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IS 7816 (1975): Guide for testing insulation resistance of rotating machines [ETD 15: Rotating Machinery]



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IS : 7816 - 1975

Indian Standard

GUIDE FOR TESTING INSULATION RESISTANCE OF ROTATING MACHINES

(Second Reprint MARCH 1983)

UDC 621.313 : 621.317.333



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INDIAN STANDARDS INSTITUTION
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Indian Standard

GUIDE FOR TESTING INSULATION RESISTANCE OF ROTATING MACHINES

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Indian Standard

GUIDE FOR TESTING INSULATION RESISTANCE OF ROTATING MACHINES

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 15 October 1975, after the draft finalized by the Rotating Machinery Sectional Committee had been approved by the Electrotechnical Division Council.

0.2 This guide describes characteristics of insulation resistance of windings, the manner in which these characteristics may serve to indicate the condition of the winding and the testing procedure for obtaining insulation resistance values.

0.3 This standard has been prepared with a view to achieving the following objectives:

- a) To describe and define insulation resistance as applied to the winding of a rotating machine.
- b) To review the factors which affect or change insulation resistance characteristics and recommend uniform test conditions.
- c) To outline and recommend uniform methods for measuring insulation resistance together with precautions for avoiding erroneous results.
- d) To provide a basis for interpreting insulation resistance test results to estimate the suitability of the insulation system of winding for service or for high voltage test.
- e) To present empirical formulae, based on machine ratings, for the calculation of recommended minimum insulation resistance values for various types of rotating machines.

0.4 This standard is not intended to be applied for routine or type testing for insulation resistance of rotating machines but to bring out the various factors influencing the insulation resistance of a machine and to help in the correct assessment of the condition of the insulation whenever this information is required. It is, therefore, expected to assist both the manufacturer and the user to verify the condition of the insulation of the machine.

0.5 In the preparation of this standard, assistance has been derived from IEEE Code No. 43 'Recommended guide for testing insulation resistance of rotating machinery' issued by Institution of Electrical and Electronics Engineers, USA.

0.6 In reporting the result of a test made in accordance with this standard if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960*.

1. SCOPE

1.1 This guide lays down method for the measurement of insulation resistance of armature and field windings of all types and voltages of rotating electrical machines rated 1 MW and above.

1.2 This standard also recommends minimum values of insulation resistance of windings of ac and dc rotating machines.

2. TERMINOLOGY

2.1 For the purpose of this standard, in addition to the definitions given in IS : 1835 (Part XXXV)-1973† the following definition shall apply.

2.1.1 Polarization Index — It is the ratio of the 10-minute insulation resistance value to the 1-minute resistance value.

3. GENERAL INFORMATION

3.1 Insulation resistance is the term generally used to describe the quotient of the applied voltage between the windings and frame or between open windings divided by the current at some given time measured from the start of electrification; thus references to terms like 'one-minute' or 'ten-minute' insulation resistance have been made in this guide.

NOTE 1 — Before commencing the insulation resistance test, the continuity of the winding shall be checked.

NOTE 2 — The current which results from the applied direct voltage consists of two parts; that which flows in leakage paths over the surface of the insulation and that which flows within the volume of the insulation. The current which flows within the volume of the insulation may be further subdivided as follows:

- a) The capacitance charging current is of comparatively high magnitude and short duration. Usually the charging current has effectively disappeared by the time the first readings are taken, and does not affect the measurements.
- b) The absorption current decays at a decreasing rate from a comparatively high initial value to zero. The resistance-time relationship is a power function which may be plotted on log-log graph paper as a straight line. Usually the resistance measured in the first few minutes of a test is largely determined by the absorption current.
- c) The conduction current, which, with the surface leakage current, is practically steady with time. These currents predominate after the absorption current has become insignificant.

NOTE 3 — The discharge current which flows after the removal of the impressed voltage in a suitable discharge circuit consists of following two parts:

*Rules for rounding off numerical values (*revised*).

†Electrotechnical vocabulary: Part XXXV Rotating machines.

- a) The capacitance discharge current which is nearly instantaneous, depending upon the discharge resistance, and
- b) The absorption discharge current which decays from a high initial value to zero.

3.2 The insulation resistance of a rotating machine winding is a function of the type and assembly of insulating material. In general, it varies directly with the thickness of the insulation and inversely with conductor surface area.

