PETROBRAS	**TECHNICAL SPECIFICATION**	Nº. I-ET-3010.00-5111-712-P4X-001	
	CLIENT:		SHEET: 1 of 23
	JOB:		-
	AREA:		
SRGE	TITLE: **SUBMERSIBLE INDUCTION MOTORS FOR SEA WATER LIFT PUMPS FOR OFFSHORE UNITS**		INTERNAL
			ESUP

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1 OBJECTIVE

This specification establishes the necessary technical requirements for design, manufacture, and supply of Submersible Induction Motors for Sea Water Lift Pumps 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, ISO, 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, 29 and 32;
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 60092	Electrical installations in ships – Part 350: General construction and test methods of power, control and instrumentation cables for shipboard and offshore applications.

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 INMETRO – INSTITUTO NACIONAL DE METROLOGIA NORMALIZAÇÃO E QUALIDADE INDUSTRIAL

Portaria 115	March 21st, 2022

2.2.5 API – AMERICAN PETROLEUM INSTITUTE

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

2.2.6 ASME – AMERICAN SOCIETY OF MECHANICAL ENGINEERS

ASME B 1.20.1	Pipe Threads, General Purposes (Inch)

2.2.7 IMO - INTERNATIONAL MARITIME ORGANIZATION

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

2.2.8 ISO – INTERNATIONAL ORGANIZATION FOR STANDARDIZATION

ISO 21940-11	Mechanical Vibration – Rotor Balancing - Part 11: Procedures and tolerances for rotors with rigid behaviour.

2.2.9 RULES OF CLASSIFICATION SOCIETY

2.2.10 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] SPECIFICATION FOR SEA WATER LIFT PUMP AND START SEA WATER LIFT PUMP

[7] 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. 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.

3.3 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 5 years and considering requirement stated in item 4.1.2.7.

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 frequency of 60 Hz.

4.1.1.2 The motors rated voltage shall be selected according 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. This specification is valid for low and medium-voltage submersible induction motors.

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

Notes:
- Accelerating time (t_a) 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 3 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 shall be validated by motor Manufacturer prior to submission to Petrobras.

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 5 s.

Note: Shorter values of permissible locked rotor time (t_{lr}) proposed by motor Manufacturer 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 Motors shall be designed for a minimum of 1000 starts per year for the minimum lifetime specified in the Project Documentation.

4.1.2.8 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 1.5s;

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

4.1.3.3 Within the limits stated in items 4.1.3.1 and 4.1.3.2, the temperature rise shall comply with requirements of IEC 60034-1.

4.1.3.4 Motors 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.

4.1.3.5 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.

4.1.3.6 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 Medium-voltage submersible motors shall have efficiency of at least 90.4 %, at rated voltage and full load and considering +0% tolerance.

4.1.4.2 Low-voltage submersible motors shall have efficiency of at least 87.5 %, at rated voltage and full load and considering +0% tolerance.

4.1.5 STATOR WINDING

4.1.5.1 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.

4.1.5.2 The stator winding shall be either form-wound or cable-wound construction.

4.1.5.3 FORM-WOUND STATOR WINDINGS

4.1.5.3.1 Form-wound windings shall have insulation impregnation either by global fully vacuum pressure (VPI) or by resin rich technology.

4.1.5.3.2 Coils shall be insulated by mica tape.

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

4.1.5.3.4 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.

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

4.1.5.3.6 Form-wound stator windings shall have Thermal Class F (155 °C), or Thermal Class higher than F, with a maximum temperature rise at full load not exceeding the limit defined to Thermal Class B (130 °C), according to IEC 60085 and IEC 60034-1, when the motor is operating in worst thermal condition regarding load, harmonics, and cooling fluid system.

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

4.1.5.4 CABLE-WOUND STATOR WINDINGS

4.1.5.4.1 Windings and neutral point insulation shall be uniform.

4.1.5.4.2 For cable-wound stator windings, the maximum continuous operation temperature of the winding shall be limited, at least, to 10 °C below the actual thermal class of the motor winding insulation, when the motor is operating in worst thermal condition regarding load, harmonics, and cooling fluid system.

4.1.5.4.3 Splices are not allowed in the winding of cable-wound stators. Winding terminations shall be qualified (e.g. wye and terminal connections) with the same requirements of the cable and lifetime when in contact with the cooling fluid for the required operational conditions.

4.1.5.4.4 Detailed procedure (execution/step by step) for the following activities shall be sent to Petrobras approval:

a) motor windings terminations and output cable sealing;

b) Y (or delta) connection of the windings;

c) end-windings bracing and supports.

4.2 MECHANICAL CHARACTERISTICS

4.2.1 ENCLOSURE

4.2.1.1 Motors shall have minimum protection degree IP-68.

4.2.1.2 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, where applicable;

c) Terminal Boxes last coat colour Light Green Munsell 5G8/4, where applicable;

d) Terminal Boxes interior last coat colour Safety Orange Munsell 2.5YR6/14.

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

Note: Terminal boxes in AISI 316 without painting are acceptable.

4.2.1.3 If the rotor is not designed to withstand reverse rotation, the package shall have means to prevent reverse rotation caused by the water column.

4.2.1.4 Cable-glands and sealing system of these motors shall ensure that no sea water leakage into the motor windings occurs. The sealing system description and the identification of each sealing element (static and dynamic seals, elastomeric and metal seals) shall be provided.

