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1 OBJECTIVE

This specification establishes the necessary technical requirements for design, manufacture, and supply of Medium-Voltage Induction Motors for Offshore Units.

2 REFERENCE STANDARDS AND DOCUMENTS

2.1 GENERAL

2.1.1 The standards, codes and recommendations that shall be applied to motors design are listed below.

2.1.2 At motors design, national laws and regulations shall have priority, followed by Classification Society rules, followed by IEC standards. Other standards shall be applied where specified by PETROBRAS.

2.1.3 Exceptionally, where it is clearly justifiable and approved by PETROBRAS, ANSI, NEMA, IEEE, VDE and others internationally recognized standards may be used.

2.1.4 All standards shall be used on their latest revisions.

2.1.5 Manufacturer shall provide the necessary spare parts for the commissioning and pre operation periods.

2.2 CODES, STANDARDS AND RECOMMENDED PRACTICES

2.2.1 IEC – INTERNATIONAL ELECTROTECHNICAL COMMISSION

IEC 60034	Rotating Electrical Machines – Parts 1, 2, 5, 6, 7, 8, 9, 11, 12, 14, 15, 18, 25, 26, 27 and 29;
IEC 60072	Dimensions and Output Series for Rotating Electrical Machines – All parts;
IEC 60079	Explosive Atmospheres – Parts 0, 2, 7 and 14;
IEC 60085	Electrical Insulation - Thermal Evaluation and Designation;
IEC 60270	High-voltage Test Techniques – Partial Discharge Measurements;
IEC 61892	Mobile and Fixed Offshore Units – Electrical Installations – Parts 1, 3 and 7;
IEC 61800	Adjustable Speed Electrical Power Drive Systems – Part 4.

2.2.2 IEEE – INSTITUTE OF ELECTRICAL AND ELECTRONIC ENGINEERS (only where specified)

IEEE Std 522	Guide for Testing Turn Insulation of Form-Wound Stator Coils for Alternating-Current Electric Machines
IEEE Std 620	Guide for the Presentation of Thermal Limit Curves for Squirrel Cage Induction Machines
IEEE Std 1799	Recommended Practice for Quality Control Testing of External Discharges on Stator Coils, Bars, and Windings
IEEE Std 112	Standard Test Procedure for Polyphase Induction Motors and Generators

2.2.3 NEMA – NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (only where specified)

MG1	Motors and Generators

2.2.4 ASTM – AMERICAN SOCIETY FOR TESTING AND MATERIALS (only where specified)

ASTM B26/B26M	Standard Specification for Aluminium-Alloy Sand Castings
ASTM B108/B108M	Standard Specification for Aluminium-Alloy Permanent Mold Castings
ASTM B221	Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes

2.2.5 ISO – INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (only where specified)

ISO 20816-1	Mechanical Vibration – Measurement and Evaluation of Machine Vibration – Part 1: General Guidelines

2.2.6 INMETRO – INSTITUTO NACIONAL DE METROLOGIA NORMALIZAÇÃO E QUALIDADE INDUSTRIAL

Portaria 115	March 21st, 2022

2.2.7 API – AMERICAN PETROLEUM INSTITUTE

API Std 541	Form-wound Squirrel-Cage Induction Motors - 500 Horsepower and Larger (only where specified)

2.2.8 ASME – AMERICAN SOCIETY OF MECHANICAL ENGINEERS

ASME B 1.20.1	Pipe Threads, General Purposes (Inch)
ASME BPVC-VIII-1	Rules for Construction of Pressure Vessels Division 1

2.2.9 IMO - INTERNATIONAL MARITIME ORGANIZATION

IMO IA811E	Code for the Construction and Equipment of Mobile Offshore Drilling Units (MODU CODE)

2.2.10 ANSI/ISA – THE INSTRUMENTATION, SYSTEM, AND AUTOMATION SOCIETY

ANSI/ISA 7.0.01	Quality Standard for Instrument Air

2.2.11 RULES OF CLASSIFICATION SOCIETY

2.2.12 SECRETARIAT OF LABOUR – BRAZILIAN MINISTRY OF ECONOMY

NR-10	Segurança em Instalações e Serviços em Eletricidade;
NR-12	Segurança no Trabalho em Máquinas e Equipamentos;
NR-37	Segurança e Saúde em Plataformas de Petróleo.

2.3 REFERENCE DOCUMENTS

[1] I-ET-3010.00-1200-956-P4X-002 - GENERAL PAINTING

[2] I-ET-3010.00-1200-300-P4X-001 - NOISE AND VIBRATION CONTROL REQUIREMENTS

[3] GENERAL SPECIFICATION FOR AVAILABLE UTILITIES

[4] I-LI-3010.00-5140-700-P4X-001 - ELECTRICAL EQUIPMENT DATA SHEET MODELS

[5] I-ET-3010.00-5140-700-P4X-001 - SPECIFICATION FOR ELECTRICAL DESIGN FOR OFFSHORE UNITS

[6] ELECTRICAL SYSTEM DESCRIPTIVE MEMORANDUM

Note: Documents without code in the list are documents with variations according to project characteristics. Verify in project documentation list the reference for codes of these documents.

3 GENERAL CONDITIONS

3.1 ENVIRONMENTAL

3.1.1 Induction motors and their accessories shall be suitable for storage, service and installation on severe petrochemical, marine, tropical, damp and saline environment.

3.1.2 It shall be considered a design ambient temperature of 45°C, continuously. Motors installed inside engine room (with steam boilers) shall have design ambient temperature of 50°C, continuously. Classification Society requirements, when more restrictive, shall be complied with.

3.2 RATING

3.2.1 Induction motors shall have rated power calculated, with service factor 1.0, considering the oversizing factor of 10% applied to driven machine brake power.

3.2.2 Oversizing factor lower than stipulated above shall be submitted to PETROBRAS for approval.

3.3 SUPPLY

3.3.1 It shall not be acceptable out of date or obsolete equipment or components. Technical support and supply of replacement parts shall de guaranteed for ten (10) years.

3.3.2 Motors and their auxiliary systems shall be designed and manufactured taking into account the minimum life period specified in the Project Documentation. Motors shall be also capable of operating continuously without being stopped for maintenance purposes for at least 3 years.

4 CONSTRUCTIVE CHARACTERISTICS

4.1 ELECTRICAL CHARACTERISTICS

4.1.1 RATED VOLTAGE AND FREQUENCY

4.1.1.1 The induction motors following this Technical Specification shall have rated voltage greater than 1 kV and rated frequency of 60 Hz.

4.1.1.2 The motors rated voltage shall be selected according to I-ET-3010.00-5140-700-P4X-001 - SPECIFICATION FOR ELECTRICAL DESIGN FOR OFFSHORE UNITS, considering the voltage levels of the electrical system indicated in the ELECTRICAL SYSTEM DESCRIPTIVE MEMORANDUM.

4.1.2 STARTING PERFORMANCE

4.1.2.1 The motor shall be designed for direct on-line start and to accelerate the connected load to running speed with 80 % of rated voltage at the motor terminals.

4.1.2.2 Unless otherwise stated in Project Documentation, for motors with service type S1, the accelerating time (t_a) at 80 % of rated voltage, when DOL (direct on-line) started, shall not exceed:

a) the permissible locked rotor time (t_{lr}), at rated voltage and running temperature (hot start), minus 2 seconds (t_{lr} – 2 s) and;

b) the time t_E minus 2 s (t_E – 2 s), for Ex e motors.

Notes:
- Accelerating time (ta) shall be calculated considering direct on-line start;
- Accelerating time (t_a) shall include the driven machine coupled and loaded at expected normal service condition;
- Running temperature means steady state operational temperature at rated load;
- These requirements are not applicable for motors fed from VSD and soft-starters. If bypass of VSD or soft-starter with contactor is foreseen, the requirements are applicable.

4.1.2.3 Maximum accelerating time (t_a), considering DOL start at rated voltage with driven machine coupled, shall be 5 s.

Note: Accelerating time (t_a) bigger than these values shall be submitted to PETROBRAS approval, including protection coordination graphics and relays' settings, proving that it is possible to provide reliable protection to the motor. These protection coordination graphics are not included in motor Manufacturer scope.

