IS 15881 (2009): Three phase cage induction motors specifically designed for IGBT conerter supply [ETD 15: Rotating Machinery]

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Indian Standard

THREE PHASE CAGE INDUCTION MOTORS SPECIFICALLY DESIGNED FOR IGBT CONVERTER SUPPLY — SPECIFICATION

ICS 29.160.30

BUREAU OF INDIAN STANDARDS
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NEW DELHI 110002

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Indian Standard

THREE PHASE CAGE INDUCTION MOTORS SPECIFICALLY DESIGNED FOR IGBT CONVERTER SUPPLY — SPECIFICATION

1 SCOPE

The information in this standard applies to three-phase, low and medium voltage (up to 690 V), squirrel-cage induction motors, specifically designed for use with Insulated Gate Bipolar Transistor (IGBT) converters. The frame sizes covered are up to 400 frame.

2 REFERENCES

The following standards contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

IS No.	*Title*
325 : 1996	Three-phase induction motors (*first revision*)
1231 : 1974	Dimensions of three-phase foot-mounted induction motors
2223 : 1983	Dimensions of flange mounted ac induction motors
4728 : 1975	Terminal markings and direction of rotation for rotating electrical machinery
8223 : 1999	Dimensions and output series for rotating electrical machines
12065 : 1987	Permissible limits of noise level for rotating electrical machines
12075 : 1987	Mechanical vibration of rotating electrical machines with shaft heights 56 mm and higher—Measurement, evaluation and limits of vibration severity
15880 : 2009	Three phase induction motors when fed from IGBT converters — Application guide

3 TERMINOLOGY

For the purpose of this standard, the following terms and definitions shall apply.

3.1 Base Rating Point — Base rating point for motors defines a reference operating point at a specified speed, fundamental voltage, and torque or power.

3.2 Breakaway Torque (Motor) —The torque that a motor produces at zero speed when operating on a converter.

3.3 Maximum Operating Speed (Motor) — Maximum operating speed is the upper limit of the rotational velocity at which a motor may operate based on mechanical considerations.

3.4 Motor Output Capability — It is the mechanical output capability of the motor when operated on a converter. Generally the motor is capable of producing constant torque (power proportional to speed) at and below base rated speed and constant power (torque inversely proportional to speed) above base rated speed, except where limited by the following:

a) Effect of reduced speed on cooling;

b) Additional losses introduced by harmonic content; and

c) Torque produced when operated within the limitations of the converter output power.

3.5 Overload Capability (Motor) — The maximum load a motor can carry for a specified period of time without permanent damage or significant performance deterioration

3.6 Field Weakening — Motor operating mode where motor flux is less than the flux corresponding to the motor rating

3.7 Rated Temperature — The maximum allowable winding temperature of the motor when the drive is delivering rated output at any speed within the rated speed range for a defined and specified period of time.

3.8 Pulsating Torque — The single amplitude of variation in torque from the average torque.

3.9 Regeneration — The process of returning energy to the power source.

3.10 Regenerative Braking — A form of dynamic braking in which the kinetic energy of the motor and driven machinery is returned to the power supply system.

3.11 Voltage Boost — An additional amount of control output voltage, above the value based on constant volts per hertz, applied at any frequency. It is generally applied at lower frequencies to compensate for the voltage drop in the stator winding.

3.12 Volts/Hertz Ratio (Base) — The base volts/hertz ratio is the ratio of fundamental voltage to frequency at the base rating point.

3.13 Converter — Operating unit for electronic power conversion, changing one or more electrical characteristics and comprising one or more electronic switching devices and associated components, such as transformers, filters, commutation aids, controls, protections and auxiliaries, if any.

3.14 Drive — The equipment used for converting available electrical power into mechanical power suitable for the operation of a machine. A drive is a combination of a power converter, motor, and any motor mounted auxiliary devices.

Examples of motor mounted auxiliary devices are encoders, tachometers, thermal switches and detectors, air blowers, heaters, and vibration sensors.

3.15 Variable-Torque Speed Range (Drive) — The portion of its speed range within which the drive is capable of maintaining a varying level of torque (for the defined time rating) generally increasing with speed. It is common for the term variable-torque to be used when referring to a torque, which varies as the square of the speed, and hence the power output varies as the cube of the speed.

3.16 Constant-Power Speed Range (Drive) — The portion of its speed range within which the drive is capable of maintaining essentially constant power.

3.17 Constant-Torque Speed Range (Drive) — The portion of its speed range within which the drive is capable of maintaining essentially constant torque.

3.18 (Drive) Speed Range — All the speeds that can be obtained in a stable manner by action of part (or parts) of the control equipment governing the performance of the motor.

3.19 (Drive) System Response — The total (transient plus steady state) time response resulting from a sudden change from one level of control input to another.

3.20 Pulse Frequency — Pulse frequency (also called carrier frequency, switching frequency, and chopping frequency) is the frequency of the switching pulses used by a converter to generate the output voltage or current wave form.