3.3 Insulation resistance measurements are affected by the factors given below:

- a) Surface condition,
- b) Moisture,
- c) Temperature,
- d) Magnitude of test voltage,
- e) Duration of application of test voltage,
- f) Residual charge in the winding,
- g) Ageing of insulation, and
- h) Mechanical stresses.

3.3.1 The effects of some of these factors are described in 4.

3.4 Readings of insulation resistance are usually taken after the application of test voltage for 15 seconds and 1 minute and if facilities are available after 10 minutes to provide data for obtaining the polarization index.

3.4.1 The polarization index may be expressed as the ratio of the values of 10-minute to 1-minute insulation resistances.

3.4.2 Alternatively, the polarization index may be expressed by the ratio of values of 60-second to 15-second insulation resistances.

NOTE — Depending upon the facilities available any one of the methods, given in 3.4.1 and 3.4.2 may be chosen for expressing the polarization index but it shall be clearly specified which method is to be adopted, before the test is performed. The value of the polarization index shall be expressed along with the ratio of time employed.

3.5 The interpretation of insulation resistance measurements of machine windings is described in 8. A history of such measurements for a particular winding is valuable. The polarization index (ratio of 10-minute to 1-minute insulation resistance readings) is a useful means of determining if a machine is suitable for high voltage testing or for operation. For this purpose, the effect of temperature is usually small enough to be neglected and correction for temperature is not required. However, (see 8.2, 8.3) when only the 1-minute insulation resistance value is available, it may be compared to the calculated recommended minimum value of insulation resistance, after the observed value has been corrected for temperature (see 4.3).

4. FACTORS AFFECTING INSULATION RESISTANCE

4.1 Effect of Surface Condition

4.1.1 Foreign matter, such as carbon, dust, oil, grease and corrosive

vapour deposited on creepage surfaces, lowers the insulation resistance. The carbon dust is particularly important in the case of machines having commutators or slip rings or both as these machines have relatively large exposed creepage surfaces.

4.1.1.1 Dust on insulation surfaces which is ordinarily non-conducting when dry may, when exposed to moisture, become partially conducting and lower the insulation resistance.

4.1.1.2 If the insulation resistance is reduced because of contamination or excessive surface moisture, it may usually be brought up to its proper value, where no defect exists, by cleaning and drying to remove the moisture.

4.2 Effect of Moisture

4.2.1 Regardless of the cleanliness of the winding surface, if the winding temperature is at or below the dew point of the ambient air, a moisture film forms on the insulation surface and lowers the insulation resistance. The effect is more pronounced if the surface is contaminated. It is important to make resistance measurements when the winding temperature is above the dew point.

4.2.2 Many types of winding insulation are hygroscopic and moisture may be drawn into the body of the insulation from the humid ambient air. Absorbed moisture has a large effect on the insulation resistance. Machines in service are usually at a temperature high enough to keep the insulation comparatively dry. Machines out of service may be heated to keep the winding temperature at least 5°C above the dew point.

4.2.3 If the machine is out of service for a long time, it is likely to absorb moisture. Drying out operation in accordance with 8.4.1 of IS : 900-1965* shall, therefore, be carried out before the machine may be put into operation if the insulation resistance value and the values of polarization index are low. Figure 1 illustrates a typical example of the values of insulation resistance for 10 minutes and 1 minute during drying process.

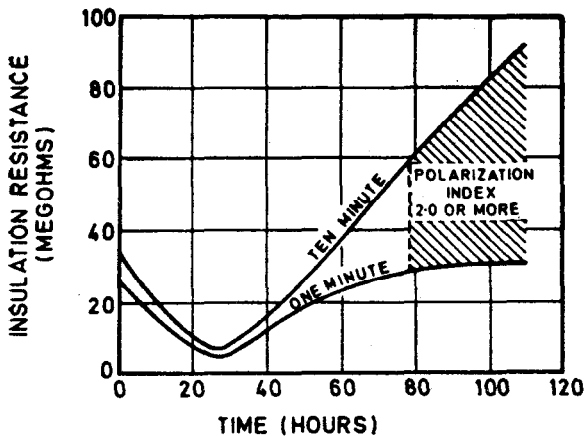
4.2.4 When tests are to be made on a machine that has been in service, the tests should be made before the machine winding temperature drops to room temperature. The opportunity should be taken to test at several temperatures to establish the applicable temperature coefficient (see 4.3.4).

