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Guidance on Industry Standard for High Voltage Induction Motors (IEC)

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ENGINEERING TECHNICAL PRACTICES

Foreword

This is the first issue of Engineering Technical Practice (ETP) GIS 12-203. This Guidance on Industry Standard (GIS) is based on the following heritage documents from merged BP companies:

BP (RPSE)

GS 112-4

Guidance for Specification GS 112-4 High Voltage induction Motors

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1. Scope

This document provides guidance on industry standard for the design, materials, fabrication, inspection, testing, documentation, and preparation for shipment of high-voltage, three-phase cage induction motors based on IEC 60034.

This document relates to induction motors suitable for operation on alternating current supplies at voltages in excess of 1 kV but not exceeding 15 kV. Normally the rating for such machines will be in excess of 150 kW. The value of 150 kW as the break point between low voltage and high voltage machines is based upon economic considerations for motors taken in isolation. Overall system considerations must always be born in mind and on occasions it may be better to employ one voltage level and to consider the use of soft start techniques, at low voltage, for relatively large motors, and unit transformers, at high voltage, for relatively small motors.

This document should be applied to normal classes of induction motors generally found in industry and includes machines which may be required for installation in areas classified as hazardous or non-hazardous. Provided that decided advantage can be proven, there is no objection to employing machines, suitable for use in one particular area classification, within a less onerous area (e.g. type 'e' in either zone 2 or non-hazardous areas).

This document does not apply in all respects to motors for special applications such as downhole duties and totally submerged environments, or to motors with special features such as hollow shafts.

2. Normative references

The following normative documents contain requirements that, through reference in this text, constitute requirements of this technical practice. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this technical practice are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies.

American Petroleum Institute (API)

API 670 Machinery Protection Systems

European Standard (EN)

EN 50209 Test of insulation of bars and coils of high-voltage machines.

Electricity Supply Industry (ESI)

ESI Standard 44-5 Testing insulation systems of stator coils.

International Electrotechnical Commission (IEC)

IEC 60034-1	Rotating electrical machines – Part 1: Rating and performance.
IEC 60034-5	Rotating electrical machines – Part 5: Degrees of protection provided by the integral design enclosures of rotating electrical machines (IP code) – Classification.
IEC 60034-6	Rotating electrical machines – Part 6: Methods of cooling (IC code).



IEC 60034-7	Rotating electrical machines – Part 7: Classification of types of construction, mounting arrangements and terminal box position (IM Code).
IEC 60034-8	Rotating electrical machines – Part 8: Terminal markings and direction of rotation.
IEC 60034-14	Rotating electrical machines – Part 14: Mechanical vibration of certain machines with shaft heaths 56 mm and higher – Measurement, evaluation and limits of vibration.
IEC 60034-18	Rotating electrical machines – Part 18: Functional evaluation of insulation systems.
IEC 60072-1	Dimensions and output series for rotating electrical machines – Part 1: Frame numbers 56 to 400 and flange numbers 55 to 1 080.
IEC 60072-2	Dimensions and output series for rotation electrical machines – Part 2: Frame numbers 355 to 1 000 and flange numbers 1 180 to 2 360.
IEC 60079-1	Electrical apparatus for explosive gas atmospheres – Part 1: Flameproof enclosures “d”.
IEC 60079-2	Electrical apparatus for explosive gas atmospheres – Part 2: Pressurized enclosures “P”.
IEC 60079-7	Electrical apparatus for explosive gas atmospheres – Part 7: Increased safety “e”.
IEC 60079-15	Electrical apparatus for explosive gas atmospheres – Part 15: Type of protection “n”.
IEC 60529	Degrees of protection provided by enclosures (IP code).
IEC 60751	Industrial platinum resistance thermometer sensors.
IEC 60851	Winding Wires – Test Methods.
IEC 61000-4-5	Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test.

International Standards Organization (ISO)

ISO 15	Rolling bearings – Radial bearings – boundary dimensions, general plan.
ISO 281	Rolling bearings – Dynamic load ratings and rating life.
ISO 1132	Rolling bearings – Tolerances.
ISO 1940	Mechanical vibration – Balance quality requirements of rigid rotors.

National Electrical Manufacturers Association (NEMA)

NEMA MG1	Motors and Generators.
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3. Standard design requirements

3.1. General

- a. Motors shall have an expected lifetime of 20 years. They shall be suitable for 4 years of uninterrupted operation under conditions specified. Rolling element bearings are exempted from expected lifetime requirement.
- b. Motors shall be capable of meeting their specified duty for 26 000 hours (3 years) without being stopped for maintenance purposes.
- c. Within the range of applicability, motors shall have a minimum full-load efficiency that complies with EU Recommendations curve Eff-2. Preference will be given to motors that comply with Eff-1.



