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Draft Indian Standard

GUIDE FOR TESTING DIRECT-CURRENT (dc) MACHINES

Rotating Machinery Sectional Committee, ETD 15

FOREWORD

This Indian Standard was adopted by the Indian Standard Institution on 20 November 1979, after the draft finalized by the Rotating Machinery Sectional Committee had been approved by the Electrotechnical Division Council.

The requirements of dc machines are covered in IS 15999 (Part 1) /IEC 60034-1. This guide has been prepared with a view to provide guidance on the methods of tests of dc machines. This standard, therefore, shall be read in conjunction with IS 15999 (Part 1) /IEC 60034-1.

The term 'large dc machine' (see 5.7.3) has been used in this standard. Whether the machine is large or not would depend upon the size and output in kW/rpm.

This guide covers instructions for conducting and reporting the more generally applicable and acceptable tests to determine the characteristics of direct current machines. It is not intended to cover all possible tests nor those of research nature. The guide shall not be deemed as making it obligatory to carry out any or all the tests discussed here in any given transaction.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS 2: 2022. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

GUIDE FOR TESTING DIRECT-CURRENT (dc) MACHINES

1 SCOPE

This standard covers methods for conducting and reporting the tests for dc machines except traction machines, marine service, air transport and mill type motors. This standard applies to direct current generators and motors rated 0.3 kW and higher.

2 TERMINOLOGY

For the purpose of this standard, the definitions given in IS 1885 (Part 35) shall apply.

3 GENERAL CONDITIONS

The provisions given in 5.5 of IS 15999 (Part 2/Sec 1) / IEC 60034-2-1 shall apply for reference, temperature, general conditions of tests and class of accuracy of measuring instruments.

4 PREPARATION FOR TESTS

4.1 Instruments shall be so chosen that quantities to be measured fall within 20 to 95 percent of the scale of the instrument.

4.2 While measuring by more than one instrument, readings for each measurement on all instruments should be preferably taken simultaneously.

4.3 Before starting the tests, the value of the air gap between main pole and armature, and inter pole and armature shall be measured by means of feeler gauges. When the machine is small and there is no possibility of measuring air gap by feeler gauges, the air gap may be calculated by measuring the diameter of the bores at the centre of main poles and inter poles before inserting armature into magnetic system. Subtract the armature diameter value from bore diameters and half of these values will be the air gap between main pole and armature, and interpole and armature.

The spacing of brushes along the surface of commutator shall also be checked.

4.4 After checking that the machine is ready for the test, the brush bedding shall be done depending upon the commutator surface. Brushes shall be fixed in geometrical neutral position, with the armature held in one position and by connecting a sensitive moving coil instrument to the brushes and passing pulses from separate source of supply through the main pole winding. If the brushes are in magnetic neutral position, the

Instrument pointer shall not be deflected or deflection shall be minimum and equal in opposite directions when the armature is set in different positions with respect to machine poles.

4.5 When the machine is running at rated load, the magnetic neutral position of the brushes is determined by the following condition at changes in direction of rotation of the machine:

- a) The speed is practically constant at a constant voltage, load and field current of the motor; and
- b) The terminal voltage is practically constant at a constant speed, load and field current of the generator, provided the field winding is connected to an independent source of supply.

In case of machines with compound excitation, the system of excitation (that is, commutative or differential) shall be kept unchanged at either right- or left-hand rotation of the machine.

5 TEST METHODS

5.1 The standard describes methods for the following tests:

- a) Measurement of winding resistances,
- b) Measurement of winding insulation resistance,
- c) Determination of open circuit characteristics,
- d) Determination of regulation characteristics for generator and motor,
- e) Determination of external characteristics (for generator only),
- f) Temperature-rise test,
- g) Checking of commutation at rated load and at short-time current overload ,
- h) Determination of efficiency of a machine,
- j) Measurement of vibrations,
- k) Load saturation characteristics (for excitors only),
- m) Nominal exciter response for dc excitors,
- n) Over-speed test, and
- p) High voltage test.
- q) Measurement of inductance of armature winding and main pole winding.

5.2 Measurement of Winding Resistance

5.2.1 Resistance of all windings shall be measured in accordance with 7 of IS 4029.

5.2.2 When the resistance of armature with a simple lap or simple wave winding is measured, it is recommended to measure the resistance between commutator bars $K/2p$ apart (where K is the number of commutator bars and $2p$ total number of poles). In case when ' $K/2p$ ' ratio is a fractional number, it shall be rounded off to the nearest whole number.