4.1.2.4 Permissible locked rotor time (t_{lr}) at rated voltage and running temperature (hot start) shall be equal to or longer than 12 s.

Note: Shorter values of specified permissible locked rotor time (t_{lr}) shall be submitted to PETROBRAS for approval.

4.1.2.5 The number of starts and intervals shall be:

a) With the motor initially at ambient temperature (cold start), three (3) starts in succession, coasting to rest between starts;

b) With the motor initially at running temperature (hot start), two (2) starts in succession, coasting to rest between starts.

4.1.2.6 After a cooling period of 30 minutes at standstill, another starting sequence of at least two successive starts shall be possible.

4.1.2.7 CANCELLED.

4.1.2.8 Motors shall be designed for a minimum of 1000 starts per year for the minimum lifetime specified in the Project Documentation.

4.1.2.9 Unless otherwise specified in Project Documentation, the locked rotor current (I_{lr}), at rated voltage shall not exceed 6.0 times the rated current (I_r), accepting tolerances of IEC 60034-1.

Note: Unless otherwise stated in Project Documentation, this requirement is not applied to converter-fed motors.

4.1.3 OPERATING PERFORMANCE

4.1.3.1 Motors shall operate satisfactorily under the following continuous conditions:

a) Variation of ±10% of rated voltage, at rated frequency;

b) Variation of ±5% of rated frequency, at rated voltage;

c) Combined variation of voltage and frequency of ±10% of the rated values (sum of absolute values), provided the frequency variation does not exceed ±5% of rated frequency.

4.1.3.2 Motors shall withstand and operate satisfactorily under the following transient conditions, based on IEC 61892-3:

a) Variation of ±20 % of rated voltage with the maximum recovery time of 1.5 s;

b) Variation of ±10 % of rated frequency with the maximum recovery time of 5 s.

4.1.3.3 Within these limits, the temperature rise shall comply with requirements of IEC 60034-1.

4.1.3.4 Current stator pulsation, when driving loads such as reciprocating pumps or compressor shall not exceed 66 % of rated RMS full load current for all specified loading conditions, according to NEMA MG1.

4.1.3.5 Unless otherwise specified in Project Documentation, motors with power up to 630 kW shall have torque characteristics as stated in IEC 60034-12 for Design N.

Note: Manufacturer shall comply with this requirement, despite the scope of IEC 60034-12 being for motors up to 1 kV. Deviations shall be presented to PETROBRAS approval.

4.1.3.6 Unless otherwise specified in Project Documentation, motors above 1600 kW shall have torque characteristics complying with:

a) locked rotor torque (T_l) ≥ 50 %T_N;

b) pull-up torque (T_u) ≥ 30 %T_N;

c) breakdown torque (T_b) ≥ 160 %T_N.

4.1.3.7 The torque-speed characteristic of the motor at rated frequency with 80 % rated voltage applied at the motor terminals shall have an accelerating torque margin above the load torque-speed curve of at least 10 % of the motor torque curve.

4.1.3.8 Motor for loads with intermittent service shall be rated for the adequate duty type, as defined in IEC 60034-1.

4.1.4 EFFICIENCY

4.1.4.1 Unless otherwise stated in Project Documentation, the minimum acceptable efficiency at rated voltage and full load, considering +0 % tolerance, shall be as defined in Table 1.

Table 1 - Medium-Voltage Induction Motors Minimum Efficiency.

Rated Power [kW]	Minimum Efficiency [%]
≤ 300	94.2
> 300 and ≤ 1200	95.2
> 1200	96.4

4.1.4.2 It shall be acceptable minimum efficiency of 96 %, at rated voltage and full load and considering +0% tolerance, for motors above 1200 kW, when the locked rotor current (I_{lr}) at rated voltage is limited in Project Documentation to 4.5 times the rated current (I_r) or less.

4.1.4.3 CANCELLED.

4.1.5 WINDINGS INSULATION

4.1.5.1 Windings shall be of a form wound global fully vacuum pressure impregnated (VPI) construction.

4.1.5.2 Coils shall be insulated by mica tape.

4.1.5.3 Stator coils and terminals shall have uniform insulation levels throughout the winding length.

4.1.5.4 For motors with a rated voltage of 3 kV and above, windings shall be provided with an anti-corona protection system in the slot of the coil.

4.1.5.5 For motors with a rated voltage of 4 kV and above, field stress grading tape shall also be used for anti-corona protection.

4.1.5.6 For motors with rated voltage of 4 kV and above, stator windings, including the lead connections, shall have a sealed insulation system to be capable of withstand a spray test for sealed winding conformance, according to NEMA MG1 Part 20.

4.1.5.7 The motor insulation system shall be, at least, thermal class 155 (F) in accordance with IEC 60085 without exceeding thermal class 130 (B) temperature limits for the motor rated output at maximum ambient air temperature.

4.1.5.8 The stator winding system, including connections, end windings and terminal lead extensions, shall be supported, wedged and braced to prevent insulation cracking. Bracing, blocking and wedging shall be suitably secured to withstand the vibration and forces during the required lifetime of the machine.

4.1.5.9 Conductors connected between stator coils and terminals bushings shall permit movement of the stator during start up and thermal expansion.

4.1.5.10 Motor manufacturer shall provide a complete winding data presented on a form as shown in Annex G of API 541. The data shall be sufficient to permit the owner to have a set of stator coils built if required.

4.2 MECHANICAL CHARACTERISTICS

4.2.1 ENCLOSURE

4.2.1.1 Motors installed open deck shall have minimum protection degree IP-56. All other motors shall have protection degree IP-55.

Note: Open deck is a deck that is completely exposed to the weather from above or from at least one side.

4.2.1.2 Motors and terminal boxes shall have the same protection degree.

4.2.1.3 Unless otherwise indicated on project documents, motors with horizontal shafts shall comply with International Mounting code IM B3 (according to IEC 60034-7).

4.2.1.4 The following additional characteristics shall be provided:

a) Identification nameplate of AISI-316 stainless steel;

b) Painting proper for offshore installations and pre-qualified according to I-ET-3010.00-1200-956-P4X-002 - GENERAL PAINTING;

c) Enclosure last coat colour Light Green Munsell 5G8/4, for general purpose motors;

d) Enclosure last coat colour Red Munsell 5R4/14, for motors driving fire fighting equipment;

e) Terminal boxes interior last coat colour Safety Orange Munsell 2.5YR6/14.

f) Sealing devices (retainers, V-ring, labyrinth, etc.) between shaft and enclosure;

g) Caulking at the connection cables passage through the casing;

h) Screws, nuts, washers and all other connecting and mounting components proper to saline aggressive atmosphere;

i) Non-sparking copper-free aluminium for external fans (frame and blades). The aluminium shall be ANSI 356.0 alloy according to ASTM-B26/B26M, ANSI 359.0 alloy according to ASTM B108/B108M, 6063 alloy according to ASTM-B221, or 6351 alloy according to ASTM-B221.

Note: Last coat colour is applicable to motor and terminal boxes. Terminal boxes in AISI 316 without painting are acceptable.

4.2.1.5 Through-hole mounting of auxiliary components (e.g., terminal boxes, electrical conduits, cable trays, tubing or any other devices) onto the motor enclosure or its terminal boxes is not allowed. The auxiliary components shall be attached to the enclosure in such a way that does not affect the IP (Ingress Protection) rating of the motor. Measures shall also be taken to avoid galvanic corrosion due to the dissimilarity between the materials of the fixing elements and the motor enclosure and its terminal boxes.

4.2.2 COOLING SYSTEM

4.2.2.1 For outdoor installation, motors with rated power below 5600 kW shall be TEFC (Totally Enclosed Fan Cooled – according to NEMA MG1) cooling type, independent of area classification and they shall comply with the cooling methods IC 411, IC 511 or IC 611 defined in IEC 60034-6.

4.2.2.2 For outdoor installation, motors with rated power 5600 kW and above shall have closed-circuit air-water heat exchangers and they shall comply with the cooling methods IC7A1WX or, IC8A1WX (X can be any method of movement from 1 to 8).