3.2. Starting requirements

- a. Motors shall be suitable for direct on-line starting or re-acceleration with any voltage between 80% and 100% of rated voltage applied at machine terminals.
- b. Motors shall be capable of recovering normal operation following a power interruption not exceeding 0.2 seconds, followed by a sudden restoration to 60% voltage for 3 seconds, and then a sudden restoration to 80% voltage.
- c. Motor shall be capable of re-acceleration and ultimate recovery under most arduous load conditions from 80% voltage.
- d. If these requirements cannot be met, manufacturer shall provide detailed information regarding re-acceleration ability of motor.

3.3. Degree of protection

- a. The degree of ingress protection (to IEC 60529) shall be at least:

Land and coastal installations	IP54 for the machine and auxiliaries IP55 for the terminal box and bearing housings
Offshore installations	IP56 for the machine, auxiliaries, terminal boxes And bearing housings
Submerged electric motors and electric drives of seal-less pumps	IP68 for the applicable parts

- b. Motor enclosure shall be equipped with a normally open drain hole in accordance with IEC 60034-5 to IP44. Attention shall be paid to correct location of drain hole, especially for vertical motors. This is not applicable for Ex "d" machines.
- c. Drain holes for Ex "e" and Ex "n" HV motors shall be fitted with screwed plugs, accessible in operating position.

3.4. Methods of cooling

Preference is given to motors with methods of cooling IC 4A 1 A 1 (411), IC 5A 1 A 1 (511), IC 6A 1 A 1 or IC 8A 1 W7 in accordance with IEC 60034-6.

Note for Offshore Installations: Cooling water shall be treated fresh water wherever possible.

Where use of salt water is unavoidable, cooler materials and design (e.g. flow rates, velocities, tube design) shall be such as to minimise corrosion or erosion for water with characteristics specified.

3.5. Type of construction and mounting

- a. Type of mounting for standard machines shall be either IM B3 (IM 1001), IM B5 (IM 3001), IM V1 (IM 3011), or IM V6 (IM 1031) in accordance with IEC 60034-7.
- b. Bearing housings, especially for vertical machines with upwards drive-end shaft, (mounting arrangement IM V3 [IM 3031] and IM V6 [IM 1031] to IEC 60034-7) shall be sealed to prevent water entry to machine via shaft. Water and dirt collecting on upper bearing endshield shall not reduce performance or lifetime of machine.
- c. Frame sizes, dimensions of foot-mounted machines, and mounting flange dimensions shall be in accordance with IEC 60072-1 and IEC 60072-2

3.6. Machines for use in hazardous areas

For machines to be used in hazardous areas the following information shall be provided:



- a. Type of protection of the following components in accordance with IEC 60079:
 1. Machine
 2. Terminal box
 3. Auxiliary devices
- b. Temperature group and gas group in accordance with IEC 60079
- c. Number of the test certificate or registered mark of the testing authority.
- d. For machines with type of protection "e" -the te time
- e. For machines with type of protection "d" -any information essential to ensuring flame-proof character of enclosure
- f. For machines with type of protection "p" :
 1. Minimum and, when applicable, maximum pressure during operation, or the minimum rate of flow of protective gas.
 2. Internal free volume, and minimum volume of protective gas necessary for purging enclosure.

Motors for use in hazardous areas in the European Economic Area must comply with the relevant EN 500XX series CENELEC standards or national variants and these should be referenced in place of the IEC 60079 series for the relevant protection concepts.

3.6.2. Type n motors

- a. Machine shall comply with IEC 60079-15.
- b. For machines used in zone 2 areas same temperature limitations apply as for machines in non-hazardous areas.
- c. In addition, to prevent thermal ignition, temperatures of external or internal surfaces to which a potentially explosive atmosphere has access shall not exceed limiting temperatures of class T3 temperature group under normal operating conditions
- d. Auxiliary devices mounted on machine for protective, alarm or other purposes shall comply with appropriate standards for protection of electrical equipment used in hazardous areas.
- e. Equipment shall be suitable for an area characterized by T3 temperature group and IIA gas group, unless otherwise specified.
- f. For type 'n' machines a Certificate of Conformity shall be supplied.
- g. The rated voltage of type 'n' machines shall not exceed 11 kV.
- h. Type 'n' machines rated 3 kV and above shall include facilities for purging the machine with inert gas or compressed air before starting (following release of flammable gas or vapour).

Research work has indicated that electric motors can produce incendive discharges during starting.

Investigations show that corona discharges can occur on contaminated windings of high voltage machines. Should flammable gas or vapour be present in the machine at this time then an explosion could occur. This phenomena does not occur below 3 kV and the concept of non sparking machines remains valid at and below this voltage level. Therefore, certified type 'n' (and type e) machines can be installed without further precautions when rated at 3 kV or less. Also, they can be installed at voltage levels up to 11 kV in zone 2 areas provided that precautions are taken to



ensure that no flammable gasses or vapours are present in the machine during start up following a release. At this time it is not considered prudent either to install type e machines rated above 3 kV in zone 1 or to install type 'n' or type e machines in zone 2 areas when rated above 11 kV.