4.3 Effect of Temperature

4.3.1 When polarization index is used to determine the insulation condition the effect of temperature is usually small enough to be disregarded and it is not necessary to make a temperature correction. The effect of temperatures on polarization index is small if the machine temperature does not change between the 1- and 10-minute readings.

4.3.2 Insulation resistance of most of the insulating materials varies inversely with temperature.

*Code of practice for insulation and maintenance of induction motors (revised).



Initial Winding Temperature 25°C

Final Winding Temperature 75°C

FIG. 1 TYPICAL VALUES OF 1-MINUTE AND 10-MINUTE INSULATION RESISTANCE DURING THE DRYING PROCESS OF A CLASS B INSULATED AC ARMATURE WINDING OF LARGE MACHINE

NOTE — The polarization index values in the figures relates to 10-minutes to 1-minute insulation resistance values.

4.3.3 To minimize the effect of temperature when comparing the results of insulation resistance test, or when applying the recommended minimum value of insulation resistance as given in 9, it is important that the test value should be corrected to 40°C. The correction may be made conveniently by use of the following formula:

$$R_{40^{\circ}\text{C}} = K_{40^{\circ}\text{C}} \times R_t$$

where

- $R_{40^{\circ}\text{C}}$ = insulation resistance (in megohms) corrected to 40°C,
 R_t = measured insulation resistance of the winding (in megohms) at $t^{\circ}\text{C}$, and
 $K_{40^{\circ}\text{C}}$ = temperature coefficient of insulation resistance as observed for temperature $t^{\circ}\text{C}$ found in accordance with 4.3.4 (see Fig. 2).

NOTE — For example, it may be noted that an insulation having a resistance of 100 megohms at 6°C might have a resistance at 40°C of 10 megohms and at 72°C of 1 megohm.

4.3.3.1 The insulation resistance temperature coefficient is influenced by the same variables which affect insulation resistance (see 4.1 and 4.2).

4.3.4 The correction of insulation resistance to 40°C may be done by making measurements at several temperatures, all above the dew point, and plotting the results. When a logarithmic scale is used for insulation

resistance and a linear scale for temperature, test points should approximate a straight line which indicates the 40°C value. For a similar condition, $K_{40^{\circ}\text{C}}$ for any temperature may be determined from such a plot by inversion of formula given in 4.3.3.

4.3.5 The value of the temperature coefficient of insulation resistance is also dependent on the class of insulation system used (see IS : 1271-1958*).

4.3.6 An approximate value for the temperature coefficient may be obtained by using Fig. 2 which is based on doubling of insulation resistance for each 18°C reduction in temperature (above dew point).

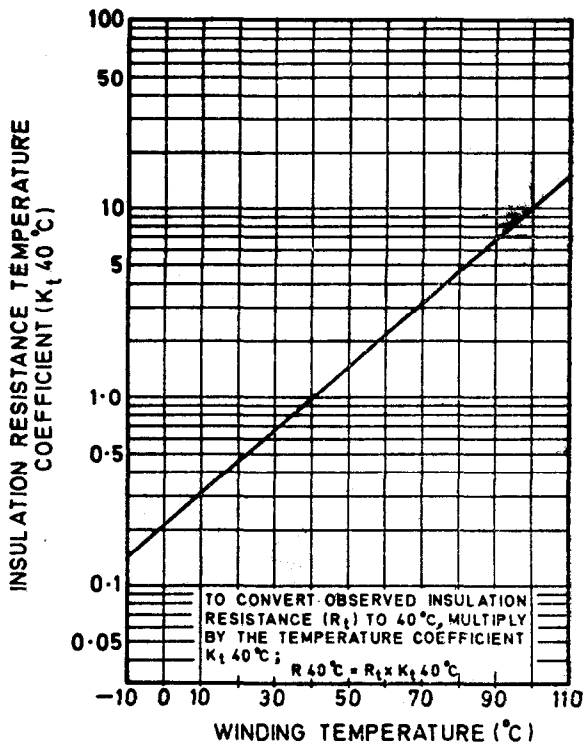


FIG. 2 APPROXIMATE TEMPERATURE COEFFICIENT OF INSULATION RESISTANCE OF ARMATURE WINDING OF ROTATING MACHINE

4.4 Effect of Magnitude of Test Voltage

4.4.1 In the measurement of insulation resistance the applied voltage shall

*Specification for classification of insulating materials for electrical machinery and apparatus in relation to their thermal stability in service.

be restricted to a value appropriate to the voltage rating of the winding. This is particularly important in the case of small, low-voltage machines, or wet or water-soaked units. If the test voltage is too high, the applied test voltage may actually overstress and cause failure of the insulation.

