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Wind Turbine - Doubly-fed Induction Generator

风力发电机组 双馈异步发电机

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Wind Turbine - Doubly-fed Induction Generator

1 Scope

This document specifies the type, technical requirements, test methods, inspection rules, warning signs, product information, packaging, transportation and storage, environmental protection and safety of low-voltage doubly-fed induction generator for grid-connected wind turbines with a rated voltage of 1,140 V and below.

This document is applicable to low-voltage doubly-fed induction generator for grid-connected wind turbines with a rated voltage of 1,140 V and below (hereinafter referred to as “the generator”).

2 Normative References

The contents of the following documents constitute indispensable clauses of this document through the normative references in the text. In terms of references with a specified date, only versions with a specified date are applicable to this document. In terms of references without a specified date, the latest version (including all the modifications) is applicable to this document.

GB/T 191 Packaging - Pictorial Marking for Handling of Goods

GB/T 755-2019 Rotating Electrical Machines - Rating and Performance

GB/T 997 Rotating Electrical Machines - Classification of Types of Construction, Mounting Arrangements and Terminal Box Position for (IM Code)

GB/T 1029 Test Procedures for Three-phase Synchronous Machines

GB/T 1032-2012 Test Procedures for Three-phase Induction Motors

GB/T 1971 Rotating Electrical Machines - Terminal Markings and Direction of Rotation

GB/T 1993 Cooling Methods for Rotating Electrical Machines

GB/T 2900.25 Electrotechnical Terminology - Rotating Electrical Machines

GB/T 4942-2021 Degrees of Protection Provided by the Integral Design of Rotating Electrical Machines (IP code) - Classification

GB/T 10068 Mechanical Vibration of Certain Machines with Shaft Heights 56 mm and Higher - Measurement, Evaluation and Limits of Vibration Severity

GB/T 10069.1 Measurement of the Airborne Noise Emitted by Rotating Electrical Machines and the Noise Limits - Part 1: Method for the Measurement of Airborne Noise Emitted by

U_{dc}: DC bus voltage, V.

U_r: operating voltage of the rotor, V.

U_0: no-load stator voltage, V.

U_{r0}: rotor locked open-circuit voltage, V.

η: efficiency, %.

5 Structural Type and Main Parameter Series

5.1 Structural Type

5.1.1 The protection degree of the enclosure of the generator shall not be lower than IP54 specified in GB/T 4942-2021. Under special circumstances, it may be determined by the generator manufacturer and the user through consultation. The protection degree of the junction box shall not be lower than IP54 specified in GB/T 4942-2021, and a ground terminal shall be provided in the junction box. The protection degree of the slip ring chamber of the generator shall not be lower than IP23.

5.1.2 The cooling mode of the generator shall comply with the stipulations of GB/T 1993. The cooling mode beyond the scope specified in the Standard shall be determined by the generator manufacturer and the user through consultation. The primary or secondary cooling medium shall not cause harm to the product or the surrounding environment. If liquid cooling is adopted, there shall be no leakage and corrosion, etc.

5.1.3 The stator winding and rotor winding leading-out terminals and the connecting terminals in the junction box shall all have corresponding signs, and it shall be ensured that their writing is clearly visible throughout the generator's period of use. The generator wire-end markings and rotation directions shall comply with the stipulations of GB/T 1971, or be determined by the generator manufacturer and the user through consultation.

5.1.4 The structure and installation type of the generator shall comply with the stipulations of GB/T 997. The structure and installation type beyond the scope specified in the Standard shall be determined by the generator manufacturer and the user through consultation.

5.1.5 An electric heating device shall be installed inside the generator. The power selection of the electric heating device is based on JB/T 7836.1.

5.1.6 The generator shall be equipped with a stator winding temperature sensor, bearing temperature sensor and carbon brush wear sensor to monitor the operating status of the generator. If other types of sensors need to be added, this shall be determined by the generator manufacturer and the user through consultation.

5.1.7 An oil filling structure shall be set up for the lubrication of the generator bearings, and the filling mode shall be determined by the generator manufacturer and the user through

c) The maximum water temperature at the inlet of the water-cooling cooler or the maximum ambient water temperature of the water jacket-cooling motor does not exceed 40 °C;

d) Relative air humidity: the monthly average maximum relative humidity in the wettest month is 90% (the monthly average minimum temperature in that month is not higher than 25 °C).