3.21 Pulse Width Modulated Control — A control where the frequency and magnitude of the output voltage or current are accomplished by pulse modulation in which the duration of the pulses is varied.

3.22 Skip Band — Small band of operating frequencies where steady-state operation of the drive is inhibited

3.23 Peak Rise Time (Voltage) — The time required for the voltage to make the change from 10 percent to 90 percent of the zero to peak voltage value, either before overshoot or in the absence of overshoot.

3.24 Six Step Control — A control where the frequency and magnitude of the output voltage or current are accomplished by creating a wave form made up of 6 discrete steps.

3.25 Speed Stability — Speed stability is the amplitude of the variation in speed from the average speed, expressed in percent, throughout the entire speed range when the drive is connected to the driven equipment.

3.26 Bonding — Electrical connection of metallic parts of an installation together and to ground (earth).

3.27 EMC (Electromagnetic Compatibility) — Ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment.

3.28 Protective Earthing (PE) — Earthing a point or points in a system or in an installation or in equipment for the purposes of electrical safety.

4 SERVICE CONDITIONS

4.1 General

Machines should be properly selected with respect to their service conditions, usual or unusual, both of which involve the environmental conditions to which the machine is subjected and the operating conditions. Machines conforming to this specification are designed for operating in accordance with their rating under usual service conditions. Some machines may also be capable of operating in accordance with their rating under one or more unusual service conditions. Special machines may be required for some unusual conditions.

Service conditions, other than those specified as usual, may involve some degree of hazard. The additional hazard depends upon the degree of departure from usual operating conditions and the severity of the environment to which the machine is exposed. The additional hazard results from such things as overheating, mechanical failure, abnormal deterioration of the insulating system, corrosion, fire and explosion.

Although past experiences of the user may often be the best guide, the manufacture of the driven or driving equipment or the manufacturer of the machine, or both, should be consulted for further information regarding any unusual service conditions which increase the mechanical or thermal duty on the machine and as a result, increase the chance for failure and consequent hazard. This further information should be considered by the user, his consultants, or others most familiar with the details of the application involved when making the final decision.

4.2 Usual Service Conditions

a) An ambient temperature in the range of −15°C to 40°C. for machines with grease lubricated bearings.
b) An altitude, which does not exceed 1 000 m.
c) Installation on a rigid mounting surface.
d) Installation in areas or supplementary enclosures which do not seriously interfere with the ventilation of the machine.

4.3 Unusual Service Conditions

The manufacturer should be consulted if any unusual service conditions exist which may affect the construction or operation of the motor. Among such conditions are:

a) Exposure to:
   i) Combustible, explosive, abrasive or conducting dusts.
   ii) Lint or very dirty operating conditions where the accumulation of dirt may interfere with normal ventilation.
   iii) Chemical fumes, flammable or explosive gases.
   iv) Nuclear radiation
   v) Steam, salt-laden air or oil vapour.
   vi) Damp or very dry locations, radiant heat, vermin infestation or atmospheres conducive to the growth of fungus.
   vii) Abnormal shock, vibration or mechanical loading from external sources.
   viii) Abnormal axial or side thrust imposed on the motor shaft.
b) Operation where:
   i) Low noise levels are required.
   ii) The voltage at the motor terminals is unbalanced by more than one percent.
c) Operation at speeds above the highest rated speed.
d) Operation in a poorly ventilated room, in a pit, or in an inclined position.
e) Operation where subjected to:
   i) Torsional impact loads.
   ii) Repetitive abnormal overloads.
   iii) Reversing or electric braking.
f) Multi-motor applications:

Special consideration must be given to applications where more than one motor is used on the same converter. Some of these considerations are:

a) Possible large variation in load on motors where load sharing of two or more motors are required.
b) Protection of individual motors.
c) Starting or restarting of one or more motors.
d) Interaction between motors due to current perturbations caused by differences in motor loading.

4.4 Operation in Hazardous (Classified) Locations

Motors operated from converters should not be used in any Division 1 hazardous (classified) locations unless the motor is identified on the nameplate as acceptable for such operation when used in Division 1 hazardous (classified) locations.

For motors to be used in any Division 2 hazardous (classified) locations, the motor manufacturer should be consulted.

Failure to comply with this warning could result in an unsafe installation that could cause damage to properly or serious injury or death to personnel or both.

5 DIMENSIONS, TOLERANCES AND FRAME DESIGNATIONS

These shall be as given in IS 1231, IS 2223 and IS 8223.

6 ENCLOSURES

These shall be as given in 5 of IS 325.

7 COOLING

The method of cooling shall conform to 6 of IS 325. Two typical ways of motor cooling are described below.

7.1 Shaft Mounted Fans

Cooling in this case is a function of motor speed and is also called self-ventilation with internal fan. It is coded as IC 0A1.