4.4.2 Insulation resistance tests are usually made at direct voltage of 500 to 5 000 volts depending upon the rated voltage of the winding. The value of insulation resistance decreases somewhat with an increase in applied voltage, however, for machines in good condition substantially the same insulation resistance is obtained for any test voltage up to the peak value of the rated operating voltage.

4.4.3 If the insulation resistance decreases significantly with an increase in applied voltage it may be an indication of imperfections or fractures of the insulation aggravated by the presence of dirt or moisture, or may be due to the effects of dirt or moisture alone, or may result from numerous other phenomena not necessarily associated with any defect or weakness. The change in resistance is more pronounced at voltages considerably above operating voltage as used in dc high voltage insulation testing.

4.5 Effect of Duration of Application of Test Voltage; Polarization Index

4.5.1 The measured insulation resistance of a winding normally increases with the duration of application of the direct test voltage (see Fig. 3). The increase usually is rapid when the voltage is first applied and the readings gradually approach a fairly constant value as time elapses. After 30 seconds of voltage application, these resistances may be a small fraction of their final values. The measured insulation resistance of a dry winding in good condition may continue to increase for hours with constant test voltage continuously applied; however, a fairly steady value is usually reached in 10 to 15 minutes. If the winding is wet or dirty, the steady value is usually reached in 1 or 2 minutes after the test voltage is applied. The slope of the curve which is an indication of insulation conditions, is usually apparent if a 10-minute test is made.

4.5.1.1 The amount of insulation resistance increase with the duration of the test voltage application may be useful in appraising the cleanliness and the dryness of a winding. If facilities are available, the test voltage may be applied for 10 minutes or more to develop the dielectric absorption characteristic. This characteristic may be used to advantage to detect moisture or dirt in the windings.

4.5.2 The polarization index is the ratio of the 10-minute resistance value to the 1-minute resistance value. The polarization index may be considered as a means of expressing the shape of the characteristic curve (see 4.5.1.1 and Fig. 1 and 3) in terms of a single numerical quantity, since a rising curve tends to increase the index and a flat curve tends to lower it. The polarization index is useful in the appraisal of the winding for dryness and for fitness

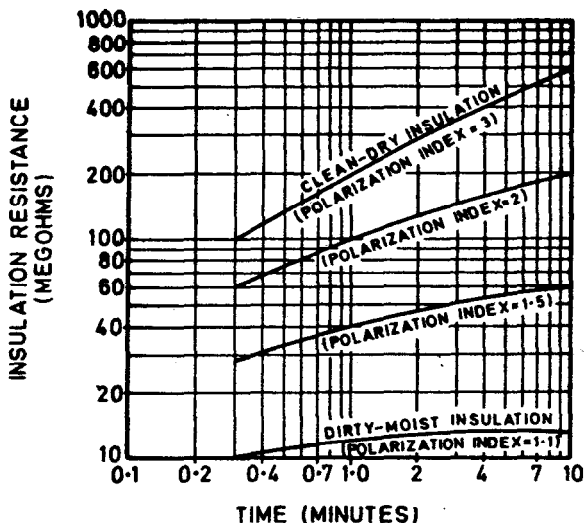


FIG. 3 TYPICAL CURVES SHOWING VARIATION OF INSULATION RESISTANCE WITH TIME FOR CLASS B INSULATED ALTERNATING-CURRENT ARMATURE WINDINGS

for high voltage tests. The measurements for determining polarization index should be made just prior to making the high voltage test (see 8 and 9).

4.5.3 The 1-minute readings of insulation resistance are influenced by the absorption characteristics. However, the 1-minute insulation resistance is useful for evaluating insulation condition where comparisons are to be made with earlier and later data, similarly obtained.

4.6 Effect of Existing Charge on Winding Insulation Resistance Measurements

4.6.1 Insulation resistance measurements may be in error if residual charges exist in the insulation. Therefore, before measuring insulation resistance or polarization index, windings shall be completely discharged to the earthed machine frame. If any doubt exists as to the sufficiency of discharge, discharge current should be measured. It should be negligible compared to the expected test current.

