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NATIONAL STANDARD OF THE
PEOPLE'S REPUBLIC OF CHINA

ICS 29.160

CCS K 20

GB/T 20834-2024

Replacing GB/T 20834-2014

Technical requirements for motor-generator

发电电动机技术要求

Issued on: September 29, 2024

Implemented on: April 01, 2025

**Issued by: State Administration for Market Regulation;
Standardization Administration of the People's Republic of China.**

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Technical requirements for motor-generator

1 Scope

This document specifies the overall technical requirements for generator motors and their ancillary equipment, as well as requirements for product identification, material and component storage, factory and field testing, supply and trial operation, and warranty period.

This document is applicable to three-phase, 50 Hz, reversible salient-pole synchronous generator motors (hereinafter referred to as "generator motors") directly connected to pump-turbines with a rated capacity of 100 MVA and above. For units with a rated capacity of less than 100 MVA or a frequency of 60 Hz, this document can be used as a reference.

2 Normative references

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

GB/T 755, *Rotating electrical machines -- Rating and performance*

GB/T 2900.25, *Electrotechnical terminology -- Rotating electrical machines*

GB/T 5321, *Measurement of loss and efficiency for electrical machine by the calorimetric method*

GB/T 7894-2023, *Fundamental technical requirements for hydro generators*

GB/T 11805, *General specifications of automatic control components (devices) and their related system for hydro-turbine generating sets*

GB/T 18482, *Specification for start-up test of reversible pumped-storage units*

GB/T 25442, *Standard methods for determining losses and efficiency of rotation electrical machines from tests (excluding machines for traction vehicles)*

GB/T 36550, *Basic terminology of pumped storage power station*

GB 50084, *Code of design for sprinkler systems*

GB 50193, *Code of design for carbon dioxide fire extinguishing systems*

NB/T 47004.1, *Plate heat exchangers - Part 1: Plate-and-frame heat exchangers*

3 Terms and definitions

For the purposes of this document, the terms and definitions defined in GB/T 2900.25, GB/T 755, GB/T 7894 and GB/T 36550 apply.

4 On-site operating conditions

Unless otherwise specified, the generator motor shall be able to operate continuously at rated speed under the following environmental conditions:

- a) Altitude shall not exceed 1000 m;
- b) Cooling air temperature shall not exceed 40°C;
- c) Inlet water temperature of air cooler and oil cooler shall not be higher than 30°C and not lower than 5°C;
- d) Relative humidity shall not exceed 85%;
- e) Meet the requirements of local earthquake acceleration. The purchaser shall provide the requirements of horizontal and vertical acceleration values according to the geographical conditions of the location.

For operating environments that are different from the above requirements, the on-site operating conditions shall be determined by negotiation between the supplier and the purchaser.

5 Ratings and parameters

5.1 Capacity and power

5.1.1 The rated capacity under power generation conditions refers to the apparent power output at the rated frequency, rated voltage and rated power factor, and the unit is MVA.

5.1.2 The rated power under electric working condition refers to the mechanical power output on the shaft under rated frequency, rated voltage and rated power factor, and the unit is MW.

5.1.3 The capacity/power of the generator motor shall match the turbine operating output power of the pump-turbine and the maximum input power of the pump operating condition.

5.6 Efficiency and loss

5.6.1 Weighted average efficiency

The weighted average efficiency of the generator motor is calculated according to formula (1) in GB/T 7894-2023. The purchaser shall provide the weighted coefficients for the generating condition and the motoring condition respectively according to the operating mode of the unit in the system.

5.6.2 Losses

The losses and efficiency of the generator motor shall be measured by calorimetry and shall comply with GB/T 25442 and GB/T 5321. The losses include:

- a) Copper loss of stator winding;
- b) Copper loss of excitation winding;
- c) Core loss;
- d) Ventilation loss;
- e) Guide bearing loss;
- f) Thrust bearing loss (only the loss value allocated to the rotating part of the generator motor is taken into account);
- g) Stray loss;
- h) Excitation system loss (such as excitation transformer, rectifier and voltage regulator loss);
- i) Brush electrical and friction loss;
- j) Other losses (such as thrust bearing external circulation oil pump, external cooling fan power and other related losses).

NOTE: The tolerances for winding loss I^2R , ventilation loss, motor thrust bearing loss, motor guide bearing loss and total loss shall be determined in accordance with GB/T 7894.

5.7 Electrical parameters and time constants

5.7.1 The basic values of electrical parameters such as synchronous reactance, transient reactance, super transient reactance, short circuit ratio and time constant shall be based on the power generation conditions.