7.2 Separate Cooling Arrangement

Here cooling air supply is from a blower directly mounted to the motor. This method is coded as IC 0A6.

It is possible that at reduced speeds, the shaft mounted fan of the motor may not be sufficient to maintain a normal temperature rise, due to diminished effectiveness of internal air circulation.

This is of primary concern for loads, which require close to 1.0 p.u. torque at low speeds. Loads, which require reduced torques at lower speeds, may not impose problem (for example centrifugal pumps and fans).

8 MATERIALS

These shall be as given in 7.1 of IS 325.

9 RATED VOLTAGE, POWER AND SPEED OF MOTORS

9.1 Voltage

Preferred voltage shall be 415 V. This voltage rating applies to the maximum level of the rms fundamental voltage to be applied to the motor over the rated speed range.

9.2 Base Power and Speed Rating

Preferred kW rating shall be as per 8.3 of IS 325.

Preferred speed ratings are 250, 333, 375, 500, 600, 750, 1 000, 1 500, and 2 500, 3 500, 4 500 rpm.

NOTE — It is not practical to build induction motors of all kW ratings at all speeds.

10 RATING

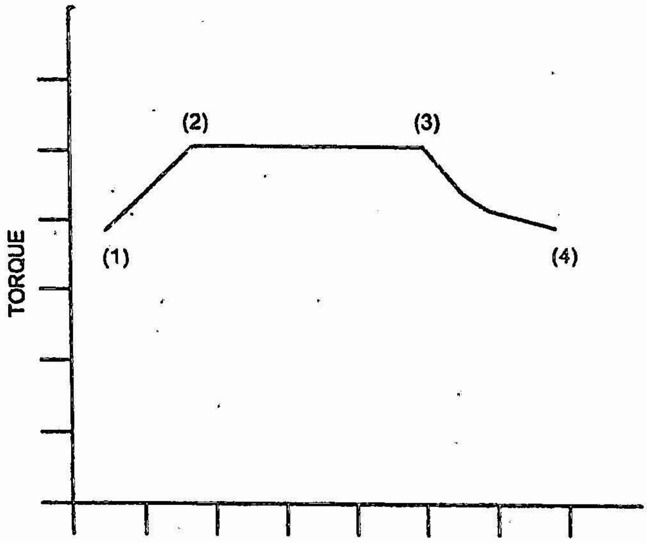
10.1 Basis of Rating

Definite-purpose converter-fed ac induction motors covered by this specification shall be rated based on identification of the applicable load points selected from the four load points shown in and defined in Fig. 1. The base rating shall be defined coincident with point (3) in Fig. 1 by specifying the motor voltage, speed and power or torque at that point.

When the voltage rating at reference points (3) and (4) are different, then unless otherwise specified, the voltage is assumed to reach the maximum value at a frequency between points (3) and (4) as per a constant volts to hertz relationship equal to the voltage at point (3) divided by the frequency at point (3).

10.2 Speed Range

Defined speed ranges illustrated by the points shown



Description of Points

(1) — Torque at minimum speed based on temperature considerations and voltage boost.
(2) — Lowest speed of the constant torque range based on temperature consideration.
(3) — Base rating point at upper end of constant torque range.
(4) — Maximum operating speed based on constant power and any limitation on rotational speed.

NOTES

1 Reducing overload capacity may be necessary for speed range over the base speed.

2 Operation below the base rating point may necessitate the use of a blower for correct cooling of the motor.

Fig. 1 Basis of Rating

in Fig. 1 are based on the base rating point (3) speed for a given machine.

10.2.1 *Lowest Speed of Constant Torque Range Point (2)*

The preferred ratio of speed at base rating point (3) to that at point (2) shall be 1, 2, 3, 4, 6, 10, 20 or 100 except where point (2) is zero rpm, in which case the ratio is undefined. (Example: expressed as 6 to 1, 6:1).

10.2.2 *Maximum Operating Speed — Point (4)*

The preferred ratio of speed at point (4) to that of base rating point (3) shall be 1, 1.5, 2, 2.5, 3 or 4.

10.2.3 *Minimum Speed — Point (1)*

The minimum speed may be zero.

NOTE — It is not practical to build induction motors of all kW ratings at all speed ranges or combinations of speed ranges.

10.2.4 *Other Speed Ranges*

Other speed ranges may be speed specified by agreement between the purchaser and the manufacturer.

11 DUTY

11.1 Variable Speed

The motor is intended for varied operation over the defined speed range and not for continuous operation at a single or limited number of speeds.

11.2 Continuous

The motor can be operated continuously at any single speed within the defined speed range.

12 PROVISION FOR EARTHING

Provision for high frequency earthing of the motor shall be made on the motor body. Two bolts shall be provided for facilitating termination of a pad type of earthing interconnection. The terminal box shall also contain one number additional bolt inside the box, for terminating the armor or the fourth conductor of the power supply cable.