5.2.3 The resistance of the armature winding shall be measured before and after the temperature-rise test at the same commutator bars as far as possible at one and the same position of the armature. Care shall be taken to secure accurate resistance measurements, since a small error in measuring resistance will cause a comparatively large error in determining the temperature.

5.3 Measurement of Insulation Resistance - Insulation resistance shall be measured between winding and frame (earth), and between winding and winding.

5.3.1 The insulation resistance when the high voltage test is applied, shall not be less than two megohm. The insulation resistance shall be measured with dc voltage of about 500 V applied for a sufficient time for the reading of the indicator to become practically steady, such voltage being taken from an independent source or generated in the measuring instrument.

NOTE - When it is required to dry out windings at site to obtain the minimum value of insulation resistance, it is recommended that procedure for drying out as specified in IS 900 and IS 15429 may be followed.

5.4 Determination of Open Circuit Characteristics

5.4.1 The no-load curve represents the dependence of the armature voltage on the field current at rated speed of a direct current machine at no-load condition at both separate and self excitation. In the latter case, the series field winding (if used) shall not carry the current of the shunt field winding. The no-load characteristics curve of series excited generators shall be determined only at separate excitation.

5.4.2 If the speed (n) differs from rated value (n_{rated}) when determining the no-load characteristics curve, the no-load voltage (V_o) may be calculated by following formula:

$$V_o = V \frac{n_{rated}}{n}$$

Where

V = measured voltage

5.4.3 The no-load saturation curve is determined by the field excitation required to provide given voltages at rated base speed and no load. The data should be taken at properly spaced voltages to permit an accurate plot from zero field current up to approximately 125 percent of rated voltage.

5.4.3.1 Separately driven - The machine should be driven at rated speed by any suitable means. Its brushes should be well fitted and located on the magnetic neutral position (*see 4.4*). If possible, field current should be supplied from a separate source to stabilize the voltage and facilitate the taking of data. Simultaneous readings of field current and armature voltage should be taken. A set of readings should be taken beginning with zero field current and increasing until maximum voltage is obtained. Three readings taken should be as near as possible to 90 percent, 100 percent and 110 percent of rated voltage. The residual voltage may be measured at the beginning and completion of this test. To avoid hysteresis effects, the field current should never be carried above the desired point and then decreased. If this should occur during the test, the field current should be reduced to zero and increased to the desired value. Another set of readings may be obtained by starting at maximum voltage and decreasing field current. To avoid hysteresis effects, the field current should never be carried below the desired point and then increased. If this should occur during the test, the field current should be increased to the maximum value and decreased to the desired value

5.4.3.2 Self driven (except series motors) - If no suitable separate drive is available, data for an approximate no-load saturation curve may be taken by operating the machine as an uncoupled motor

from a separate source of direct-current power. This source shall be adjustable from approximately 25 percent to 125 percent of rated voltage. Field current required to obtain rated speed at the different voltages differ from no-load saturation curve data by the effects of the armature currents which are required to operate the machine as an uncoupled motor. The machine may become unstable at low voltage and precautions against over speed should be observed.

5.4.4 For motors the no-load curve shall be determined by running the machine as generator.

5.5 Determination of Regulation Characteristics

5.5.1 Regulation characteristics of a dc generator represent the dependence of the terminal voltage on the load current at constant field current and shall be determined at winding temperature approximately equal to the working temperature.

5.5.2 Regulation characteristics of a dc motor represents the dependence of the speed of motor on the load current at constant field current and shall be determined at temperature approximately equal to working temperature.

5.5.3 Regulation characteristics shall be plotted at various loads from zero load to 150 percent of rated value.

5.5.4 In case of compound or series excitation, regulation test shall be done up to a value of load where the speed does not exceed the permissible limits.

5.6 Determination of External Characteristics (for Generators Only)

5.6.1 The external characteristic curve of dc generators represents the dependence of the terminal voltage on the load current or output at constant speed and field current (for separately excited generators) or at constant setting of field rheostat (for self-excited machines) and is determined at a winding temperature approximately equal to the design working temperature.

5.6.2 External characteristics shall be plotted at various loads from zero load to 150 percent of rated value.

5.6.3 The departure of the voltage from rated value (ΔV) in percent shall be calculated for any point of the curve from the following

Formula :

$$\Delta V = \frac{V - V_{rated}}{V_{rated}} \times 100 \text{ percent}$$

where

V = the voltage at the given point of the curve, and

V_{rated} = the rated voltage of the machine

5.6.4 For large machines external characteristics test shall be performed if it is agreed between the purchaser and the supplier.