5.7.2 Electrical parameters and time constants shall meet the requirements of GB/T

6.3 Correction of temperature rise limit under non-reference operating conditions and rated conditions

When the rated operating conditions of the generator motor deviate from the operating conditions specified in Chapter 4, the temperature rise limit shall be corrected in accordance with the provisions of GB/T 755.

6.4 Bearing temperature

6.4.1 Under normal operating conditions, the maximum temperature of the bearing of the generator motor measured by the embedded thermometer method shall not exceed the following values:

- a) Thrust bearing Babbitt alloy pad: 80°C;
- b) Guide bearing Babbitt alloy pad: 75°C.

6.4.2 The buried depth of the temperature sensor shall be 20 mm~30 mm from the friction surface.

7 Operating characteristics and electrical connections

7.1 Special operating requirements

7.1.1 The ability of the generator motor to withstand unbalanced current and overcurrent shall meet the requirements of GB/T 7894.

7.1.2 The generator motor shall be able to withstand the impact of short-term overload and rapid speed increase caused by load shedding of other units in the same water supply system, but the maximum short-term overload shall not exceed 150% of the rated load.

7.1.3 When operating in electric mode, the generator motor shall be able to withstand 150% over torque for 15 s without losing synchronization.

7.2 Electric starting method

The generator motor shall meet the requirements of static frequency converter (SFC) starting and back-to-back synchronous starting when starting in electric mode.

9.3 Critical speed

The first-order critical (bending) speed of the unit shall not be less than 120% of the maximum design speed. For units with a speed of 500 r/min or less, the first-order critical (bending) speed shall not be less than 125% of the maximum design speed.

9.4 Vibration analysis and natural frequency

The structural components of the generator motor shall be subjected to steady-state and transient vibration analysis and natural frequency calculation, the latter of which shall meet the requirements of GB/T 7894.

9.5 Structural strength and rigidity

9.5.1 The generator motor as a whole and its components shall have sufficient strength and rigidity. Under normal operating conditions, special operating conditions and extreme operating conditions, the stress, deformation, vibration, swing and displacement of the whole and its components shall meet the requirements of relevant technical documents and be within a reasonable range, and shall not cause harmful deformation or damage to the generator motor.

9.5.2 Normal operating conditions of generator motors shall include steady-state operation (including rated load operation, partial load operation, leading phase operation, lagging phase operation, etc.), operating condition conversion and start and shutdown. Special operating conditions shall include load shedding in generating conditions, power failure in motoring conditions and emergency shutdown. Extreme operating conditions shall include single-phase short circuit of stator winding to ground, sudden short circuit of two-phase and three-phase, short circuit of half of the rotor poles, mis-synchronization, earthquake and operation at maximum design speed.

9.5.3 The working stress of all parts of the generator motor shall not exceed the specified maximum allowable stress. Fatigue analysis is required for parts subjected to alternating stress, vibration or impact stress. Appropriate safety margins shall be left for rigidity and fatigue strength.

9.5.4 The working stress and deformation of the main components of the generator motor can be calculated by classical formula analysis or by finite element analysis. Finite element analysis is suitable for important components with large capacity and high speed and complex structure, such as stator frame, frame, rotor center body, magnetic pole, yoke, main shaft and shaft system.

9.5.5 The average stress of the main load-bearing parts of the generator motor is calculated analytically using classical formulas or using the finite element method. The allowable stress under normal working conditions shall not exceed 1/3 of the material

pump turbine shall be able to pass through the inner diameter of the stator core during installation and maintenance. If the middle disassembly method is adopted and the lower frame is used as a load-bearing component, the lower frame shall be able to withstand the lifting of the pump turbine top cover, runner and other major parts without causing harmful deformation. The generator motor shall replace the rotor poles and stator bars without hanging the rotor and removing the upper frame, and facilitate preventive inspection of the stator winding ends and stator core.

12.3 The stator frame and core clamping structure and its process shall be able to adapt to the requirements of frequent start-up, shutdown and working condition conversion of the unit to prevent the core from loosening and warping. If the stator core adopts a through-core screw clamping structure, measures shall be taken to fully insulate the through-core screw and the core to avoid short circuit between the through-core screw and the core.

12.4 The fixing structure and materials of the stator bars in the slots and at the ends shall be able to prevent the bars from loosening, sinking and wearing due to long-term effects of thermal stress and vibration under frequent starting and stopping and various normal and abnormal operating conditions.