6.1.2 Electrical operating conditions

6.1.2.1 The generator shall be able to normally operate under the following electrical conditions:

a) Under the grid conditions of rated voltage tolerance and rated frequency tolerance specified in GB/T 19963.1, the generator shall be able to normally operate;

b) For motors with Type II insulation structure in accordance with GB/T 22720.2 and designed to be powered by voltage source converters, the manufacturer shall mark the pulse peak coefficient (OF) of the insulation structure in accordance with GB/T 22720.1; the phase-to-phase should satisfy the pulse voltage level (U_p/U_a) C, and the phase-to-ground should satisfy level (U_p/U_a) B, or the level agreed between the manufacturer and the user.

NOTE: when a generator needs to operate beyond one or more of the above-mentioned limit conditions, its special requirements can be determined by the generator manufacturer and the user through consultation.

6.1.2.2 The generator shall be able to withstand the unit requirements specified in GB/T 19963.1, and continuously operate without disconnecting from the grid.

6.2 Basic Performance

6.2.1 The generator shall be manufactured in accordance with the drawings and technical documents approved by the prescribed procedures.

6.2.2 The appearance and installation dimensions of the generator shall comply with the requirements of the outline drawings agreed with the user.

6.2.3 When the generator is idling, it shall be smooth, flexible and without stagnation.

6.3 Temperature and Temperature Rise Limit

6.3.1 During the temperature rise test of the generator, the temperature detection of the stator winding shall adopt the embedded thermometer method (ETD) and the resistance method (R), and the temperature detection of the rotor winding shall adopt the resistance method (R). For the temperature rise limit, see GB/T 755-2019. Under non-benchmark operating conditions beyond what is specified in this document, the temperature rise limit shall be corrected in accordance with the stipulations of GB/T 755-2019. When the altitude exceeds the requirements of this document, it shall be corrected in accordance with the requirements of GB/T 31140.

6.3.2 The temperature rise or temperature of the collector ring, electric brush or brush device shall not affect its normal operation.

6.3.3 When measured using the embedded thermometer method (ETD), the operating temperature of the rolling bearings shall not be higher than 95 °C.

6.4 Characteristics

6.4.1 System information exchange

The designers of the generator and the converter shall provide each other with relevant information as follows:

---The generator designer shall provide the converter designer with the rated parameters and equivalent circuit parameters of the generator;

---The converter designer shall provide the generator designer with the maximum voltage, maximum current, voltage harmonics, switching frequency, DC bus voltage, phase-to-ground peak voltage at the motor end, phase-to-phase peak-to-peak voltage, sudden changes of voltage expected to appear at the motor end, and impulse rise times of the converter, etc.

This information is necessary to ensure that the generator complies with the user's requirements and comprehensively evaluate the interaction effect between the generator and the converter.

6.4.2 Reference temperature

When the generator adopts Class F insulation, all its characteristics are plotted when the winding reference temperature is 115 °C.

When the generator adopts Class H insulation, all its characteristics are plotted when the winding reference temperature is 135 °C. This temperature shall be indicated on the characteristic curve.

6.4.3 Generator characteristics

The specified characteristics of the generator refer to the relation curve among the total active power of the generator (P_e), the active power of the stator (P_s), the active power of the rotor (P_r), the reactive power of the rotor (Q_r), the stator current (I_s), the operating voltage of the rotor (U_r), the rotor current (I_r), as well as the efficiency (η) and rotation speed (n) when the motor rotor winding is power by the converter, and maintains the rated voltage, rated frequency and rated power factor. The characteristic curve shall be measured within the entire operating speed range ($n_{min} \sim n_{max}$) when the generator is in a thermal state and after the temperature rise test of the generator.

6.5 Tolerances

6.5.1 No-load current tolerance

alternating current for a duration of 1 minute, and there shall be no breakdown or flashover. The test shall be immediately carried out after the exit-factory test is completed. The effective value of the stator test voltage is $2U_N$ + 1,000 V, with a minimum of 1,500 V; the effective value of the rotor test voltage is $2U_{dc}$ + 1,000 V.

6.10.2 Interturn withstand voltage

6.10.2.1 The random-wound winding shall be able to withstand the interturn insulation impulse voltage test without breakdown for 3 seconds. The peak value of the impulse test voltage shall comply with the stipulations of GB/T 22719.2.

6.10.2.2 The form-wound winding shall be able to withstand the interturn insulation impulse voltage test without breakdown for 3 seconds. The peak value of the impulse test voltage shall comply with the stipulations of GB/T 22714.

6.11 Short-time Voltage Increase

The generator shall be able to withstand a short-time voltage increase test without manifesting any fault. During the test, adjust the generator stator voltage to 1.3 times the rated voltage, and the frequency shall not be lower than the power frequency for a duration of 3 minutes, and the insulation shall not be damaged.

6.12 Harmonic Waves

6.12.1 Under the no-load operating status of the generator, and at the rated rotation speed, power is supplied through the rotor sinusoidal voltage and rated slip frequency. The total harmonic distortion (THD) of the stator line end voltage of the generator shall not exceed 5%, and the frequency measurement range shall include all harmonic waves from the rated frequency to the 50^{th} harmonic wave.