4.2.2.3 For indoor installation, motors with rated power below 630 kW shall be TEFC (Totally Enclosed Fan Cooled – according to NEMA MG1) cooling type, independent of area classification and they shall comply with the cooling methods IC 411, IC 511 or IC 611 defined in IEC 60034-6.

4.2.2.4 For indoor installation, motors with rated power 630 kW and above shall have closed-circuit air-water heat exchangers and they shall comply with the cooling methods IC7A1WX or, IC8A1WX (X can be any method of movement from 1 to 8).

4.2.2.5 If closed-circuit air-water heat exchanger is specified, the system shall comply with the "water type", "inlet water temperature" and "inlet pressure" defined in GENERAL SPECIFICATION FOR AVAILABLE UTILITIES. The maximum acceptable water flow per motor is 7.5 [m^3/(h.MW)].

4.2.2.6 Air-water heat exchangers shall be manufactured, tested and certified as required for pressure vessels and following the requirements of ASME BPVC-VIII-1 and Classification Society.

4.2.2.7 Unless otherwise stated in Project Documentation, air-water heat exchangers shall comply with the following requirements:

a) Heat exchanger material of all parts in contact with cooling water (pipes, flanges, header, etc.) shall be in corrosion resistant alloy, for example, 9010 copper-nickel alloy. The fins shall be of copper or aluminium. It shall not be permitted use of carbon steel, even with internal organic coating;

b) galvanic corrosion between dissimilar metals shall be avoided;

c) load losses shall not exceed 0.7 kgf/cm^2;

d) heat exchanger shall be built into or mounted on the machine casing, always on a position to allow easy access for maintenance;

e) the tubing shall be double tube type so that any leakage from the internal tube will be collected by the external one. The internal tube shall be according to item a). The external tube shall be of copper, with fins of the same material. It shall be avoided galvanic corrosion between dissimilar metals.

f) it shall be provided protection to avoid the water to be in contact with the windings, in case of leakage, crack in pipes or condensation in exchanger;

g) it shall be provided means for draining off the water in case of leakage;

h) an alarm system shall be provided for signalling of leakage of water between the internal and the external tube;

i) installation of auxiliary fans shall be avoided, by all means;

j) thermometers shall be installed at the exchanger water inlet and outlet;

k) manometers shall be installed at the exchanger water inlet and outlet;

l) differential pressure detectors shall be installed at exchanger water inlet and outlet;

m) it shall be provided two inspection windows at opposite sides each other;

n) it shall be provided facilities to perform hydrostatic test for heat exchangers and blocking valves on site, as well as for testing the water leakage alarm unit.

4.2.2.8 For air-water heat exchangers water inlet and outlet shall be at the opposite side of the Power Terminal Box(es).

4.2.3 MOTION AND INCLINATION LIMITS REQUIREMENTS

For floating units, motors shall operate normally within motion and inclination limits (static and dynamic) specified in IMO MODU CODE, IEC 61892 series and Classification Society rules.

4.2.4 BALANCE

Motors shall be constructed so that, when running at any and every working speed, all revolving parts are well balanced.

4.2.5 VIBRATION

The motors shall comply with the requirements of IEC 60034-14, unless otherwise stated on Project Documentation.

4.2.6 NOISE LEVEL

4.2.6.1 Motors shall comply with the requirements of IEC 60034-9, and I-ET-3010.00-1200-300-P4X-001 - NOISE AND VIBRATION CONTROL REQUIREMENTS. The strictest requirement shall prevail.

4.2.6.2 Bent fan blades shall be used in the motor to achieve the noise limit, if not possible with straight fan blades.

4.2.7 BEARINGS

4.2.7.1 Motors shall have either sleeve or rolling element bearings. Bearings shall have a minimum lifetime of 25,000 hours, under rated load conditions.

4.2.7.2 Rolling element bearings shall not be used for 2 pole motors when the rated power is greater than 750 kW.

4.2.7.3 Rolling element bearings shall not be use for 4 pole motors when the rated power is greater than 1000 kW.

4.2.7.4 All motors lubricated with grease shall have bearings fitted with a greasing fitting and automatic bleeder device, in accordance with IEC 60072-1.

4.2.7.5 Bearings shall be fitted with sealing device, in order to avoid grease leakage or penetration of water and humidity.

4.2.7.6 Vertical motors shall have bearings designed to withstand axial stress imposed by the driven machine.

4.2.7.7 Means shall be provided to avoid the circulation of currents between the shaft and the bearings (see IEC 60034-25 as reference).

4.2.8 LUBRICATION

4.2.8.1 Rolling element bearings shall be lubricated with grease. In this case, they shall be lubricated at the factory, in order to avoid necessity of lubrication before operation starts.

4.2.8.2 Sleeve bearings may be fitted with a self-lubrication or forced lubrication system.

4.2.8.3 Motors with sleeve self-lubricated bearings shall have a thermometer temperature indicator and a sight glass indicator for oil level.

4.2.8.4 When ring lubrication is used, the rings shall be so constrained that they cannot leave the shaft.

4.2.8.5 Motors with forced oil lubrication sleeve bearings shall have a common lubrication system with the driven machine. Packager shall provide the necessary instruments.

Note: For motor driving gas compressor, the bearing lubrication system shall be independent from the oil used by the sealing system of the compressor.

4.2.8.6 Motors with oil lubrication shall have means to avoid liquid or gaseous oil to penetrate the windings area.

4.2.9 TERMINAL BOXES

4.2.9.1 All motors shall have two groups of terminal boxes, first one named Power Terminal Box(es) and second one named Auxiliary Terminal Box(es).

4.2.9.2 Unless otherwise indicated on the project documents, the Power Terminal Box(es) shall be fitted to the casing, on the left side, considering the motor viewed from the D-end, with the feet at 6 o'clock and the Power Terminal Box at 9 o'clock (designation L according to IEC 60034-7 for motors with feet).

4.2.9.3 Unless otherwise stated in project documents, the cable entry, tubing entry (when applicable) or any other device entry shall be from bottom side. It shall be possible to install the boxes on any of the four positions (from 90º to 90º), around its own axis, allowing adjustment for cable entry from top, bottom, front or rear side.

Note: Power Terminal Box(es) rotation is not required for Ex p motors and for motors with surge capacitors and surge arresters installed inside Power Terminal Box(es). In these cases, the cable entry side will be defined during Detailed Design.

4.2.9.4 Power Terminal Box(es) shall be used exclusively for power connections and installation of CTs, surge capacitors, surge arresters and partial discharge sensors.

4.2.9.5 Terminal Box(es) doors, above 20 kg shall have lifting eyelets.

4.2.9.6 Auxiliary Terminal Box(es) shall be used exclusively for connection of heating resistor, control, sensors and electric protection devices. There shall be separate holes for heating and control (or sensor) cables.

4.2.9.7 Auxiliary Terminal Box(es) shall be located at the opposite side of the Power Terminal Box(es), except for those linked to sensors installed inside it, for example, Auxiliary Terminal Boxes for current transformers and partial discharge sensors.

4.2.9.8 At the Power Terminal Box(es) the distance between terminal bushings with connectors and the cable inlet, shall be suitable to contain the cables stress-relief cones.

4.2.9.9 Motors shall have a removable non-magnetic plate fixed to the Power Terminal Box(es) to enable disconnection and removal of the motor to maintenance, keeping the cables terminations.

4.2.9.10 Soldered terminals shall not be used. The terminals insulation supports shall be of non-hygroscopic and non-combustible materials.

4.2.9.11 If single-core cables are used, the removable plate and the cable glands shall be of non-magnetic material to avoid magnetic induction.

4.2.9.12 The Power Terminal Box(es) shall be able to relief the overpressure caused by internal short-circuit.

4.2.9.13 CANCELLED.

4.2.10 GROUNDING CONNECTORS

4.2.10.1 Motors enclosures shall have a grounding connector fitted on its base, outside the terminal boxes, at the same side of the Power Terminal Box(es) and indelibly marked with the grounding symbol.

4.2.10.2 Motors shall have one additional grounding connector inside the Power Terminal Box, indelibly marked with grounding symbol.