12.5 The poles shall adopt structures and measures to prevent harmful deformation of the pole coils. The design of the pole coils and inter-pole connections shall be able to withstand the thermal stress, vibration, load rejection or centrifugal force at the maximum design speed during operation, and meet the fatigue strength requirements.

12.6 The pole coil lead wire adopts a bent structure. The bending radius shall not be less than 4 times the lead wire thickness.

12.7 To prevent the centrifugal force from causing the pole insulation support plate to break, the pole insulation support plate shall be fixed relative to the pole core. The insulation design between the pole coil and the core shall meet the requirements of creepage distance. It is advisable to use L-shaped angle insulation, or use insulating materials for effective sealing, etc.

12.8 When using a shrink-fit sliding rotor structure, the sliding rotor shall not loosen under various operating conditions and during maintenance. The tightening calculation shall fully consider the influence of factors such as the centrifugal force of the sliding rotor, the radial force of the guide bearing, the matching length between the sliding rotor and the shaft, and thermal deformation.

12.9 The thrust bearing and guide bearing structures and their lubricating oil circulation and cooling systems shall be able to adapt to the requirements of the unit's forward and reverse bidirectional rotation operation and hot start-up of the unit.

12.10 The structure and geometry of the thrust bearing and guide bearing bushing shall ensure that an oil film can be easily formed when the unit rotates in both forward and reverse directions.

12.11 The thrust bearing of the generator motor shall be equipped with a high-pressure oil jacking device for use during the start-up and shutdown of the unit. During the start-up of the unit, it is advisable to allow the high-pressure oil jacking device to exit operation when the speed reaches (50%~80%) the rated speed. A backup pump shall be set for the high-pressure oil jacking device.

13 Ventilation and cooling system

13.1 The stator and rotor of the generator motor shall adopt an axial and radial closed ventilation cooling system without an external fan. The ventilation cooling system shall meet the requirements of forward and reverse bidirectional rotation of the unit.

13.2 The air cooler shall have a heat exchange margin of 10%~15%. When the bearing uses an external circulation oil cooler, the oil cooler shall be set up as N+1 units.

13.3 When the cooling water of the bearing oil cooler is interrupted, the unit shall be allowed to run at rated speed and rated load for 10 min. The thrust bearing and guide bearing shall not be damaged.

13.4 The working water pressure of air coolers and oil coolers is generally designed to be 1.0 MPa~2.5 MPa. The specific working water pressure shall be specified in the technical agreement between the supplier and the purchaser. Cooler static pressure test: The test water pressure is 1.5 times the working water pressure and is maintained for 30 min. The pressure is then reduced to the working pressure and maintained for 30 min without pressure drop.

13.5 The pressure resistance of plate heat exchangers shall be in accordance with NB/T 47004.1.

13.6 The ventilation and cooling of the collector rings and carbon brushes of the generator motor shall be designed in combination with the carbon powder dust removal.

14 Braking system

14.1 The braking system of the generator motor shall be able to adapt to the requirements of forward and reverse bidirectional rotation and frequent start and stop operation of the unit.

14.2 Electrical brakes and mechanical brakes shall comply with the requirements of GB/T 7894.

14.3 Mechanical brakes shall not produce chemicals that are harmful to the environment and shall be equipped with dust collection devices. Brake rings shall be designed to be detachable. Brake blocks shall be made of wear-resistant and heat-resistant materials. The normal service life shall be no less than 5 years.

18 Materials and parts storage

The storage of generator motors shall comply with the requirements of GB/T 7894.

19 Factory and field tests

19.1 Factory test

The items of factory test shall comply with the provisions of GB/T 7894.

19.2 Field test

The items of on-site tests shall comply with the provisions of GB/T 7894 and GB/T 18482. If necessary, the following tests may be conducted:

- a) Charging capacity test (including temperature rise measurement of end structure);
- b) Black start test.

20 Supply

In addition to complying with the contents listed in GB/T 7894, the scope of supply of generator motors shall also include electric starting devices and related ancillary equipment.

Along with the supply of generator motor products, the supplier may submit to the purchaser the technical documents and drawings related to the main body and its ancillary equipment according to the calendar days after the contract takes effect as specified in the special technical agreement. The specific information of the relevant technical documents and drawings shall comply with the provisions of GB/T 7894.

21 Trial operation and warranty period

21.1 Trial operation

Before the generator motor and its ancillary equipment are installed and tested on site and put into commercial operation, they shall be put into operation for 15 d. The 15-d operation shall comply with the provisions of GB/T 18482.

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