13 DIRECTION OF ROTATION

The direction of rotation of shaft shall be in accordance with IS 4728.

The phase sequence of the output power from the converter may not be the same as the phase sequence of the power into the converter. Direction of rotation should be checked by momentary application of voltage to the motor before connecting the motor to the driven equipment.

14 SERVICE FACTOR

A motor covered by this specification shall have a service factor of 1.0

15 OCCASIONAL EXCESS CURRENT (OVERLOAD)

Definite purpose converter-fed motors shall be capable of withstanding occasional excess current for a period of not less than 1 min when the motor is initially at normal operating temperature. The magnitude of the current and the time in minutes between successive applications of this current are as follows:

Momentary Overload as a Percent of Base Current	*Time Interval Between Overloads*, min
110	≥ 9
125	≥ 28
150	≥ 60

Repeated overloads may result in operation where winding temperatures are above the maximum values given by 17.1.1, which will result in reduced insulation life. If the overload is part of normal duty cycle, the relative equivalent temperature rise must be calculated per 17.1.2 to ensure that the limits in 17.1.1 are not exceeded.

Any other overload regimes imposed by the process requirements shall form part of agreement between the motor manufacturer, the drive manufacturer and the user.

16 USE OF EMBEDDED THERMAL DETECTOR

Considering the nature of operation of the converter fed motor, it is advisable to go in for at least two numbers embedded thermal detector per phase of the windings. If RTD's are to be provided, then these will be for frames 280 and above. These are apart from such detectors used for the bearing protection as may be called for.

17 PERFORMANCE

17.1 Temperature Rise

When motor is used with converter output supply, the HVF (Harmonic voltage factor) factor of the converter to be considered while determining the temperature rise. Converter output with different HVF factors will give different values of temperature rise for the same motor. Hence it is recommended that the HVF factor is determined prior to temperature rise test.

It is assumed that while testing the motor with converter supply, the HVF factor of converter is maximum 3 percent. The temperature rise limits defined in this clause are based upon this value of 3 percent.

17.1.1 *Maximum Temperature Rise for Variable Speed Duty*

The maximum intermittent temperature rise of the windings, above the temperature of the cooling medium, shall not exceed the values given in Table 1 when tested at any rated load within the rated speed range with the IGBT converter. The relative equivalent temperature rise T_e for a defined load/speed cycle as determined according to 17.1.2 shall not exceed the values given in the table. All temperature rises in the table are based on a maximum ambient temperature of 40°C.

The temperature attained by cores, squirrel-cage windings and miscellaneous parts shall not injure the insulation of the machine in any respect.

17.1.2 *Relative Equivalent Temperature Rise for Variable Speed Duty*

The load cycle of the definite purpose coverter-fed motor may be comprised of varying load conditions at varying speeds within the defined speed range. The minimum load within a load cycle may have the value zero.

The reference to a load cycle, given in this standard, is to be considered as integral figures over a long period of time such that thermal equilibrium is reached. It is not necessary that each cycle be exactly the same as another (which would be periodic duty, which implies times too short for thermal equilibrium to be reached). They will be similar and can be integrated to give a nominal pattern with the same thermal life expectancy. An example of a load cycle based on temperature and time of operation is shown in Fig. 2.

The rate of thermal aging of the insulation system will be dependent on the value of the temperature and the duration of operation at the different loads and speeds within the load cycle. A thermal life expectancy of the motor operating over the load cycle can be derived in relation to that for the motor operating continuously at a temperature equal to that for the temperature classification of the insulation system. This relative thermal life expectancy can be calculated by the following equation:

$$\frac{1}{t_l} = \Delta t_1 \times \frac{\Delta t_1}{2\,k} + \Delta t_2 \times \frac{\Delta t_2}{2\,k} + \ldots\ldots + \Delta t_n \times \frac{\Delta t_n}{2\,k}$$

where

t_l is relative thermal life expectancy for the load cycle related to the thermal life expectancy for continuous operation at the temperature rating of the insulation class.

$\Delta t_1 \ldots \Delta t_n$ is difference between the temperature rise of the winding at each of the various loads within the load cycle and the permissible temperature rise for the insulation class.

$\Delta t_1 \ldots\ldots \Delta t_n$ is period of time for operation at the various loads expressed as a per unit value of the total time for the load cycle.

k=10°C is difference in temperature rise which results in a shortening of the thermal life expectancy of the insulation system by 50 percent.