4.2.10.3 Motors with rated voltage above 11 kV shall have one grounding connector inside the Power Terminal Box (meant for grounding the cable shield) and two grounding connectors outside the terminal boxes, fitted in symmetrical opposition. All grounding connectors shall be indelibly marked with grounding symbol.

4.2.10.4 For grounding cables and grounding connectors cross sections, see I-ET-3010.00-5140-700-P4X-001 - SPECIFICATION FOR ELECTRICAL DESIGN FOR OFFSHORE UNITS.

4.2.11 TERMINALS

4.2.11.1 Unless otherwise specified in Project Documentation, motors shall be furnished with six power terminals, marked according to IEC 60034-8.

4.2.11.2 For motors fed from VSD, if self-balancing differential protection is not required, three power terminals are acceptable.

4.2.11.3 For grounding terminals see item 4.2.10.

4.2.11.4 All motor cables (power and control) shall be indelibly marked inside the terminal boxes.

4.2.12 INSPECTION WINDOWS

4.2.12.1 Motors with rated voltage of 11 kV and greater shall have openings with removable caps (drive and non-drive ends) and suitable pathways to allow inspection by borescope. These openings shall give access to the rotor core ends, stator end-windings, stator coils connections, air gap and bearings.

4.2.12.2 Motor design shall consider easily removable covers for the inspection of the air gap in at least three positions (spaced 90º apart) in accordance with API 541.

4.2.13 LATERAL AND TORSIONAL ANALYSIS

4.2.13.1 For motors with rated voltage of 11 kV and greater, lateral analysis shall be carried out for rigid workshop floor and final site conditions (flexible skid or foundation) in accordance with API 541.

4.2.13.2 For motors with rated voltage of 11 kV and greater, torsional analysis shall be performed in accordance with API 541 and IEC 61800 (for converter-fed motors).

4.3 ACCESSORIES

4.3.1 LIFTING EYELETS

All motors shall be fitted with lifting eyelets. In case of Packager propose air-water heat exchanger it shall be fitted with lifting eyelets.

4.3.2 HEATING RESISTORS

4.3.2.1 All motors shall have internal heating resistors.

4.3.2.2 Heating resistors shall maintain the surface temperature of the stator windings at not less than 5 K above ambient air temperature to preserve the integrity of the insulation system at minimum ambient air temperature.

4.3.2.3 The heating resistors shall be shielded type, with rated voltage 220 Vac for each individual resistance used. The resistors shall be suitable to 220 Vac 2ph ungrounded power supply.

4.3.2.4 For motors certified for installation in hazardous areas, the temperature at surfaces with heater turned on and environmental temperature of 45 ºC shall not exceed the limits defined by IEC 60079.

4.3.2.5 For Ex p motors, additionally to the previous item, the heating resistors shall be certified for operation in hazardous areas, in order to be turned on before motor purge.

4.3.2.6 A warning plate shall be located next to the Auxiliary Terminal Box with the label:

ATENÇÃO!
AQUECEDOR LIGADO EM 220VCA.

4.3.2.7 The heating resistors shall not cause any damage to winding or insulation parts.

4.3.3 CURRENT TRANSFORMERS

4.3.3.1 Motors with rated voltage 11 kV and above shall be provided with 3 (three) window-type current transformers for self-balancing differential protection with “Wye” connection.

4.3.4 WINDING TEMPERATURE DETECTORS

4.3.4.1 Motors for gas compression shall be fitted with nine (three per phase) platinum resistance temperature detectors (RTDs), three-wire, 100Ω at 0ºC, embedded in the windings and complying with IEC 60034-11.

4.3.4.2 All other motors shall be fitted with six (two per phase) platinum resistance temperature detectors (RTDs), three-wire, 100Ω at 0ºC, embedded in the windings and complying with IEC 60034-11.

4.3.4.3 All motors fed from VSDs shall be fitted with six (two per phase) PTC thermistors connected in series at the terminal box. The PTC thermistors shall be additional to the RTDs required on 4.3.4.2.

4.3.4.4 CANCELLED.

4.3.5 BEARING TEMPERATURE DETECTORS

4.3.5.1 Motors (for any kind of bearing) shall have two temperature detectors installed on each bearing. The type of the detectors shall be platinum resistance RTDs, three-wire 100Ω at 0°C.

4.3.5.2 Each detector shall execute both functions: alarm and TRIP (switch off the motor).

4.3.5.3 The measuring points shall be according to IEC 60034-1.

4.3.5.4 Bearing temperature sensors shall be connected to temperature controllers supplied by Packager and installed in a Package Panel. Package Panel shall be the Package Control Panel, in case of Packages with this kind of panel. For Packages without Package Control Panel, Package Panel(s) shall be installed in the Package skid and shall be proper to external auxiliary voltage 220 Vdc ungrounded. Package Panel(s) shall comply with item 4.4.2. Trip and alarm signals shall be dry contacts, available for remote actuation.

4.3.5.5 CANCELLED.

4.3.6 PRESSURE DETECTORS

4.3.6.1 Motors with pressurised enclosure (Ex p) shall have two underpressure detectors.

4.3.6.2 Motors with oil lubricated bearings shall have lubrication oil pressure switches installed in both bearings.

4.3.6.3 Pressure detectors shall be connected to pressure controllers supplied by Packager and installed in Package Panel(s), as defined in 4.3.5.4.

4.3.6.4 Motors with pressurized enclosure (Ex p) shall have an external pressure indicator installed on the frame in order to monitor pressure inside the motor enclosure.

4.3.6.5 Water cooled motors shall have differential pressure detectors, as defined in 4.2.2.7.

4.3.6.6 Motors with sleeve bearings shall have lubrication oil pressure transducers installed in both bearings when driving Main Injection Water Pumps.

Note: When the pump package monitors the lubrication oil system and this signal is available for remote monitoring, the requirement above is not mandatory.

4.3.7 VIBRATION SENSORS

4.3.7.1 Motors for gas compressors shall have permanently installed the following vibration sensors according to the type of bearing:

a) sleeve bearings: two accelerometers per bearing and two non-contact proximity probes per bearing;

b) rolling elements bearing: one accelerometer per bearing;

c) axial bearing (if any): two non-contact proximity probes per axial bearing.

4.3.7.2 Motors for other type of loads than those indicated in item 4.3.7.1 with sleeve bearings shall have two permanently installed non-contacting proximity probes per bearing.

4.3.7.3 Motors for other type of loads than those indicated in item 4.3.7.1 with rolling element bearings and a rated power equal to or greater than 400 kW shall be provided with one permanently installed accelerometer per bearing.

4.3.7.4 For motors where accelerometers are not required, they shall have two clearly marked positions, X and Y, at each bearing housing with a flat surface for mounting of a magnetic portable accelerometer.

4.3.7.5 Vibration sensors shall be connected to vibration controllers supplied by Packager and installed in a Package Panel, as defined in 4.3.5.4.

4.3.7.6 CANCELLED.

4.3.8 PRESSURE CONTROL SYSTEM

4.3.8.1 Motors with pressurized enclosure (Ex p) shall comply with requirements of IEC 60079-2.

4.3.8.2 Motors with pressurized enclosure (Ex p) shall be proper to air supply quality according to ANSI/ISA 7.1.01 and GENERAL SPECIFICATION FOR AVAILABLE UTILITIES. If the motor requires a better air supply quality, Manufacturer shall include air treatment devices.

4.3.9 CABLE GLANDS

4.3.9.1 Cable glands shall be of stainless steel AISI 316.

4.3.9.2 Unless otherwise stated, threaded joints shall be taper type, NPT with standardized tolerances according to ASME B 1.20.1. For motors certified for installation in hazardous areas, threaded joints shall comply with requirements of IEC 60079-0.

4.3.9.3 Unless otherwise stated in project documentation, cable glands shall be included in manufacturer scope of supply.

4.3.10 PARTIAL DISCHARGE SENSORS

4.3.10.1 Motors with rated voltage 6 kV or greater and with rated power 5 MW or greater shall be supplied with a set of three units of 80 pF coupling capacitors, installed in the Power Terminal Box or in a specific Terminal Box, used as sensors for on-line Partial Discharge (PD) measurement.

