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Guide for magnetization test of generator stator core

发电机定子铁心磁化试验导则

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4 Symbols

Clause 4 defines the symbols used throughout the document. The geometric ones are the width of the stator ventilation ducts and their number, the outer and inner diameters of the core, the yoke height, the slot depth, the net length and the overall length of the core, and the cross-sectional area and the mass of the yoke, in metres, square metres and kilograms.

The electrical and magnetic ones are the flux density in the yoke during the test in tesla, the magnetic field strength in the yoke in amperes per metre, the excitation coil current in amperes, the excitation coil voltage and the search coil voltage in volts, the numbers of turns of the two coils, the test supply frequency and the rated frequency in hertz, the test supply capacity in kilovolt amperes, and the supply capacity factor.

The loss and temperature ones are the active power measured from the excitation current and the search coil voltage in watts, the specific total loss computed from the test result and the specific total loss of the lamination material at 1.0 T and at 1.4 T, both in watts per kilogram, the stacking factor of the core, the density of the lamination steel, the test time in minutes, the ambient temperature and the temperature at each measuring point in degrees Celsius.

Four further symbols carry temperature rises in kelvin: the maximum and the minimum rise from the start to the end of the test, the difference between them for the same part of the core, and the corrected values of the maximum rise and of the maximum difference together with the measured values from which they are obtained.

5 Preliminary calculation

5.1 The cross-sectional area of the yoke follows from Formula (1) as the product of the net length of the core and the yoke height; the net length is derived from the core length, the width of the ventilation ducts and their number through the stacking factor, and the yoke height from the outer and inner diameters and the slot depth. The stacking factor is fixed by

the manufacturer and normally lies between 0.93 and 0.96 for laminations 0.35 mm thick and between 0.94 and 0.97 for laminations 0.50 mm thick.

5.2 The mass of the yoke follows from Formula (2) from the outer diameter, the yoke height, the yoke cross-section and the density of the lamination steel. That density is fixed by the manufacturer; for laminations 0.35 mm to 0.50 mm thick it is normally between 7 600 and 7 850 kilograms per cubic metre according to GB/T 2521.1 and GB/T 2521.2.

5.3 The number of excitation turns follows from Formula (3), which relates it to the excitation voltage, the test frequency, the yoke cross-section and the flux density, and is then rounded to a whole number; the test frequency is normally 50 Hz or 60 Hz and the yoke flux density is taken as 1.0 T for hydrogenerators and 1.4 T for cylindrical-rotor synchronous generators, the number actually used on site being adjusted to the conditions found there. The excitation ampere-turns follow from Formula (4) and the excitation current from Formula (5), the magnetic field strength of the lamination steel at 1.0 T or at 1.4 T being given by the manufacturer.

5.4 The capacity of the test supply follows from Formula (6), where the capacity factor is normally taken as 1.1 or settled from the actual conditions. Where the supply is a three-phase transformer and two of its phases are used for the test, the transformer capacity shall be three times the calculated value; where capacitor compensation is used, the supply capacity is configured to the compensated requirement.

5.5 The search coil voltage follows from Formula (7) from the excitation voltage and the ratio of search coil turns to excitation coil turns; the number of search coil turns is normally 1 or 2.

6 Test requirements

6.1 Enough safety clearance is kept around the stator core under test and around the test equipment, and warning signs are posted. 6.2 The test supply is a sound alternating current supply whose capacity meets the calculated requirement.

6.3 Instruments and their ranges are chosen from the preliminary calculation. Electrical measuring instruments are of accuracy class 0.5 or better and a power analyser is preferred; where a wattmeter is used it is a matched low power factor wattmeter. Instrument transformers are of accuracy class 0.2 or better.

6.3.3 Temperature is preferably measured with an infrared thermal imager, and may also be measured with an infrared spot pyrometer, an alcohol thermometer or a thermocouple instrument; mercury thermometers are not permitted. The imager shall be accurate to +/-2 °C or to the reading multiplied by +/-2 percent, and alcohol thermometer or thermocouple measurement to +/-1 °C. A portable infrared spot pyrometer is recommended alongside the imager. Where embedded temperature detectors are used, they are distributed evenly around the inner and outer circumference of the core at top, middle and bottom.

6.4 The excitation cable is rated above the supply voltage and has a cross-section suited to the test current; it is unscreened and unarmoured; it is wound evenly around the circumference of the core or arranged symmetrically, all cables wound in the same direction. Insulating material is placed where the cable meets the corners of the core, the insulation resistance between coil, core and frame meets DL/T 5420, and the cable route avoids scaffolding, cladding panels and other items that induced eddy currents could overheat. Where the leads are long or the turns numerous, the number of turns is set one or two turns below the calculated value to offset the voltage drop in the coil itself.

6.5 The search coil is preferably wound on the core alone; its cable is rated above the calculated search coil voltage and is likewise unscreened and unarmoured. Where the excitation coil is wound evenly the search coil may be placed anywhere on the circumference; where the excitation coil is arranged symmetrically the search coil goes midway between two adjacent excitation coils; where the excitation coil is a single turn the search coil goes in the orthogonal position.

7 Test method

7.1 Before the test the bore of the core is clean and free of foreign matter and the laminations free of burrs, the temperature detectors built into the generator are reliably earthed, the insulation of the through bolts meets the technical rules, any bars or windings already in the slots are left open circuit, and the wiring, the tightness of the joints and the condition of the cables are checked. 7.2 The excitation and search coils are then wound as required; Figure 1 gives the connection diagram with voltage and current transformers, voltmeter, ammeter and low power factor wattmeter, the last three replaceable by a power analyser.

7.3 The initial temperature of the core and the ambient temperature are measured before the test and shall not differ by more than 5 K. 7.4 During the test the core temperature and temperature rise are watched closely; local overheating or smoke calls for an immediate stop, the test being restarted once the cause has been removed. Vibration and noise are monitored as well, and abnormal vibration or noise calls for the supply to be cut. Where the magnetization test still cannot be carried out, the low flux eddy current method of Annex A may be considered.

7.5 The flux density in the yoke is obtained from the measured search coil voltage by Formula (8), which relates it to the test frequency, the yoke cross-section and the number of search coil turns. 7.6 The active power is measured from the excitation coil current and the search coil voltage, and the actual core loss is that power multiplied by the ratio of excitation turns to search coil turns.

7.7.1 For generators of 50 Hz rated frequency, Table 1 sets 1.4 T for 45 min for cylindrical-rotor synchronous generators and 1.0 T for 90 min for hydrogenerators. As a rule the flux density shall not fall below 1.26 T for the first and 0.9 T for the second; where site