A relative equivalent temperature rise based on continuous operation at that temperature rise for the load cycle time and resulting in the same level of relative thermal life expectancy for the defined load cycle can be determined as follows:

$$t_e = k \times \log_2 \frac{[1]}{t_1} + t_R [\text{or } t_e = k \times 3.322 \times \log_{10} \frac{(1)}{t_2} + t'_R]$$

Table 1 Temperature Rise

(*Clauses* 17.1.1, 17.1.3, 17.1.4, 17.1.5 *and* 18)

Sl No.	Maximum Intermittent Winding Temperature Rise °C			Relative Equivalent Temperature Rise (T_e) °C	
	Insulation Class	Resistance Method	Embedded Detector Method	Resistance Method	Embedded Detector Method
(1)	(2)	(3)	(4)	(5)	(6)
i)	F[1)]	130	140	105	115
ii)	H[1)]	155	170	125	140

[1)] Where a Class F or Class H insulation system is used, special consideration should be given to bearing temperature, lubrication, etc.

where

t_e = relative equivalent temperature rise, and

t_R = permissible temperature rise for insulation class (*see* Fig. 2).

17.1.3 *Maximum Temperature Rise for Continuous Duty*

The maximum temperature rise of the winding, above the temperature of the cooling medium, shall not exceed the values given for relative equivalent temperature rise in Table 1.

17.1.4 *Temperature Rise for Ambients Higher than 40°C*

The temperature rises given in Table 1 are based upon a reference ambient temperature of 40°C. However, it is recognized that induction machines may be required to operate in an ambient temperature higher than 40°C. For successful operation of inductions machines in ambient temperatures higher than 40°C, the temperature rises of the machines given in Table 1 shall be reduced by the number of degrees that the ambient temperature exceeds 40°C.

17.1.5 *Temperature Rise for Altitudes Greater than 1 000 m*

For machines which operate under prevailing barometric pressure and which are designed not to exceed the specified temperature rise at altitudes from 1 000 m to 4 000 m, the temperature rises, as checked by tests at low altitudes, shall be less than those listed in Table 1 by 1 percent of the specified temperature rise for each 100 m of altitude in excess of 1 000 m.

17.2 Torque

17.2.1 *Breakaway Torque*

The motor should be capable of producing a breakaway torque of at least 140 percent of rated torque requiring not more than 150 percent rated current when the voltage boost is adjusted to develop rated flux in the motor and when the converter is able to produce the required minimum fundamental frequencies.

For frequencies below 5 Hz rated flux occurs approximately when:

$$V_{LL} = \sqrt{3} \times I_L \times \frac{R_{LL}}{2} + V_{LL}\ rated \times \frac{f}{f\ \text{rated}}$$