4.3.10.2 Manufacturer shall be responsible to supply and install in motor, beyond the sensors, an Auxiliary Terminal Box including all devices (e.g. BNC connectors) required to allow the connection of a portable monitoring equipment (portable monitoring equipment supplied by others).

4.3.10.3 The coupling capacitors shall be positioned according to IEC TS 60034-27-2 recommendations and shall comply with minimum performance according to IEC TS 60034-27-2.

4.3.10.4 For motors installed in hazardous areas, motor certification shall include the Auxiliary Terminal Box.

4.3.11 IDENTIFICATION PLATE

The identification plate shall be marked according with IEC 60034-1 and the following information shall be included:

a) PETRÓLEO BRASILEIRO S/A – PETROBRAS;

b) PETROBRAS Unit name;

c) Motor identification tag;

d) PETROBRAS RM number;

e) PETROBRAS PCM number;

f) PETROBRAS AFM number;

g) Frame designation;

h) Service factor;

i) Efficiency at 100% load;

j) Bearings identification numbers;

k) Permissible locked rotor time (t_{lr});

l) Cooling method designation;

m) Ratio between Locked-rotor (T_l), breakdown (T_b) and rated torque (T_N);

n) Ratio between locked-rotor current (I_{lr}) and rated current (I_r);

o) Type of Ex protection, according to IEC 60079-0, including time t_E, for Ex e motors.

4.3.12 UNUSUAL TOOLS

Unless otherwise stated, water cooled motors shall be supplied with a tool for rotor removal. One tool per platform for each different motor is required. It is acceptable one tool for different motors, since this tool is suitable for all the motors considered.

4.4 ADDITIONAL REQUIREMENTS FOR MOTORS INSTALLED IN HAZARDOUS AREAS

4.4.1 Motors and electrical accessories installed in hazardous areas shall comply with IEC 60079 (all parts) INMETRO *Portaria* nº 115, March 21st, 2022.

4.4.2 Electrical accessories installed in external safe or hazardous areas, which shall be kept operating during emergency shutdown ESD-3P or ESD-3T shall be certified for installation in hazardous areas Zone 2 Group IIA temperature T3, unless they are automatically de-energized if there is gas in the equipment area, according to IEC 61892-1.

4.4.3 The kind of protection Ex and the EPL required for the motor shall be selected and specified according to requirements of IEC 60079-14.

4.4.4 Motors with DOL shall have kind of protection Ex and the EPL selected following the criteria defined in Table 2.

Table 2 - Selection of Ex Protection and EPL for single-speed motors.

Rated Voltage [V]		Hazardous Area Classification		
		Zone 1 (2)	Zone 2	
1000 < V ≤ 11000	Type of Protection	Ex e (1) or Ex pxb	Ex e (1)	Ex pzc
	EPL	Gb	Gb	Gc
V > 11000	Type of Protection	Ex pxb	Ex pzc	
	EPL	Gb	Gc	

Notes:
1. In case of selection of Ex e protection and evaluation of potential stator winding discharge risk assessment - ignition risk factors, according to IEC 60079-14, greater than 6, the motors shall be provided with pre-start enclosure ventilation to guarantee enclosure free from explosive gas at the time of starting.
2. The installation of medium-voltage motors in hazardous areas Zone 1 shall be avoided.

4.4.5 Motors fed from VSD or soft-starters and installed in hazardous areas shall be certified as a unit association (motor-VSD-protective device, or motor-soft-starter-protective device), as required by IEC 60079-14. Alternatives foreseen in IEC 60079-14 for this certification (as a unit association) are acceptable.

4.4.6 Motors fed from VSDs or soft-starters shall have kind of protection Ex and the EPL selected following the criteria defined in Table 3.

Table 3 - Selection of Ex Protection and EPL for Motors fed from VSDs or Soft-starters.

Rated Voltage [V]		Hazardous Area Classification	
		Zone 1 (1)	Zone 2
1000 < V ≤ 11000	Type of Protection	Ex pxb	Ex pzc
	EPL	Gb	Gc
V > 11000	Type of Protection	Ex pxb	Ex pzc
	EPL	Gb	Gc

Notes: 1. The installation of medium voltage motors in hazardous areas Zone 1 shall be avoided.

4.5 ADDITIONAL REQUIREMENTS FOR CONVERTER-FED MOTORS (FED FROM VSD - VARIABLE SPEED DRIVES)

4.5.1 Converter-fed motors shall comply with the recommendations of IEC 60034-25.

4.5.2 Converter-fed motors shall have means to avoid or to measure the circulation of current between the shaft and the bearings sending alarm and trip signals to avoid bearing damage (see IEC TS 60034-23 as reference).

4.5.3 The rated power of converter-fed motors shall be defined taking into account the additional losses due to harmonic contents and the ventilation performance for the entire frequency variation range.

4.5.4 The rated torque of converter-fed motors shall be defined taking into account the temperature rise due to additional losses and the ratio of the VSD output voltage at motor rated frequency and the motor rated voltage.

4.5.5 The maximum and the minimum foreseen operational speed (or frequency) shall be informed in motor Data Sheet. Motor manufacturer shall inform the maximum and the minimum permissible speed (or frequency) and the field weakening frequency (f_0 – according to IEC 60034-25) in motor Data Sheet.

4.5.6 For VSDs without dV/dt output filter, the insulation of the motors shall withstand at least a line-to-line voltage peak of 2.5 times the motor rated voltage, with a rise time of 0.1 µs. The insulation system of these motors shall be qualified according to IEC 60034-18-42 (with partial discharge), complying with the severity level of the overvoltage in their terminals (impulse voltage insulation class - IVIC 1, 2, 3, 4, 5, 6, 7 or S according to IEC 60034-18-42). Manufacturer shall ensure insulation suitability for the transient voltage which achieves the motor terminals (considering peak, rise time, repetition rate and jump voltage), upgrading the insulation system if necessary. VSDs without dV/dt filter shall be submitted to PETROBRAS approval.

4.6 PROTECTION

4.6.1 GENERAL PROTECTION

Manufacturers shall inform in Motor Data Sheet the adjustment settings for the protection functions listed in Table 4. Unless otherwise stated, the relays responsible for the protection functions shall be included in scope of supply of the Manufacturer of the panel which feeds the motor.

Table 4 – Adjustment Settings to be Informed

Protection Function - Adjustment Settings to be Informed		
N°	**Description**	**Responsible for Information**
27	Undervoltage	Motor Manufacturer
37	Undercurrent or Underpower (1)	Pump Manufacturer
38	Bearing High Temperature	Motor Manufacturer
39	High Vibration (2)	Motor Manufacturer/ Driven Machine Manufacturer
46	Current Unbalance	Motor Manufacturer
48	Incomplete Sequence or Locked Rotor (3)	Motor Manufacturer
49	Thermal Image (by Current Sensors)	Motor Manufacturer
49RTD	High Temperature (by Temperature Sensors)	Motor Manufacturer/ Pump Manufacturer
51LR	AC inverse time overcurrent (locked rotor)	Motor Manufacturer
50B	Bearing Overcurrent	Motor Manufacturer
63A	Compressed Air Underpressure (4)	Motor Manufacturer
63Q	Lube Oil Underpressure (5)	Motor Manufacturer
66	Starts/Hour & Time Between Starts	Motor Manufacturer
87M	Differential Current (6)	Motor Manufacturer

Notes:

1. Only for pump loads. The function 37 setting shall be based on the electric current driven at minimal permitted flow and on the maximum time at shut-off when starting. This function shall have a time delay during start condition;
2. This protection function is required for motors driving gas compressors and when required by driven machine or other PETROBRAS documentation;
3. Trip time for motors with protection Ex e (increased safety) shall be shorter than t_E according to IEC 60079-7 for Group IIA, Class T3 (200°C);
4. Only for motors with pressurised enclosure Ex p. Two underpressure detectors, supplied by Motor Manufacturer;
5. Only for motors with lubed oil bearings;
6. Only for 11 kV motors and above. CTs for self-balanced differential protection shall be supplied installed in the Power Terminal Box;
7. CANCELLED.