4.6.2 After the application of high dc voltage, earthing of windings is important for safety as well as for test accuracy. The time required for sufficient discharge to earth may amount to several hours.

5. UNIFORM CONDITIONS FOR MEASURING INSULATION RESISTANCE

5.1 The insulation surface shall be clean and dry if the measurement is to provide information on the condition within the insulation as distinguished from the surface condition. Surface cleanliness is of great importance when tests are made in humid weather.

5.2 The winding temperature should be a few degrees above dew point to avoid condensation of moisture on the winding insulation. It is also important that comparison of insulation resistances of machine windings shall be made at 40°C. (For converting insulation resistance values to this temperature see 4.3 and Fig. 2.)

5.3 It may not be necessary that the machine should be at standstill when insulation resistance tests are made.

5.3.1 It is often desirable to make insulation resistance measurements when the rotating winding is subject to centrifugal forces similar to those occurring in service.

5.3.2 In case of generators, it is practical to make periodic insulation resistance measurements while machines are rotating on short-circuit dryout.

5.3.3 Usually, machines are at standstill during measurement of insulation resistance. Whenever this is not the case, precautions should be taken to avoid damage to equipment or injury to personnel. Historical test records of a given machine should indicate any special test condition.

6. WINDING CONNECTIONS FOR INSULATION RESISTANCE TESTS

6.1 It is desirable to test each phase separately to earth with the other phases also earthed. This provides a useful comparison both to earth and between phases under similar conditions. Furthermore, insulation resistance tests of a complete winding to earth do not provide a check of the insulation between portions of the winding.

6.2 The connecting leads, brush block assembly, cables, switches, capacitors, potential transformer, current transformer, lightning arresters, and other external equipment may influence the insulation resistance test reading on a machine winding to a marked degree. Thus, it is desirable to measure the insulation resistance of a winding exclusive of the external equipment of the machine, particularly, if the insulation resistance readings are low. Further, it is necessary to earth all internal circuits that do not form part of the winding during the test.

7. METHODS OF MEASURING INSULATION RESISTANCE

7.1 Direct measurement of insulation resistance may be made with the following instruments.

7.1.1 Direct-indicating ohmmeter with self-contained hand or power-driven generator.

7.1.2 Direct-indicating ohmmeter with self-contained battery.

7.1.3 Direct-indicating ohmmeter with self-contained rectifier using an external ac supply.

7.1.4 Resistance bridge with self-contained galvanometer and batteries.

7.2 Insulation resistance may be calculated from readings of a voltmeter and microammeter using an external dc supply.

7.2.1 The voltmeter-ammeter method is a simple method for the determination of insulation resistance by measurement of the voltage impressed across the insulation and the current which flows through it. A source of dc voltage is required and the voltmeter shall be selected to fit the maximum and minimum voltage which may be used. The ammeter is usually a multi-range microammeter selected to measure the full range of leakage currents which may be encountered at the voltage or voltages used.

7.2.2 The microammeter shall be on the highest range or short-circuited during the first few seconds of charge so that it is not damaged by the capacitance charging current and the initial absorption current.

7.2.3 It may be kept in mind that if the microammeter is at test voltage, suitable precautions should be taken to ensure safety to the operator, and by insulating the meter to avoid inaccuracies in measurement.

7.2.4 For test voltages above 5 000 volts, the lead between the test set and the winding shall be well insulated, shielded, of large diameter and spaced from earth; otherwise, leakage currents and corona loss introduce errors in the test data.

7.2.4.1 Both ends of the winding should be connected together to minimize surges, should the insulation fail during test.

7.2.5 Resistance is calculated from the formula $R = E/I$, where R is insulation resistance in megohms, E is the voltmeter reading in volts, and I is the ammeter reading in microamperes at a stated time after application of test voltage.

7.3 Another method for measurement of insulation resistance of dc windings with their own dc source is given in Appendix A.

7.4 In general, a finite time is required to bring the voltage impressed on the insulation to the desired test value. Full voltage should be applied as rapidly as possible.

7.5 Instruments in which the test voltage is supplied by motor-operated generators, batteries or rectifiers are usually used for making tests of over one-minute duration; that is for tests for dielectric absorption or polarization index (see 8 and 9).