where

V_{LL} = line-to-line rms fundamental voltage at the motor terminals,

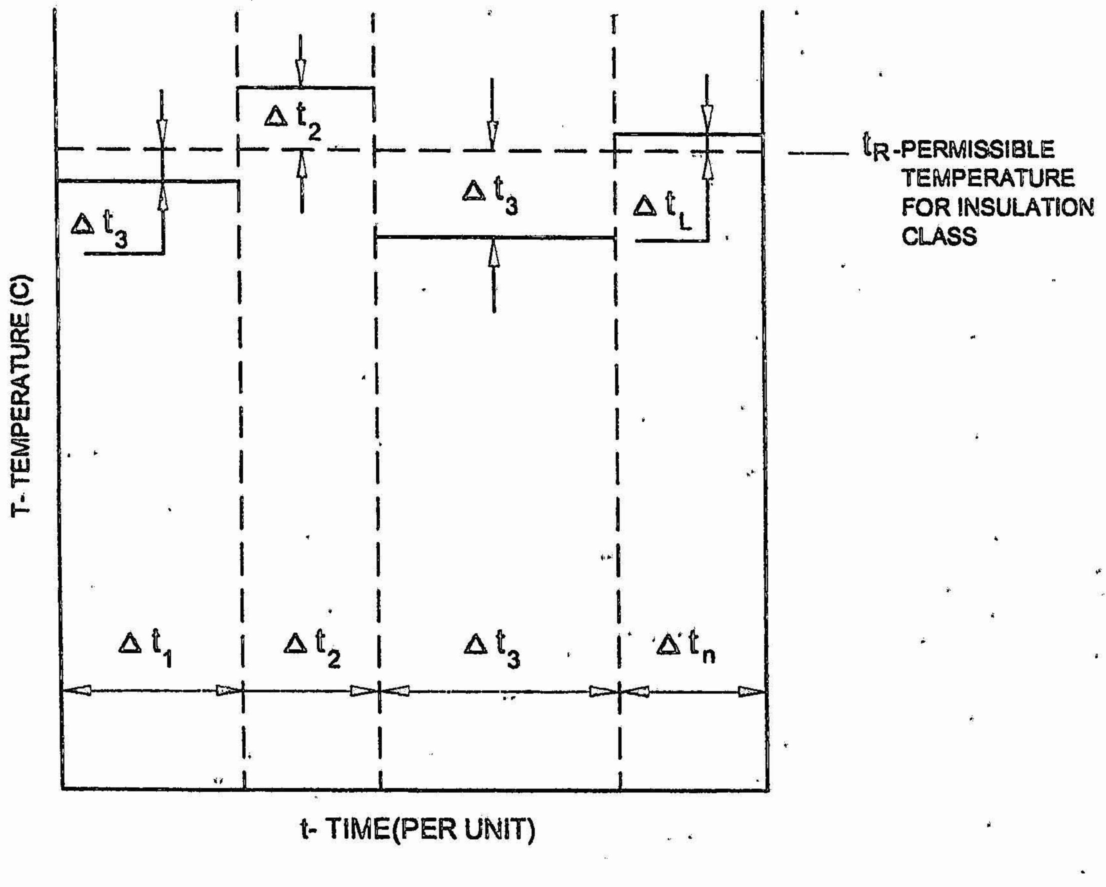


FIG. 2 LOAD CYCLE BASED ON TEMPERATURE AND TIME OF OPERATION

I_L = line current (rms) corresponding to the desired level of breakaway torque,

R_{LL} = line-to-line stator winding resistance at operating temperature, and

f = frequency.

The voltage boost should not be adjusted to exceed a value based on equal to 1.5 times rated full load current to achieve higher breakaway torque without special consideration.

Continued application of boosted motor voltage at low frequencies under no load conditions will increase motor heating. When voltage boost is required to achieve a breakaway torque greater than 140 percent of rated torque, the motor should not be operated under voltage boost condition at frequencies less than 10 Hz for more than one 1 min without consulting the manufacturer.

17.2.2 *Breakdown Torque*

The breakdown torque at any frequency within the defined frequency range shall be not less than 150 percent of the rated torque at that frequency when rated voltage for that frequency is applied.

17.3 Efficiency and Power Factor

Efficiency and power factor at rated load – base rating shall be mutually agreed to between the motor manufacturer and the customer based on information given under 21. These parameters are based upon sinusoidal power supply.

17.4 Noise Level Limits

These will be as per IS 12065 when motor is tested on no load with sinusoidal power supply, at base voltage and frequency. When the motor is to be tested with converter power supply, the limits are to be agreed between manufacturer and user.

17.5 Vibration Limits

These will be as per IS 12075 when motor is tested on no load with sinusoidal power supply, at base voltage and frequency. When the motor is to be tested with converter power supply, the limits are to be agreed between manufacturer and user.

18 TOLERANCE

These will be as per 18.1 of IS 325 and Table 1.

19 OPERATING LIMITATIONS

19.1 Starting Requirements

While definite-purpose motors may be capable of being started across-the-line, the level of locked rotor current at line frequency and voltage may exceed that for general-purpose motors. The torque versus speed profile during across the line starting of the definite-purpose motor also may be different from that of one general-purpose motors and may not be suitable for the requirements of the load. For large motors the stator end-winding support may be inadequate. If across-the-line starting capability is required by the application, these factors should be considered when selecting the motor and controls.

19.2 Variations from Rated Voltage

The rated motor fundamental line voltage as a function of motor speed is defined at the base rating point and implied at the various operating conditions in 4. Definite purpose converter-fed motors shall operate successfully throughout their defined speed range when the applied fundamental voltage does not vary from the rated value at any operating point by more than 6 percent. Performance with this variation will not necessarily be in accordance with operation at the rated voltage.

20 POWER FACTOR CORRECTION OR SURGE SUPPRESSION

The use of power capacitors for power factor correction or surge suppression on the load side of converter connected to an induction motor is not recommended. Line reactors or filter networks for converter voltage spike suppression may be acceptable. For such applications the converter manufacturer should be consulted.

21 OVER SPEEDS

Definite purpose converter-fed motors shall be so constructed that, in an emergency not to exceed 2 minutes, they will withstand without mechanical damage, overspeeds above the maximum operating speed (*see* Fig. 1) in accordance with the following:

Maximum speed Operating: Overspeed, Percent of Maximum Speed (rpm) Operating Speed

3 000 : 15

1 500 : 20

1 500 and below : 25

22 INSULATION CONSIDERATIONS

22.1 Leakage Currents

High frequency harmonics due to converters can cause an increase in the magnitudes of leakage currents in the motor due to a reduction in the capacitive reactance of the winding insulation at higher frequencies. Established and safe grounding practices for the motor frame should therefore be followed.

22.2 Voltage Spikes

Converters used to supply adjustable frequency power to induction motors do not produce sinusoidal output voltage waveforms. In addition to lower order harmonics, these waveforms also have superimposed on them steep-fronted, single-amplitude voltage spikes. Turn-to-turn, phase-to-phase and ground insulation of stator windings are subjected to the resulting dielectric stresses. Suitable precautions should be taken in the design of drive systems to minimize the magnitude of these spikes.

When operated under usual service conditions (*see* 4.2), where the converter input nominal voltage does not exceed rated motor voltage, stator winding insulation systems for definite purpose inverter fed motors shall be designed to operate under the following limits at the motor terminals.