4.6.2 SURGE PROTECTION

4.6.2.1 Motor windings shall comply with the insulation levels defined by IEC 60034-15.

4.6.2.2 For motors with rated voltage 11 kV and above, surge arresters and surge capacitors shall be used to protect motors against switching surges.

4.6.2.3 For motors with rated voltages less than 11 kV, surge arresters and surge capacitors shall be used if required by electrical studies.

4.6.2.4 Surge arresters, when required, shall be selected to limit the magnitude of the surge voltage to the lesser between the motor insulation surge withstand and the basic impulse level (BIL) of the system.

4.6.2.5 Surge arresters and surge capacitors, when required, shall be installed inside the Power Terminal Box of the motor.

4.6.2.6 Surge arresters and surge capacitors design operational temperature shall be at least 10°C above the internal temperature of the Power Terminal Box, when the motor is at rated load and steady state condition.

4.6.2.7 Motors with Ex certification shall be certified with surge arrester and surge capacitors installed inside Power Terminal Box and the certification shall cite the surge components inside the Power Terminal Box.

4.6.2.8 Motor manufacturer shall inform the temperature inside the Power Terminal Box in steady state and full load condition.

4.6.2.9 Alternative locations for surge arresters and surge capacitors shall be submitted to PETROBRAS approval.

4.6.2.10 Motors fed from soft-starters and from VSD shall not have surge capacitors and surge arresters.

4.6.2.11 The surge arresters rated voltage shall be selected according to the type of the grounding system.

4.6.2.12 Surge arrester and surge capacitors shall be three individual single-phase units.

4.6.2.13 The connection leads to the capacitors and arresters shall be at least 107 mm². Leads shall have only gradual bends (if any) and shall be as short as possible with the total length on each capacitor and arrester not to exceed 0.6 m.

5 TECHNICAL DOCUMENTATION AND INFORMATION

5.1 DOCUMENTS TO PROPOSAL

The following documents and information shall be annexed to the proposal for the motor and all related equipment and accessories:

a) Preliminary dimensional drawings, including weights;

b) Technical catalogue;

c) Preliminary dimensional drawing and technical information for air-water and air-air coolers, when applicable;

d) Information about air-water coolers, including water flow data (minimum, maximum, operational), water speed (minimum, maximum, operational).

e) Preliminary dimensional drawing and technical information for bearings, when applicable;

f) Preliminary dimensional drawing and technical information for pressurisation system, when applicable;

g) CANCELLED;

h) Data-sheet following template of I-LI-3010.00-5140-700-P4X-001 - ELECTRICAL EQUIPMENT DATA SHEET MODELS completely filled in, when not issued by PETROBRAS;

i) Starting time calculation report including calculation of the relation t_a/t_{lr}. Current-speed curves, torque-speed curves for motor and driven machine and power factor-speed curve, printed on the same graphic. At least two reports shall be presented, one for rated voltage and other for 80 % of rated voltage;

j) Report of potential stator winding discharge risk assessment - ignition risk factors, for Ex e motors, according to IEC 60079-14;

k) Temperature rise test report for motors installed in hazardous area and for motors fed from VSD or when required in data-sheet;

l) Permissible torque-frequency curve for motors fed from VSD;

m) Voltage-frequency curve for motors fed from VSD (according to IEC 60034-25);

n) Electrical and mechanical parameters, including:
- locked-rotor, pull-up (if applicable) and breakdown torques;
- efficiency and power factor for 100%, 75% and 50% of load;
- locked-rotor power factor and current;
- capacitance-to-ground of the stator winding;
- motor electrical model with reactances and resistances for rated speed and for locked rotor conditions;
- heating and cooling time constants;
- moment of inertia.

o) Painting method;

p) Air quality requirements and air treatment devices data;

q) Applicable Standards, Codes and Rules;

r) Tests List;

s) Spare parts list, including code numbers and unit price;

t) Mean Time to Repair (MTTR);

u) Number of coils in series and in parallel and number of turns per coil of the stator winding;

v) Thickness of the main and turn insulations of the stator winding;

w) Number of bars of the rotor.

Note: All warning and safety instructions shall be issued in Portuguese language, or in English and Portuguese languages.

5.2 DOCUMENTS FOR APPROVAL

The following documents and information shall be submitted for PETROBRAS approval, after Packager definition, for the motor and all related equipment and accessories:

a) Dimensional drawings with all views, cross-sections, connections, terminals location, instruments and accessories location, forces, tolerances, weights, fixation holes, disassembling required space;

b) Wiring diagram(s) for motor, instruments, panels, sensors, lubrication and pressurisation equipment, when applicable;

c) Saturation curves for current transformers (if any);

d) Details of Power and Auxiliary Terminal Boxes;

e) CANCELLED;

f) Data Sheet following template of I-LI-3010.00-5140-700-P4X-001 - ELECTRICAL EQUIPMENT DATA SHEET MODELS completely filled in with manufacturer information;

g) List of spare parts necessary for two years operating period, with code number and unit prices;

h) List of standards applicable to design, manufacturing and testing;

i) Drawing(s), specifications and Data Sheet of heat exchanger unit in the case of motors with "air-water" cooling;

j) Drawing(s), specifications and data-sheet for bearings;

k) Drawing(s), specifications and data-sheet for pressurisation system, when applicable;

l) Drawing of identification plate;

m) Speed-torque and speed-current curves at 100 % and 80 % rated voltage;

n) Speed-power factor curve;

o) Thermal limit curves (based on IEEE Std 620) indicating the maximum permissible safe time versus line current in the machine under conditions other than normal operation. It shall include three conditions:
- locked-rotor (cold and hot conditions);
- starting and acceleration (for 100 % and 80 % of the rated voltage);
- running overload (cold and hot conditions).

p) Temperature-time (or current-time) curves, at rated ambient temperature (or rated cooling water temperature for water cooled motors), showing the required stator and rotor limits and the cool-down time after:
- Three consecutive starts, with the first start at ambient temperature (cold start) with the sequence: first start; accelerating until rated speed; stop command coasting to rest; second start; accelerating until rated speed; stop command coasting to rest; third start; accelerating until rated speed; keep operating with full load;
- Two consecutive starts with the first start at running temperature (hot start), with the sequence: first start; accelerating until rated speed; stop command coasting to rest; second start; accelerating until rated speed; keep operating with full load.

q) Negative-sequence capability curve;

r) Magnetic package damage curve due to ground fault (current through stator core lamination x time, with suitable time resolution in the milliseconds range);

s) Coils connections scheme (informing, for each phase, the number of coils in series and in parallel and the positions they are placed into the slots);

t) Complete winding data presented on a form as shown in Annex G of API 541. The data shall be sufficient to permit the owner to have a set of stator coils built if required and shall include:
- number of coils, winding connection and throw;
- total copper weight, copper strand sizes, and details of both turn and main insulations;
- turns per coil and number of parallel circuits.
- length of iron including vents;
- stator bore diameter, slot depth and width, plus depth below wedge; and
- finished coil dimensions in slot, plus details of semi-conducting finish and stress or gradient paint treatment at the coil end turns.

u) In case of packager propose different values of the specified ratio in item 4.1.2.2, protection study including the compatibility of protection devices with permissible thermal times at ambient (cold start) and running (hot start) temperatures.

v) In case of Packager propose air-water heat exchanger, study with advantages and disadvantages of the system, with considerations of dimensions, weight, maintenance, price, etc.

w) Detailed information about air-water coolers, including calculation report and water flow data (minimum, maximum, operational), water speed (minimum, maximum, operational).

x) Heating and cooling time constants (stator and rotor).

y) Report of potential stator winding discharge risk assessment - ignition risk factors, for Ex e motors, according to IEC 60079-14;

z) Air quality requirements and air treatment devices data;

aa) Conformity certificates with valid dates (for type tests) for motors certified for installation in hazardous areas, according to INMETRO *Portaria* nº 115, March 21st, 2022;

bb) Lateral Analysis;

cc) Torsional Analysis;

dd) Identification plates;

ee) 3D model files.

ff) Detailed description of the equipment, including all accessories

gg) List of risks to personnel and environment related to the equipment, including pollutant emissions at rated capacity;

hh) List of risks related to changing or override of protections and safety devices;

ii) List of risks related to use of equipment out of design conditions;

jj) Procedures during emergency conditions;

kk) List of safety equipment and components, including expected lifetime for each item.

