micro-grid is considered to be a more suitable mode for the access of distributed generations. But the interconnection/splitting and grid-connection operation will impose significant effects on the traditional distribution system. The developing of acceptance test specification of grid-connected micro-grid according to corresponding technical standard will have important practical significance.

This paper studies the acceptance tests which must be performed to validate whether the grid-connection/splitting process and grid-connection operation of micro-grid meet the relevant technical requirements or not. Combining the technical requirements of micro-grid, this paper proposes the pre-conditions, measuring instruments, general process and acceptance standards of the acceptance tests, and focuses on the designing of acceptance tests of key operation, operation parameters and protection functions of micro-grid, such as the grid-connection/splitting process, power quality during the grid-connection operation and reverse power and short-circuit protection. The relevant test methods, specific steps and acceptance standards are proposed. This paper can provide a good foundation and basis for designing the acceptance tests specification of Micro-grid.

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