7.6 It is essential that the output voltage of any direct current source shall be very steady to prevent fluctuation in the charging current due to the capacitance of the machine winding. When a high-voltage dc test set is supplied by an ac source, this source should, if necessary, be regulated to provide a non-fluctuating supply to the dc test set.

7.7 Where protective resistors are used in test instruments, their effect on the magnitude of the voltage applied to the insulation under test should be taken into account. The voltage drop in the resistors may be an appreciable percentage of the instrument voltage when measuring a low insulation resistance.

7.8 To compare with previous and future test, the same voltage should be applied by the same method so that uniform test conditions permit a proper comparison of results.

7.9 The measurement of insulation resistance of direct water cooled windings of large turbo-generator machines is given in Appendix B.

8. INTERPRETATION OF INSULATION RESISTANCE TEST RESULTS

8.1 Insulation resistance history of a given machine, made and kept under uniform conditions so far as the controllable variables are concerned, is recognized as a useful way of supervising the insulation condition. Estimation of the suitability of a machine for the application of appropriate high voltage tests or for operation may be obtained by comparing present and previous records of polarization index or observed one-minute insulation resistance values corrected to 40°C (see 4.3.4).

8.2 When no previous insulation resistance history is available, recommended minimum values of polarization index or of the 1-minute insulation resistance may be used to estimate whether the condition of the winding is satisfactory for application of high voltage test or for operation. The observed 1-minute insulation resistance value after correction to 40°C should be at least equal to the recommended minimum insulation resistance value obtained from the formula in 9.3.

8.2.1 Windings having large surface area, very large machine or slow-speed machine or machines with commutators, may have values of insulation resistance slightly less than the recommended value.

8.3 The observed value of insulation resistance is a useful guide in evaluating the condition of a machine winding. It should not be considered as an exact criterion. It has several limitations.

8.3.1 Insulation resistance of a winding is not directly related to its dielectric strength. It is impossible to specify exactly the value of insulation resistance at which a winding may fail electrically.

8.4 A single insulation resistance measurement at one particular voltage does not indicate whether foreign matter is concentrated or distributed throughout the winding.

8.5 Polarization Index

8.5.1 Typical insulation resistance versus time characteristics are shown by Fig. 1 and 3, illustrating behaviour of insulation under different conditions. The curves illustrate the significance of polarization index. Polarization index is usually not affected by temperature when the machine temperature is not changing rapidly (see 4.3).

8.5.2 Depending upon the winding condition, insulation class, and machine type, values of 1 to 7 have been obtained for the polarization index. Class B insulation usually has a higher polarization index than that of a Class A insulation. Moisture or conducting dust on a winding lowers the polarization index. When high voltage ac machines have end windings, which are treated with semi-conducting material for corona elimination purposes, the polarization index may be somewhat lower than that of a similar machine which is untreated.

8.5.3 If the polarization index is reduced because of dirt or excessive moisture, it may be brought up to proper value if no defects exist by cleaning and drying to remove moisture. When drying insulation, the polarization index may be used to indicate when the drying process may be terminated (see Fig. 1).

9. RECOMMENDED MINIMUM VALUE OF POLARIZATION INDEX AND INSULATION RESISTANCE

9.1 The recommended minimum polarization index or the recommended minimum value of insulation resistance at 40°C (R_m) of an ac or dc rotating machine winding in this specified guide is the least value which a winding should have just prior to application of an appropriate high voltage test or if the machine is to be operated (see 9.2 and 9.3).

9.1.1 It is impractical to specify a definite minimum value of insulation resistance and polarization index of a rotating machine below which the machine cannot be operated.

9.1.1.1 It is recognized that it is sometime possible to operate machines with values lower than the recommended minimum value, but it is not considered good practice in the majority of cases.

9.1.2 In some cases special insulation materials or designs, not injurious to the dielectric strength, provide lower values of insulator resistance.

9.1.2.1 When the end winding of a machine is treated with a semi-conducting material, for corona elimination purposes, the observed insulation resistance may be somewhat lower than that of a similar machine which is untreated.

9.2 The recommended minimum value of polarization index, $IR_{10\text{-min}}/IR_{1\text{-min}}$ for ac and dc rotating machines is 1.5 for Class A insulation systems, 2.0 for Class B insulation systems and 1.75 for Class E insulation systems (see IS : 1271-1958*).

NOTE — The recommended minimum value of polarization index, $IR_{30\text{-sec}}/IR_{1\text{-sec}}$ should be 1.3 for all classes of insulation system of rotating machines.