Motors with base rating voltages $V_{rated} = 500$ V:

$$V_{peak} \leq 1.1 * 2 * \sqrt{2} * V_{rated} = 3.1\ V_{rated}$$

Rise time ≥ 0.1

See Fig. 9 of IS 15880 for a typical voltage response at the motor terminals for an illustration of V_{peak} and rise time.

where

V_{peak} = single amplitude zero-to- peak, line-to-line voltage; and

V_{rated} = rated line-to-line voltage.

CAUTION – When the input voltage to the converter exceeds the rated voltage of the motor, care must be taken in determining the maximum peak voltage (V_{peak}) that will be applied to the motor by the converter.

22.3 Shaft Voltages and Bearing Insulation

Shaft voltages can result in the flow of destructive currents through motor bearings, manifesting themselves through pitting of the bearings, scoring of the shaft, and eventual bearing failure. In larger frame size motors, usually 315 frame and larger, these voltages may be present under sinusoidal operation and are caused by magnetic dissymmetries in the construction of these motors. This results in the generation of a shaft end-to-end voltage. The current path in this case is from the motor frame through a bearing to the motor shaft, down the shaft, and through the other bearing back to the motor frame. This type of current can be interrupted by insulating one of the bearings. If the shaft voltage is larger than 500 millvolts peak, bearing insulation should be utilized.

More recently, for some converter types and application methods, potentially destructive bearing currents have occasionally occurred in much smaller motors. However, the root cause of the current is different. These drives can be generators of a common mode voltage, which shifts the three phase winding neutral potentials significantly from ground. This common mode voltage oscillates at high frequency and is capacitively coupled to the rotor. This results in peak pulses as high as 10 to 40 V from shaft to ground. The current path can be through either one or both bearings to ground. Interruption of this current therefore requires insulating both bearings. Alternately, shaft-grounding brushes may be used to divert the current around the bearing. It should be noted that insulating the motor bearings would not prevent the damage of other shaft-connected equipment. Insulating the non-driving end bearing of the motor, would, however, prevent the circulation of shaft current along the other shaft connected equipment.

22.4 Neutral Shift

When converters are applied to motors, the motor windings can be exposed to higher than normal line-to-ground voltages, due to neutral shift effect. Neutral shift is the voltage difference between the source neutral and the motor neutral. Its magnitude is a function of the total system design. In case of a typical IGBT converter, the magnitude of the line-to-ground voltage can be as high as $\sqrt{3}$ times the crest of the nominal sinusoidal line-to-ground voltage.

The magnitude of the neutral voltage can be reduced, if the converter is connected to an ungrounded power source, or, if this is not possible, by isolating it, from the source ground by using an isolation transformer, by using separate reactors in both the positive and the negative direct current link, or by connecting the motor neutral to the ground through a relatively low impedance. Proper selection of the method to reduce motor line-to ground voltage should be coordinated with the system designer.

In view of the above, the carrier frequency shall be carefully selected in consultation with the drive manufacturer.

NOTE — The carrier frequency selected affects the motor noise. Lower frequency causes higher noise and *vice versa*. Lower frequency helps in reduction of voltage doubling effect on long cable lengths while higher frequency application calls for introduction of output side reactors or dv/dt filters to reduce the effect of voltage doubling effects at the motor terminals.

23 RESONANCES, SOUND AND VIBRATION

23.1 General

The motor and the driven equipment (system) have natural resonant frequencies in the lateral, axial, and torsional modes. When a converter is applied to the motor, the system is excited by a spectrum of harmonics coming from the converter.

This can affect the sound level, vibration level, and torsional response of the system. The system integrator should take these effects into consideration to ensure successful system performance.

23.2 Sound and Vibration

Machine sound and vibration are influenced by the following parameters:

a) Electromagnetic design;
b) Type of converter;
c) Resonance of frame structure and enclosure;
d) Integrity, mass and configuration of the base mounting structure;
e) Reflection of sound and vibration originating in or at the load and shaft coupling; and
f) Windage.

It is recognized that it is a goal that motors applied on converter type supply systems for variable speed service should be designed and applied to optimize the reduction of sound and vibration in accordance with the percepts explained above. However, since many of these influencing factors are outside of the motor itself, it is not possible to address all sound and vibration concerns through the design of the motor alone.

23.3 Torsional Considerations

When an induction motor is operated from an converter, torque ripple at various frequencies may exist over the operating speed range. Consideration should be given to identify the frequency and amplitude of these torques and to determine the possible effect upon the motor and driven equipment. It is of particular importance that the equipment not be operated longer than momentarily at a speed where a resonant condition exists between the torsional system and the electrical system (that is, the motor electrical torque). For example, if the converter is of the six-step type then a sixth harmonic torque ripple is created which would vary from 36 to 360 Hz when the motor is operated over the frequency range of 6 to 60 Hz. At low speeds, such torque ripple may be apparent as observable oscillations of the shaft speed or as torque and speed pulsations (usually termed cogging). It is also possible that some speeds within the operating range may correspond to the natural mechanical frequencies of the load or support structure and operation other than momentarily should be avoided at those speeds.