Additional work has shown another mechanism for incentive discharge production is airgap sparking, and that this phenomenon is related to rotor current density during run up rather than rated voltage. However, no further data is yet available regarding limitations in acceptable designs.

Results of further research have yet to become available, and other solutions to the problem of incensive discharges, which are not based on purging, are now being offered by manufacturers. Before selecting machines for applications it would be prudent to determine the latest recommendations from manufacturers and relevant specialists.

3.6.3. Flameproof (type d) motors

- a. Machine shall comply with IEC 60079-1.
- b. Listed below are options to be selected where IEC 60079-1 gives alternatives:
 1. A flameproof gland shall be provided wherever a shaft passes through walls of a flameproof enclosure.
 2. Length of flame-path in a flameproof shaft entry associated with a sleeve bearing shall not be less than diameter of shaft, provided that length of flame-path does not exceed 25 mm.
 3. For shafts fitted with ball or roller bearings, radial clearance in flameproof shaft entry shall not exceed maximum diametrical clearance allowed for shaft entries used with sleeve bearings.
 4. Terminal boxes fitted to motor should have type of protection 'e'.

3.6.4. Increased safety (type e) motors

- a. Machine shall comply with IEC 60079-7.
- b. Listed below are options to be selected where IEC 60079-7 gives alternatives:
 1. Wire insulation used for machine windings shall comply with IEC 60317 and be tested in accordance with IEC 60851.
 2. Winding and rotor temperatures shall under no operating condition exceed limiting temperature determined by temperature group applicable - usually T3. Winding temperatures shall not exceed maximum temperatures specified for class B insulation materials as specified in Table 5 of IEC 60079-7.
 3. Time (te) shall be at least 5 seconds.
 4. Testing of all thermal characteristics of motor shall be carried out in accordance with appendix B of IEC 60079-7.
 5. For machines equipped with noise reduction measures, certification procedure shall take this into account.
 6. The rated voltage of Increased Safety (type e) motors shall not exceed 3 kV when intended for use in zone 1 applications.
 7. Increased Safety (type e) motors which have a rated voltage in excess of 3 kV and which are intended for zone 2 application shall include facilities for purging the machine with inert gas or compressed air before starting (following flammable gas or vapour release).



3.6.5. Pressurised (type p) motors

- a. The machine shall comply with IEC 60079-2.
- b. Temperature limitations specified in clause 7.10 of IEC 60034-1 shall apply to machines with type of protection 'p'. However, temperatures of any surface to which the potentially explosive atmosphere has access under normal operating conditions shall not exceed group T3 limitations.
- c. Terminal boxes fitted to machine shall be type of protection 'e' or 'p'.
- d. A minimum over-pressure of 0.05 kPa shall be maintained relative to external atmospheric pressure at every point within the enclosure.

3.7. Certification for use in hazardous areas

- a. Motors specified for use in hazardous areas classified as either zone 1 or zone 2 shall be certified by a National Certifying Authority.

Recognised National Certifying Authorities are identified in IEC 60079-9.

- b. Copies of the relevant certification documents shall be submitted by the manufacturer with the tender.

3.8. Additional requirements for machines in hazardous areas**3.8.1. Bonding straps**

- a. Machines shall be fitted with bonding straps across joints within or between main enclosure, the bed plate, and heat exchanger.
- b. Bonding across the mainframe and terminal box is necessary unless manufacturer can demonstrate the absence of circulating current effects.
- c. Internal steelwork, e.g. air guides, shall be such that no sparking can occur across joints.

3.8.2. Requirements for external cooling fans

In addition to the requirements this document, external cooling fans shall comply with requirements of IEC 60079.

4. Special design requirements**4.1. Duty and rating**

- a. The rating of the machine offered by the manufacturer shall be based on a class B temperature rise for all parts of machine windings.
- b. Insulation materials shall be class F, as defined in IEC 60034-18.

The required rating of a motor for a particular piece of driven equipment is usually defined by the supplier of the driven equipment after taking into account any BP requirements. This rating takes account of any design uncertainty and manufacturing tolerances which may arise and therefore the motor should be suitable for all eventualities which may arise. Traditionally, the petrochemical industry has also 'built-in' a further safety margin for the motor by specifying class B temperature rises (80 °C) whilst employing class F insulation materials (105 °C rise), both pertaining whilst operating in a 40 °C ambient air temperature or with 25 °C cooling water. If operating conditions are such that the machine is unlikely to be overloaded and if the ambient conditions are well removed from standard then consideration should be given to specifying class F rises for class F materials, especially when significant weight or cost savings can be obtained.