9.3 The recommended minimum insulation resistance (R_m) for ac and dc machine armature windings and for field windings of ac and dc machines may be determined by the following empirical relationship:

$$R_m = kV + 1$$

where

R_m = recommended minimum insulation resistance in megohms at 40°C of the entire machine winding, and

kV = rated machine voltage, in kilovolts.

R_m at 40°C is in effect one megohm per 1 000 volts plus one megohm.

9.3.1 The actual winding insulation resistance to be used for comparison with the recommended minimum value (R_m) is the observed insulation resistance corrected to 40°C, obtained by applying dc voltage to the entire winding for one minute.

9.3.2 Temperature corrections should always be made if the winding is not at a temperature of 40°C. The observed 1-minute resistance may be corrected by multiplying by the temperature coefficient of insulation resistance K_t 40°C (see 4.3.3 and 4.3.4 and Fig. 2).

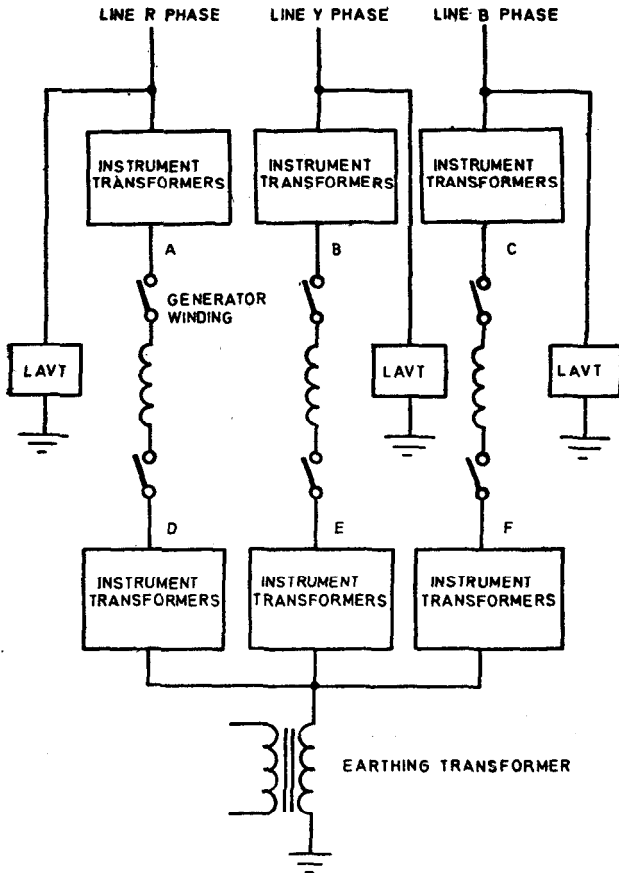
9.3.3 In actual practice, it is observed that the insulation resistance of one phase of a three-phase armature winding with the other two phases earthed, is approximately twice that of the entire winding. Therefore, when the three phases are tested separately, the observed resistance of each phase should be divided by two to obtain a value which after correction for temperature, may be compared with the recommended minimum value of insulation resistance.

9.3.3.1 If each phase is tested separately and guard circuits are used on the other two phases not under test, the observed resistance of each phase should be divided by three to obtain a value, which after correction for temperature may be compared with the recommended minimum value of insulation resistance.

9.3.3.2 A typical example of guard circuit for insulation resistance measurement is given in Fig. 4.

*Classification of insulating materials for electrical machinery and apparatus in relation to their thermal stability in service.

9.3.4 It should be noted that in practice machines with insulation resistance readings 10 to 100 times the minimum recommended value (R_m) obtained from the formula (see 9.3) are not uncommon.



NOTE 1 — During insulation resistance measurements, the connection links *A, B, C* at line end as well as *D, E, F*, at neutral end shall be removed.

NOTE 2 — While doing measurements on windings of one phase the other two phases shall be solidly earthed along with core.

NOTE 3 — While doing measurements on windings between phases, the third phase be solidly earthed.

FIG. 4 A TYPICAL GUARD CIRCUIT FOR INSULATION RESISTANCE MEASUREMENT

APPENDIX A

(Clause 7.3)

METHOD FOR MEASUREMENT OF INSULATION RESISTANCE OF dc WINDINGS WITH THEIR OWN dc SOURCE

A-1. GENERAL

A-1.1 The insulation resistance may be calculated from reading of a voltmeter using the dc source of the winding itself (see Fig. 5).