24 BEARING LUBRICATION AT LOW AND HIGH SPEEDS

Successful operation of the bearings depends on their ability to function within acceptable temperatures. Maximum operating speed for grease-lubricated bearings is limited due to temperature considerations and is a function of the bearing design, its size, the load and other considerations.

The maximum and minimum operating speeds should be taken into consideration in the selection of the bearing and lubrication systems for motors covered by this specification.

25 ACCESSORY MOUNTING

Care should be used in the selection of the accessory coupling to ensure it is able to accommodate any misalignment likely to be encountered in the assembly. If the driven accessory is a tachometer, resolver, or encoder, it also may be necessary to ensure that the coupling has adequate torsional stiffness for the desired response, resolution and stability in the intended application.

If the motor has an insulated bearing or similar means to guard against bearing currents (*see* **22.3**), it may be necessary to provide an insulated coupling or other means to prevent such shaft potentials from being applied to connected accessories.

26 TESTS

26.1 Routine Tests

Routine tests as defined in **22** of IS 325 shall be conducted.

26.2 Type Tests

Type tests as defined in **22** of IS 325 shall be conducted.

NOTE — The routine and type tests shall be conducted on a sinusoidal power supply unless otherwise specified by mutual agreement between the motor manufacturer and the user.

27 NAMEPLATE MARKING

These will be same as per **20.1** of IS 325; particular reference shall be made to this standard. In addition, bearing sizes and lubricant details also to be included. The voltage class of insulation (V_{peak}), rise time and the dv/dt level shall be included besides the above.

27.1 BIS Certification Marking

The motors may also be marked with Standard Mark.

27.1.1 The use of the Standard Mark is governed by the provisions of the *Bureau of Indian Standards Act*, 1986, and the Rules and Regulations made thereunder. The details of conditions under which the licence for the use of Standard Mark may be granted to manufactures or producers may be obtained from the Bureau of Indian Standards.

27.2 Variable Torque Applications

The following minimum information necessary to characterize the motor for variable torque applications in which the maximum operating speed does not exceed the speed corresponding to the base rating point (3) defined in Fig.1 shall be given on all nameplates. All performance data is to be based on a sine wave power supply.

The following data will correspond to base rating point (3) defined in Fig.1:

a) kW,
b) Voltage,
c) Current,
d) Speed — RPM, and
e) Frequency.

27.3 Other Applications

For applications other than variable torque, the appropriate items selected from the following list should be given.

The following data will correspond to base rating points (1), (2), or (4) defined in Fig.1:

a) kW,
b) Voltage,
c) Current,
d) Speed — RPM,
e) Frequency, and
f) Torque.

28 INFORMATION TO BE GIVEN AT THE ENQUIRY STAGE AND BEFORE PLACING THE ORDER

In addition to the information given in Annex B of IS 325, the following additional information needs to be furnished at the stage of enquiry and placing order for supply.

28.1 Data Related to the ac Drive System

The following data regarding drive capability shall be provided for judicious selection of the appropriate motor:

a) Output voltage and frequency,
b) Frequency control range,
c) Output current rating,
d) IGBT device switching frequency and rise time,
e) Speed control range,
f) Torque limit,
g) Overload capacity,
h) Braking torque,
j) List of motor protections provided with their ranges,
k) Distance between drive panel and the motor,
m) Type of power cable used between drive panel and motor,
n) Application details: Variable torque or constant toprque application, and
p) Whether NDE shaft extention is required for encoder mounting.

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Rotating Machinery Sectional Committee, ETD 15

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Rotating Machinery Sectional Committee had been approved by the Electrotechnical Division Council.

The performance characteristics and operating data for drives with converter-fed cage induction motors are influenced by the complete system, comprising supply system, converter, induction motor, mechanical shafting and control equipment. Each of these components exists in numerous technical types. Any values quoted in this technical specification are thus indicative only.

In view of the complex technical interrelations within the system and the variety of operating conditions, it is beyond the scope and object of this technical specification to specify numerical or limiting values for all the quantities which are of importance for the design of the drive.

To an increasing extent it is practice that drives consist of components produced by different manufacturers. The object of this technical specification is to explain and quantify, as far as possible, the criteria for the selection of components and their influence on the performance characteristics of the drive.

Motor Categories

There are two categories of cage induction motors, which can be applied in variable speed electric drive systems:

a) Standard cage induction motors, designed for general-purpose applications. The design and performance of these motors are optimized for operation on a fixed frequency sinusoidal supply. Nevertheless, they are generally also appropriate for use in variable speed drive systems.

b) Cage induction motors specifically designed for converter operation. The design and construction of such motors may be based on standard motors with standardized frame sizes and dimensions, but with modifications for converter operation. This category is covered in this standard.

Guidance on this field of application is given in IS 15880 : 2009 'Three phase cage induction motors when fed from IGBT converters — Application guide'.

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 or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.