6.12.2 Under the rated operating conditions and power supplied by the converter (the waveform distortion rate on the motor side is less than or equal to 3%), the harmonic current factor HCF for the determination of the stator line end current of the generator shall not exceed 5%. The frequency measurement range shall include all harmonic waves from the 2^{nd} harmonic wave to the 50^{th} harmonic wave.

6.13 Noise

When the generator operates under the condition of short-circuited rotor winding and power frequency no-load motor, the cooler normally works, measure the noise in the specified rotation direction. The noise limits of the generator shall satisfy the stipulations of GB/T 10069.3.

6.14 Vibration

When the generator is installed on the test bench and operates under the condition of short-circuited rotor winding and power frequency no-load motor, and the cooler normally works, the limits of the vibration speed and displacement shall satisfy the stipulations of GB/T 10068.

6.15 Efficiency

The efficiency of the generator under the rated operating conditions shall be greater than or equal to 96%.

6.16 Other Requirements

6.16.1 The generator shall be insulated with insulated bearings or end covers, and the generator shaft shall be equipped with a single-ended or double-ended grounding device, so as to reduce the adverse impact of shaft current on the bearings.

6.16.2 The difference between the three-phase resistance value and the average value of the three-phase resistance shall not be greater than 2% of the average value for star-connected windings; and shall not be greater than 1.5% of the average value for delta-connected windings.

6.16.3 For grounding protection, refer to the requirements of 11.1 in GB/T 755-2019.

6.16.4 The anti-corrosion of the generator shall not be lower than the requirements of C3 in GB/T 30790.5-2014.

7 Test Methods

7.1 Test Requirements

7.1.1 The power supply circuit shall comply with the requirements of 7.2.2 in GB/T 755-2019.

7.1.2 The converters used for the test shall comply with the requirements of GB/T 25388.1.

7.1.3 The measuring instruments used for the test shall comply with the requirements of 4.3 in GB/T 1032-2012.

7.2 Test Items and Methods

7.2.1 Mechanical and electrical inspection

The mechanical and electrical inspection includes the following content:

a) Appearance inspection;

b) Rotating rotor, which shall be smooth, flexible and without stagnation;

c) When the electric brush and collector ring are running, check for spark, and the contact area shall not be less than 80%;

d) Detection of sensor status;

e) Detection of generator phase sequence;

7.2.8 Determination of rotor open-circuit voltage

The following two methods can be used for determination:

a) When the rotor is stationary and in an open circuit, adjust the stator side voltage regulator, so that the rotor voltage gradually rises to the rated voltage (U_N) of the generator, then, measure and record the stator voltage, and convert it to the corresponding rotor open-circuit voltage when it is under the rated voltage;

b) The rotor is in an open circuit, tow the generator to 0.8 times ~ 0.9 times the rated speed, adjust the voltage regulator, so that the stator voltage gradually increases from 0 V to the rated voltage, then, measure and record the rotor line voltage, and convert it to the corresponding rotor open-circuit voltage in the stationary state.

7.2.9 Short-time voltage increase test

The generator shall be able to withstand a short-time voltage increase test without any fault. The following two methods can be used for the test.

a) During the test, the generator rotor winding is short-circuited and operates under the condition of power frequency no-load motor. The externally applied voltage is 1.3 times the power frequency rated voltage for a duration of 3 minutes, and the insulation shall be undamaged.

b) Under the no-load generator operating conditions, the rotor of the generator under test is excited by an independent three-phase sinusoidal AC power supply. Adjust the generator stator voltage to 1.3 times the rated voltage; the stator voltage frequency shall not be lower than the power frequency for a duration of 3 minutes, and the insulation shall be undamaged. When increasing the generator voltage to 1.3 times the rated voltage, it is allowed to simultaneously increase the rotation speed and rotor excitation current, but it shall not exceed the maximum operating speed (n_{max}), and the rotor excitation current shall not exceed the allowable limit.

7.2.10 Interturn withstand voltage test

For random-wound windings, the withstand voltage test shall be carried out in accordance with the stipulations of GB/T 22719.1.

For form-wound windings, the withstand voltage test shall be carried out in accordance with the stipulations of GB/T 22714.

7.2.11 Determination of shaft voltage

7.2.11.1 When the generator rotor winding is short-circuited and operates under the condition of power frequency no-load motor, the determination of the shaft voltage shall be carried out in accordance with the stipulations of GB/T 1032-2012.

7.2.11.2 When the generator is under doubly-fed operation, the determination of the shaft

voltage is determined by the generator manufacturer and the user through consultation.