5.7 Temperature-Rise Test

5.7.1 Temperature-rise test shall specify the values of temperature-rise of different parts of the machine and rated data of the machine.

5.7.2 The machine shall run at rated data till such time the temperature of all the parts become constant and then the temperature-rise of different parts of the machine shall be measured in accordance with 8.9 of IS 4029.

5.7.3 The temperature-rise on continuous rated large dc machines may be carried out employing indirect method.

5.7.3.1 The machine shall be running continuously under no-load condition, that is, at rated volts and zero current; and after that under short circuit condition, that is, at zero volts and rated current. The temperature-rise of the tested windings shall be considered. As equal to the sum of the winding temperature-rises measured directly after each of the above runs.

5.7.4 Where two or more similar machines are tested, back to back connection shall be resorted for loading.

5.8 Checking of Commutation at Rated Load and at Short Time - Commutation test shall be performed in accordance with IS 15999 (Part 1) / IEC 60034-1.

5.9 Efficiency Test - Efficiency test shall be conducted in accordance with IS 15999 (Part 2/Sec 1) / IEC 60034-2-1.

5.10 Measurement of Vibrations - The vibrations of the machines shall be measured in accordance with IS 12075.

5.11 Load Saturation Characteristics (for Exciters Only) - Load saturation characteristics represent the dependence of the armature voltage on the field current at rated speed and constant load resistance. The value of constant load resistance shall be equal to the field resistance at 75°C, of the machine while this exciter is feeding power. Alternatively constant load resistance shall be obtained from the following formula:

$$\text{Load Resistance} = \frac{\text{Rated Voltage}}{\text{Rated Current}} \text{ of the exciter}$$

5.11.1 Load saturation characteristics shall be plotted starting from zero field current and then gradually increasing it to its maximum value and then gradually decreasing to zero field current.

5.12 Nominal Exciter Response for dc Exciters - Nominal exciter voltage response or the response ratio is determined from the following formula in accordance with definition given in IS 1885 (Part 35).

$$\text{Response ratio} = \frac{U_{\Pi} - U_N}{U_N \cdot t}$$

where

t = 0.5 seconds,

U_{Π} = exciter voltage attained after 0.5 seconds converting the excitation voltage time area into equivalent triangle, and

U_N = rated exciter voltage or voltage at the slip-rings of the machine to be excited.

5.12.1 Testing shall be carried out as follows

5.12.1.1 The exciter which is to be tested shall be run at no-load rated voltage and corresponding field current adjusted by providing variable resistance in series of the field winding. After some time this variable resistance is short circuited. An oscillograph shall be connected across the armature terminals. From oscillograph the voltage increase in 0.5 seconds shall be found out and thus response ratio may be calculated.

5.13 Over Speed Test - All dc machines shall be tested for overspeed in accordance with IS 15999 (Part 1) / IEC 60034-1 for 2 minutes.

5.14 High Voltage Test - High voltage test shall be conducted in accordance with IS 15999 (Part 1) / IEC 60034-1.

5.15 Measurement of Inductance of Armature Winding and Mainpole Winding.

5.15.1 Armature Circuit Inductance Measurement

This test is done by applying single phase 50 Hz alternating current to the terminals of the machine and taking reading of the voltage across the armature, compensating inter pole winding and terminals of the machine. In case of series and compound machines, the series field winding should be out of circuit to prevent the machine acting like a series motors. The series field should not be shorted.

5.15.1.1 It is desirable that the connections to the armature be made with copper blocks replacing the brushes. This precaution is taken to prevent overheating the brushes and the commutator bars under the brushes. The copper blocks have approximately the shape and size of the brushes except where the copper block contacts the commutator bar. One copper block should contact each commutator bar that would be contacted by the brushes. Each copper block should be connected to each brush-holder or brush-holder bracket or stud by a shunt the same as the brush. Normal carbon brushes can be used on small machines if care is taken not to overheat them or the commutator bats.

5.15.1.2 An alternate method for connecting to the armature is to make direct connections to the risers of the commutator bars that would be contacted by the brushes. These connections short as many bars as the brush would short. The brushes should be removed from the commutator.

5.15.13 Unsaturated inductance - The armature, compensating interpole winding and terminal alternating potential and current, should be recorded for each point for the unsaturated inductance. The voltage across the open circuited shunt field should be observed with an alternating-potential voltmeter to assure that the voltage on the shunt field is not excessive.