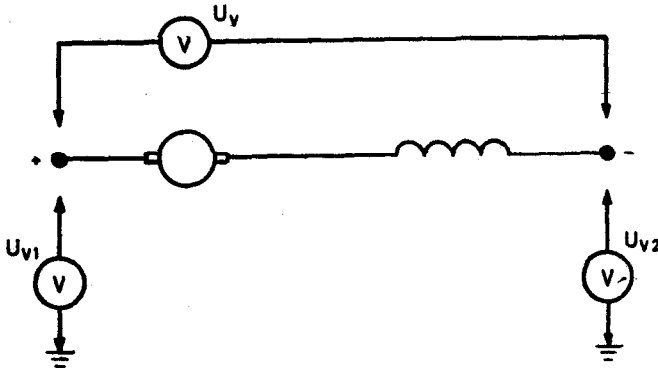


FIG. 5 CIRCUIT FOR MEASUREMENT OF INSULATION RESISTANCE OF dc WINDINGS WITH THEIR OWN dc SOURCE

The insulation resistance is calculated from the formula:

$$R = R_v \left(\frac{U_v}{U_{v1} + U_{v2}} - 1 \right)$$

where

- R = insulation resistance of the winding in ohms,
- R_v = resistance of voltmeter in ohms,
- U_v = voltage measured across the winding terminals in volts,
- U_{v1} = voltage of one polarity of winding to earth in volts, and
- U_{v2} = voltage of the other polarity of winding to earth in volts.

A-2. PROCEDURE

A-2.1 The test is carried out by running the machine at rated speed to develop the rated voltage across armature. The machine is open circuited and the voltage across armature terminals, that is, between positive and negative with respect to earth, is measured.

APPENDIX B

(Clause 7.9)

**MEASUREMENT OF INSULATION RESISTANCE OF
DIRECT WATER COOLED WINDINGS OF LARGE
TURBO-GENERATOR MACHINES**

B-1. Presence of water in the hollow conductors and the connecting hoses and headers of large turbo-generators gives rise to erroneous values of the insulation resistance if measured in the normal way. Normally the water supply and return headers housed within the machine are mounted on insulators and the pipe connections are brought out of the generator casing through insulators. This enables measurement of insulation resistance of dry windings in fairly accurate manner. However, once outside pipe connection for supply of distillate to the winding are made and distillate is under circulation then the insulation resistance of the windings is largely influenced by the resistivity of the distillate and the parallel connections of the unearthed windings with the earthed windings (while measuring insulation resistance). Hence for the measurement of insulation resistance of direct water cooled windings, the following procedure shall be followed.

- a) The insulation resistance of the windings shall be measured before connecting the external water supply connections. In case these connections are already made and water is circulated in the windings, then before measuring the insulation resistance, such connection shall be removed and the windings be dried by blowing air through the windings.
- b) As high voltage tests are to be done on the water cooled windings with water flowing through the windings, measurement of insulation resistance before and after high voltage test may not be considered as guiding factor for deciding suitability of the winding to perform high voltage test.

Typical values of insulation resistance of the direct water cooled stator winding for 200 MW turbo-generator are as follows:

- 1) For dry winding without the water flowing:

$$\frac{IR_{60}}{IR_{15}} = \frac{500 \text{ Megohms}}{200 \text{ Megohms}}$$

- 2) For winding while the water is flowing:

$$IR_{60} = IR_{15} = 30 \text{ to } 70 \text{ kilo-ohms}$$

INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

Quantity	Unit	Symbol
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Supplementary Units

Quantity	Unit	Symbol
Plane angle	radian	rad
Solid angle	steradian	sr

Derived Units

Quantity	Unit	Symbol	Definition
Force	newton	N	1 N = 1 kg.m/s ²
Energy	joule	J	1 J = 1 N.m
Power	watt	W	1 W = 1 J/s
Flux	weber	Wb	1 Wb = 1 V.s
Flux density	tesla	T	1 T = 1 Wb/m ²
Frequency	hertz	Hz	1 Hz = 1 c/s (s ⁻¹)
Electric conductance	siemens	S	1 S = 1 A/V
Electromotive force	volt	V	1 V = 1 W/A
Pressure, stress	Pascal	Pa	1 Pa = 1 N/m ²

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