Note: All warning and safety instructions shall be issued in Portuguese language, or in English and Portuguese languages.

5.3 DOCUMENTS AFTER APPROVAL

Assembly, Installation, Operation and Maintenance manuals shall be furnished, after documentation approval, containing at least the following information (including all requirement of NR-12):

a) Technical specifications for the motor, all components and accessories, in accordance with the approved requirements (as built);

b) List of standards followed for design, fabrication and tests;

c) Detailed description of motor and accessories;

d) List of risks for operators during operation and maintenance;

e) List of risks related to suppression of safety protective devices;

f) List of risks related to use out of design conditions;

g) List of lifetime for safety components and accessories;

h) Details regarding any spare units;

i) Installation procedures;

j) Storage and preservation treatment procedures;

k) Operating procedures;

l) Procedures for preventive and corrective maintenance of motor and all accessories, including list of necessary tools;

m) Procedures for emergency conditions;

n) Technical reports of all tests;

o) Starting, operational and stopping procedures, including permissible number of starts per time, procedures before starting and procedures after normal and abnormal stopping;

p) Lubrication plan with recommended lubricating oil or grease.

q) Lifting procedures;

r) Bearings and seals disassembly and assembly procedures;

s) Rotor disassembly and assembly detailed procedures, with drawings and weights of each part, lifting drawings, support drawings to receive each disassembled part, drawings of activity sequences, lifting heights, etc.

t) Conformity certificates with valid dates (for routine and special tests) for motors installed in hazardous areas according to INMETRO *Portaria* nº 115, March 21st, 2022;

u) As built and certified version for all documents cited in items 5.1 and 5.2;

v) Capacitance curve during VPI process.

Note: All warning and safety instructions shall be issued in Portuguese language, or in English and Portuguese languages.

6 INSPECTION AND TESTS

6.1 GENERAL

6.1.1 CANCELLED.

6.1.2 The minimum tests required for medium-voltage motors are split depending on the phase of the motor supply (manufacturing process, final acceptance tests and string tests).

6.1.3 Any other test required by Classification Society shall be also carried out.

6.1.4 Type tests (T) shall be carried out on the first of a batch of identical motors. Type tests reports carried out on a prototype motor are acceptable only for those tests indicated in Table 6.

6.1.5 CANCELLED.

6.1.6 Routine tests (R) shall be carried out on each motor.

6.1.7 Special tests (S) shall be carried out on each motor.

6.1.8 For all tests required it shall be provided test procedures which shall be approved by PETROBRAS. After tests have been performed test reports shall be also issued.

6.1.9 CANCELLED.

6.1.10 For tests which are required to be performed at rated frequency, the frequency of 60 Hz shall be considered.

6.2 TESTS DURING THE MANUFACTURING PROCESS

6.2.1 Tests required during the manufacturing process are indicated in Table 5.

6.2.2 For the sample coils tests required in Table 5, at least two additional sample coils for each motor shall be manufactured as for the production machine, at the same time and under the same conditions as the production winding, including the VPI process.

Table 5 – Tests to be performed during the manufacturing process

Component	Test	T	R	S	Test Procedure and Acceptance Criteria
Sample coils	Impulse voltage withstand test (1)			x	IEC 60034-15
	Dielectric dissipation test (tan δ and Δ tan δ)			x	IEC 60034-27-3
	Partial discharge			x	IEC 60034-27-1 Limits by note 2
Stator	Stator core test			x	API 541
	Surge test before impregnation and coils connections			x	IEEE 522
	Surge test after impregnation			x	IEEE 522
	Partial discharge			x	IEC 60034-27-1 Limits by note 3
	Sealed winding conformance test (Spray Test)			x	NEMA MG 1
	Dielectric dissipation test (tan δ and Δ tan δ)			x	IEC 60034-27-3
	Measurement of stator end-winding structural dynamics at standstill			x	IEC 60034-32
	Blackout test (corona)			x	IEEE 1799
Rotor	Balancing			x	API 541
Heat Exchanger	Hydrostatic pressure test for air-water heat exchanger			x	ASME BPVC-VIII-1

Notes:
1. Impulse voltage withstand test shall be carried out for main insulation and interturn insulation as required by IEC 60034-15.
2. Qm shall be less than or equal to 8 ηC (or 80 mV) for phase-to-ground rated voltage.
3. Qm shall be less than or equal to 25 ηC for phase-to-ground rated voltage and less than or equal to 50 ηC for phase-to- phase rated voltage. During the test the PDIV and PDEV voltage levels shall be recorded according to IEC 60034-27-1.

   Note: Qm is the Largest Repeatedly Occurring PD Magnitude (as defined by IEC 60034-27-1) recorded by a measuring system which has the pulse train response in accordance with IEC 60270 and considering 10 pulses per second.

6.3 FINAL ACCEPTANCE TESTS

6.3.1 Final Acceptance Tests list are indicated in Table 6.

Table 6 - Minimum Tests List for Final Acceptance Tests (FAT)

Test	T	R	S	Test Procedure and Acceptance Criteria
Measurement of winding's resistances (cold condition)		x		IEC 60034-2-1
Check of phase sequence, direction of rotation and terminal markings		x		IEC 60034-8
No-load losses and current at rated voltage and frequency (1)		x		IEC 60034-2-1
No-load characteristic (saturation curve) at rated frequency		x		IEC 60034-2-1
Locked rotor current test		x		IEC 60034-28
Locked rotor torque test		x		IEEE 112
Insulation resistance (before withstand voltage test)		x		IEC 60034-27-4
Withstand voltage test		x		IEC 60034-1
Insulation resistance and polarization index of stator windings (post withstand voltage test)		x		IEC 60034-27-4
Functional Tests of all auxiliary devices		x		Manufacturer's standard
Withstand voltage tests on RTDs, space heaters and insulated bearings where applicable		x		IEC 60034-1
Insulation resistance tests on RTDs and space heaters where applicable		x		IEC 60204-1
Insulation resistance of insulated bearings		x		IEEE 112
Temperature rise at full load (2)	x			IEC 60034-1, clause 8 or IEC 60034-29
Performance test at rated frequency at 100%, 75% and 50% of load (3)(4)	x			IEC 60034-2-1
Bearing housing vibration tests at no-load (5)(6)		x		IEC 60034-14 (7)
Shaft vibration (where sleeve bearings are provided) (5)(6)		x		IEC 60034-14 (7)
Electrical and Mechanical run-out		x		IEC 60034-14 (7)
Overspeed test		x		IEC 60034-1
Measurement of shaft voltage at no-load		x		IEEE 112
Determination of magnetic centre (where sleeve bearings are provided)		x		API Std 541
Sleeve bearing inspection		x		API Std 541
Bearing temperature rise at no load and rated speed		x		API Std 541
Air-gap measurement between stator and rotor (for motors with rated power of 400 kW and above)		x		API Std 541
Noise level at no load		x		IEC 60034-9
Measurement of moment of inertia			x	Manufacturer's standard
Bearing housing natural frequency			x	API Std 541
Occasional excess current test for motors up to 315 kW	x			IEC 60034-1
Momentary excess torque test	x			IEC 60034-1
Measurement of torque and current as function of speed from standstill to rated speed			x	IEEE 112
Measurement of partial discharge at rated voltage (7)			x	IEC 60034-27-2 Limits by note 8
Measurement of pull-up and breakdown torques and their relative slips			x	IEC 60034-2-1
Unbalance response test			x	API Std 541
Dielectric dissipation test (tan δ and Δ tan δ)			x	IEC 60034-27-3
Verification of degree of enclosure protection (IP) (11)	x			IEC 60034-5
Temperature rise test at full load for Ex motors	x			IEC 60079-0
Maximum overpressure test for Ex p motors	x			IEC 60079-2