Reading should be taken in approximately 10 percent steps from 10 percent to 60 percent of rated current.

NOTE - This test is required to be carried out at the manufacturer's work place and not at site. If it is necessary to carry out this test at site, arrangements are to be made for sc source.

5.15.14 Saturated inductance - This test is the same as the unsaturated inductance except that the shunt field is carrying the same shunt field direct current as for rated load. Record the shunt-field current in amperes for each point as well as the above alternating-current readings.

5.15.15 The inductance is determined from the slope of the curve plotted from the above data. The volts-per-ampere slope of the curve near the origin (ohms) is used in the equation given below to obtain the inductance in henrys:

$$1H = \frac{1\Omega}{2\pi f}$$

5.15.16 The alternating-current impedance may be assumed to be entirely reactance although precautions should be taken to verify this by measuring the alternating-current resistance of the circuit as tested to see that it is negligible.

5.15 .2 Measurement of Inductance of Main Pole Windings

5.15.2.1 Shunt-field inductance test - The machine should be driven at rated speed. In the case of multispeed-rated machine, the machine should be driven at lowest rated speed. The test is taken with an oscillograph. The elements of the oscillograph should be connected to record as follows:

- a) Timing wave,
- b) Armature terminal voltage,
- c) Shunt-field current, and,
- d) Shunt-field voltage.

5.15.2.2 The test should be taken at no-load with the shunt-field connected to an exciter having a current capacity of several times the rated shunt field current. No rheostats or external resistors are to be used in the shunt field circuits. All other windings in the direct axis should be open circuited.

NOTE - This test is required to be carried out at the manufacturer's work place and not at site. If it is necessary to carry out this test at site, arrangements are to be made for ac source

5.15.2.3 Adjust the exciter to give rated voltage on the machine. Measure the shunt- field voltage. Reduce the field current to zero and open the field switch. Adjust the exciter voltage to above value of shunt-field voltage. Trigger the recording apparatus and suddenly close the field switch.

5.15.2.4 The initial slope dl_{fo}/dt of shunt-field current wave should be determined from the developed film. The unsaturated self-inductance of shunt-field circuit is calculated by:

$$L_{fo} = \frac{E_{fo}}{\frac{dl_{fo}}{dt}} = (\text{H})$$

Where

- L_{fo} = Self inductance of shunt field circuit (unsaturated), in henrys;
- E_{fo} = exciter voltage in volts; and
- dl_{fo}/dt = Initial slope of field current from oscillogram, in ampere per seconds

5.15.2.5 An alternate method of calculation is to use the initial slope of the armature voltage trace. Care should be taken not to include the effects of residual voltage.

The self-inductance may be computed by:

$$L_{fo} = \frac{E_{fo}}{\left(\frac{In}{V_{tl}}\right) \left(\frac{dV_{to}}{dt}\right)}$$

where

- I_{fl}/V_{tl} = ratio of field terminal voltage as obtained from the unsaturated part of the saturation curve corresponding to the speed at which this test was made, and
- (dV_{to}/dt) = initial slope of the armature voltage from oscillogram in volts per second.

5.15.2.6 The higher inductance from these two methods should be used.

Annex 1

The latest revisions of the following standards should be used in this standard.

Sl No	IS Number	Title
i)	IS 15999 (Part 1): 2021/ IEC 60034-1: 2017	Rotating electrical machines - Part 1 : Rating and performance
ii)	IS 2: 2022	Rules for rounding off numerical values (<i>revised</i>).
iii)	IS 1885 (Part 35) : 2021/ IEC 60050: 411 : 1996	Electrotechnical Vocabulary: Part 35 Rotating Machinery (Second Revision)
iv)	IS 4029: 2010	Guide for testing three-phase induction motors
v)	IS 900: 2019	Code of Practice for Storage, Installation and Maintenance of Induction Motors (Third Revision)
vi)	IS 15999 (Part 2/Sec 1): 2023/ IEC 60034-2-1 : 2014	Rotating Electrical Machines Part 2 Determining Losses and Efficiency from Tests Section 1 Standard Methods (Excluding Machines for Traction Vehicles)
vii)	IS 12075 : 2008	Mechanical Vibration of Rotating Electrical Machines with Shaft Heights 56 mm and Higher - Measurement, Evaluation and Limits of Vibration Severity
viii)	IS 15429 : 2004	Storage, Installation and Maintenance of dc Motors - Code of Practice