7.2.12 Determination of harmonic voltage and current

7.2.12.1 Under the no-load generator state and at the rated speed, determine the total harmonic distortion (THD) of the stator line end voltage of the generator. The frequency measurement range shall include all harmonic waves from the rated frequency to the 50^{th} harmonic wave.

7.2.12.2 Under the rated operating conditions, determine the stator line end current harmonic current factor (HCF) of the generator. The frequency measurement range shall include all harmonic waves from the 2^{nd} harmonic wave to the 50^{th} harmonic wave.

7.2.13 Overspeed test

Carry out the test in accordance with the stipulations of GB/T 1032-2012.

7.2.14 Ground withstand voltage test

7.2.14.1 The ground withstand voltage test shall be carried out after all tests are completed.

7.2.14.2 Between the winding under test and the generator enclosure, apply the test voltage, and the other non-test windings and PT100 shall be electrically connected to the core and enclosure. During the test, all components of the generator shall be installed in place (except the lightning arrester), just like under normal operating conditions.

7.2.14.3 The test voltage shall be power frequency voltage and be as clos to a sinusoidal waveform as possible.

7.2.14.4 The test shall start from no more than half of the full value of the test voltage, then, uniformly or in steps of no more than 5% of the full value, gradually increase to the full value. The time for the voltage to increase from half the value to the full value shall not be less than 10 seconds.

7.2.14.5 This test is only performed on new motors that have been assembled. During acceptance inspection, the windings shall not be repeatedly subjected to the withstand voltage test of full voltage. However, when the user insists on conducting the second test, the test voltage shall be 80% of the full value.

7.2.15 Vibration determination

The generator is installed on the test bench and operates under the condition of short-circuited rotor winding and power frequency no-load motor, and the cooler normally works, the rest shall comply with the stipulations of GB/T 10068.

7.2.16 Noise determination

The generator is installed on the test bench and operates under the condition of short-circuited rotor winding and power frequency no-load motor, and the cooler normally works, the rest shall

9 Warning Signs

Users shall be reminded of the warning content of the product during operation. The manufacturer shall set warning signs in prominent positions on the product and ensure that they are clearly visible throughout the generator's period of use. All contents of safety and warnings shall be re-stated in the user manual.

10 Product Information

10.1 Markings

10.1.1 The product nameplate shall contain at least the following content:

a) Manufacturer's name;

b) Product name, model and main product parameters specified by the manufacturer;

c) Enclosure protection degree;

d) Mass;

e) Product No. and exit-factory date.

10.1.2 The main parameters of the product include rated voltage, rated current of the stator, winding wiring mode, insulation class, frequency, rotation speed range, rated rotation speed, rated power factor and rotor open-circuit voltage.

10.1.3 The nameplate shall be fixed in a prominent position on the generator enclosure and shall be easily visible when the generator is installed in the engine room. The specific position can be determined by the generator manufacturer and the user through consultation.

10.2 Document Configuration

The following documents shall be provided to the user before the generator exits the factory.

a) Product user manual (operation and maintenance instructions), which shall at least include the following content:

   1) The specifications, upon which, the product is designed;

   2) Product performance parameters;

   3) Operation, inspection and maintenance procedures;

   4) Recommended on-site inspection and maintenance frequency, methods and acceptance rules;

5) Precautions for use;

6) How to deal with common problems;

7) List of wearing parts, spare parts, accessories and special tools;

8) Other matters that need to be informed.

b) Product certificate.

c) Generator packaging and shipping list.

In addition, if the client needs wind turbine generator product certification, the generator manufacturer shall also provide corresponding generator certification documents, information and certification certificates, etc.

11 Packaging, Transportation and Storage

The packaging, transportation and storage need to satisfy the following requirements:

a) When packing, each generator shall be accompanied by a product certificate, and generator outline drawings and user manuals can also be provided as needed;

b) When packaging the product, anti-rust and protective measures shall be taken for the shaft extension and other components, which shall not be affected by moisture, stains or damage due to poor packaging;

c) The pictorial markings the packaging, storage and transportation of the generators shall comply with the stipulations of GB/T 191;

d) When the generator is separately transported or lifted, the rotor and stator shall be relatively fixed, so as to prevent the rotor from moving;

e) When the generator is installed on the frame and transported in a group, the demand-side and supply-side shall negotiate to determine a scheme to prevent the rotor from axially moving;

f) When storing the product, it shall be stably placed in a dry and clean place without acid, alkali and corrosive gases. No other items shall be placed on the product;

g) The ambient temperature for generator storage shall not be lower than –40 °C;

h) When the generator has been stored for more than 2 months, the rotor shall be rotated to ensure that the bearings are in good condition.

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