Test	T	R	S	Test Procedure and Acceptance Criteria
Leakage test for Ex p motors		x		IEC 60079-2
Purging test for Ex p motors	x			IEC 60079-2
Minimum overpressure test for Ex p motors	x			IEC 60079-2
Determination of starting current ratio I_A/I_N and time t_E for Ex e motors (10)	x			IEC 60079-7
Impulse ignition test for Level of Protection "eb" stator insulation systems, for Ex e motors (10)	x			IEC 60079-7
Steady state ignition test for Levels of Protection "eb" and "ec" stator insulation systems, for Ex e motors (10)	x			IEC 60079-7
Cage rotor test for Ex e motors (10)	x			IEC 60079-7
Verification of data on name plate and visual inspection		x		IEC 60034-1 and this ET
Verification of painting (colour, thickness and adhesion)		x		I-ET-3010.00-1200-956-P4X-002 - GENERAL PAINTING
Verification of Certification Reports for Ex motors		x		Applicable IEC and INMETRO *Portaria* 115/2022
Verification of Certification Reports of group motor/VSD or motor/soft starter for motor installed in hazardous area		x		IEC 60079-14
Qualification Tests for Main Insulation, Turn Insulation, and Stress Control System for converter-fed motors (10)	x			IEC 60034-18-42

Notes:

1. For converter-fed motors, in addition to the rated frequency, no-load losses and current at rated voltage shall be also performed at minimum and at maximum continuous operating speed.
2. For converter-fed motors temperature rise tests shall be performed at three points:
   a) at rated torque and at rated speed;
   b) at maximum torque and at maximum continuous operating speed;
   c) at maximum torque and minimum continuous operating speed.
3. For converter-fed motors performance tests (power-factor and efficiency) shall be performed at three points:
   a) at rated frequency at 100 %, 75 % and 50 % load;
   b) at minimum continuous operating speed at 100 %, 75 % and 50 % of motor continuous torque capability for this speed;
   c) at maximum continuous operating speed at 100 %, 75 % and 50 % of motor continuous torque capability for this speed.
4. Performance test to include determination of power factor, efficiency, current balance and slip.
5. For converter-fed motors, bearing housing vibration and shaft vibration tests shall be performed for the whole operational speed range and during coast down.
6. The required vibration sensors shall be used, forming the basis for acceptance.
7. Test procedure and acceptance criteria shall be changed from IEC 60034-14 to API 541 when so requested in the motor Project Documentation.
8. Applicable for motors with rated voltage 6 kV or greater and rated power 5 MW or greater. The coupling capacitors installed in the machine shall be used during the tests. The measurement equipment bandwidth shall be suitable to the 80 pF coupling capacitors.
9. Largest Repeatedly Occurring PD Magnitude (Qm as defined by IEC TS 60034-27-2), recorded by a measuring system which has the pulse train response in accordance with IEC 60270 (item 4.3.3) and considering 10 pulses per second, shall be less than or equal to 260 mV.
10. Type Test reports are acceptable if analysed and approved by PETROBRAS.
11. Type Test reports are acceptable if analysed and approved by PETROBRAS and only if it refers to an identical motor.

6.4 STRING TESTS

6.4.1 String tests refer to the tests performed in the set motor-driven machine and VSD, when applicable, in order to verify the performance of the motors with their loads.

6.4.2 For single speed motors, string tests shall be performed for all set motor-driven machine with motor power equal to or greater than 1000 kW and for other smaller motors when required in driven machine Documentation.

6.4.3 For converter-fed motors all set VSD-motor-driven machine shall be submitted to string tests.

6.4.4 The following tests (and others required in the Project Documentation) shall be carried out:

Table 7 - String Tests

Test	Test Procedure and Acceptance Criteria
Measurement of noise	IEC 60034-9 and I-ET-3010.00-1200-300-P4X-001 - NOISE AND VIBRATION CONTROL REQUIREMENTS
Measurement of power factor at rated voltage and frequency for 100%, 75% and 50% of rated load.	IEC 60034-2-1
Measurement of shaft voltage	IEEE 112
Measurements at full load and rated voltage and frequency	Motor Data-Sheet
Vibration tests, including operation of lubrication system	Zone B of ISO 20816-1 (1)
Temperature rise test at full load	IEC 60034-1 and IEC 60085
Bearing temperature rise test	API Std 541
Temperature rise test at full load for Ex motors	IEC 60079-0
4 hours continuous operation at full load (2)	IEC 60034-1

Notes: 1. If driven machine manufacturer requires a different limit for vibration, the lower limit shall prevail.
2. The longer between this time and time required in driven machine Documentation shall prevail.

7 DESIGN REVIEW

7.1 GENERAL

7.1.1 For those motors indicated in the ELECTRICAL SYSTEM DESCRIPTIVE MEMORANDUM, motor manufacturer shall provide detailed technical information about the equipment in specific design review meetings with PETROBRAS.

7.1.2 Design Review meetings shall be held by the motor manufacturer at the time documents and data are available for approval by purchaser. The meetings shall include PETROBRAS, electric machine manufacturer, driven equipment manufacturer, VSD supplier (as applicable), packager, seller and other sub-suppliers as required.

7.2 DETAILED DESCRIPTION

7.2.1 The main objective of these specific Design Review meetings is to solve technical issues, avoiding future failures or problems in the equipment or during integration with other equipment.

7.2.2 Design Review meetings shall occur before fabrication, during fabrication, before Factory Acceptance Test, before Site Acceptance Test or at any additional moment required by PETROBRAS.

7.2.3 The items to be covered by the Design Review meetings shall include (not limited to):

a) contract data and datasheet information;

b) performance curves including thermal damage curves, acceleration times, and allowable stall times;

c) method of efficiency determination and guarantee of efficiency;

d) current pulsations for reciprocating loads;

e) number of starts allowed;

f) inertia of the machine and coupled equipment;

g) stator winding and winding insulation system;

h) Ex certification, where applicable;

i) rotor mechanical design, fits, construction, balance;

j) shaft design stress, short circuit torques;

k) torsional and lateral critical speed analysis, and rotor sensitivity analysis (response to an intentional unbalance);

l) foundation and base stiffness;

m) coupling type;

n) bearing and seal details;

o) bearing and coupling insulation;

p) lubricating oil type and oil inlet temperature range;

q) minimum test list;

r) “witness” and “review” points for inspections and tests;

s) data for performance of electrical power system studies;

t) review of motor drawings, and where applicable, P&IDs and auxiliary subsystem drawings;

u) installation and commissioning procedures;

v) standardization of frame and other aspects to allow interchangeability with other motors;

w) packaging, shipping, and long-term storage.

8 ANNEX I – ABBREVIATIONS AND ACRONYMS

AFM	Material Supply Permission
BIL	Basic Impulse Level
CT	Current Transformer
DOL	Direct On-Line
EFI	Earth Fault Indicator
ET	Technical Specification
FPSO	Floating, Production, Storage and Offloading Unit
FSO	Floating, Storage and Offloading Unit
IEC	International Electrotechnical Commission
IEEE	Institute of Electrotechnical and Electronic Engineers
I_{lr}	Locked rotor current
INMETRO	Instituto Nacional de Metrologia Normalização e Qualidade Industrial
I_r	Rated current
IVIC	Impulse Voltage Insulation Class
NEMA	National Electrical Manufacturers Association
PCM	Material Purchase Order
PD	Partial Discharge
PDEV	Partial Discharge Extinction Voltage
PDIV	Partial Discharge Inception Voltage
RM	Material Requisition
RMS	Root Mean Square
R	Routine Test
RTD	Resistance Temperature Detectors
SPDT	Single Pole Double Through
S	Special Test
t_a	Acceleration time
T_b	Breakdown torque
t_E	Time, in seconds, taken for an A.C. motor or stator winding, when carrying the initial starting current I_A, to be heated up to the limiting temperature from the temperature reached in rated service at the maximum ambient temperature (based on IEC 60079-7)
TEFC	Totally Enclosed Fan Cooled
T_l	Locked rotor torque
t_{lr}	Permissible locked rotor time
T_N	Rated torque at rated speed and rated output power
T	Type Test
T_u	Pull-up torque
VPI	Vacuum Pressure Impregnation