4.2.2 COOLING SYSTEM

4.2.2.1 Cooling by a dedicated fluid circulation system is acceptable. The fluid system shall provide the following, non-exhaustive, list of main functionalities where applicable:

a) lubrication of bearing and mechanical seals;

b) overpressure protection of motor and bearings;

c) cooling media of the motor rotor/stator gap, windings, mechanical seals and all pump and motor bearings;

d) dielectric media for motor (additional to the motor insulation), if applicable;

e) corrosion protection of motor.

4.2.2.2 For cable-wound stator, the design shall ensure proper cooling of windings in areas where cables are bundled together.

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

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

4.2.4.2 Motors rotor shall be factory balanced as per ISO 21940-11 Grade G2,5.

4.2.5 VIBRATION

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

4.2.5.2 Motor casing vibration shall be measured during the FAT and shall comply with the requirements of IEC 60034-14.

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.

4.2.7 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 Motors shall have bearings designed to withstand axial stress imposed by the driven machine at steady state and transient conditions considering the number of starts per year stated in item 4.1.2.7.

4.2.8 TERMINAL BOXES

4.2.8.1 Two groups of terminal boxes shall be provided, the first one named Power Terminal Box(es) and second one named Auxiliary Terminal Box(es).

4.2.8.2 Power Terminal Box(es) shall be used to accommodate power connections and installation of current transformers, surge capacitors and surge arresters, if applicable.

4.2.8.3 Auxiliary Terminal Box(es) shall be used exclusively for connection of control, sensors and electric protection devices.

4.2.8.4 Terminal Box(es) shall be supplied by motor manufacturer and shall be suitable for the location of installation (environment and hazardous area classification).

4.2.8.5 Terminal Box(es) shall have minimum protection degree IP-56.

4.2.8.6 The cable entry in the Terminal Box(es) shall be from bottom side.

4.2.8.7 Terminal Box(es) door, above 20 kg, shall have lifting eyelets.

4.2.8.8 Power Terminal Box(es) shall be installed as close as possible to the cable entry to the motor.

4.2.8.9 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.

4.2.8.10 If single-core cables are used in the Power Terminal Box(es), the removable plate and the cable glands shall be of non-magnetic material to avoid magnetic induction.

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

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

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

4.2.9 GROUNDING CONNECTORS

4.2.9.1 Power Terminal Box(es) shall have an internal grounding connector indelibly marked with grounding symbol.

4.2.9.2 Power Terminal Box(es) for motor with rated voltage above 11 kV shall have one grounding connector inside the Power (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.

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

4.3 ACCESSORIES

4.3.1 CURRENT TRANSFORMERS

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.

4.3.2 WINDING TEMPERATURE DETECTORS

4.3.2.1 The stator winding temperature shall be monitored either directly or indirectly.

4.3.2.2 Direct monitoring shall be performed by means of, at least, 2 (two) platinum resistance RTDs, three-wire 100 Ω at 0 °C, per phase, installed in the hottest points of the winding.

4.3.2.3 Indirect monitoring may be achieved by measurement of cooling fluid temperature by means of, at least, 2 (two) platinum resistance RTDs, three-wire 100 Ω at 0°C, installed in the hottest points of the motor based on the temperature rise test versus motor thermal model.

4.3.2.4 For indirect monitoring, the temperature sensors shall not be connected to motor protection relay but to machinery monitoring system (MMS) or to the Unit Automation System. These signals shall be treated according to technical requirements stated on MMS or on Automation documents. Trip signal from MMS to electrical functional unit shall be provided.

4.3.2.5 For indirect temperature windings monitoring, temperature rise test shall consider temperature sensors directly installed at the winding hottest points (to be removed after the factory tests) in order do have a correlation with the temperature of cooling fluid.

4.3.3 BEARING TEMPERATURE DETECTORS

4.3.3.1 Bearing temperature shall be monitored by means of platinum resistance RTDs, three-wire 100 Ω at 0°C. Measurement of the cooling fluid temperature is acceptable since the correlation between the temperature of the bearings and the fluid is known.

4.3.3.2 Bearing temperature sensors shall be connected to temperature controllers supplied by Packager and installed in the Package Panel.

4.3.4 VIBRATION SENSORS

4.3.4.1 Motors shall have vibration sensors installed in bearings if required by driven machine or other PETROBRAS documentation.

4.3.4.2 Vibration sensors, if required, shall be connected to vibration controllers supplied by Packager and installed in the Package Panel.

4.3.5 CABLE GLANDS

4.3.5.1 Cable glands shall be of stainless steel AISI 316.

4.3.5.2 Unless otherwise stated, threaded joints shall be taper type, NPT with standardized tolerances according to ASME B 1.20.1. For cable glands to be installed in hazardous areas, threaded joints shall comply with requirements of IEC 60079-0.

4.3.6 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) Starting torque design designation;

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

4.4 ADDITIONAL REQUIREMENTS FOR MOTORS FED FROM VSD (VARIABLE SPEED DRIVES)

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

4.4.2 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).

4.4.3 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.

4.4.4 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.

4.4.5 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.

4.4.6 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.

4.5 PROTECTION

4.5.1 GENERAL PROTECTION

Manufacturers shall inform in Motor Data Sheet the adjustment settings for the protection functions listed in Table 1. 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 1 – 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
46	Current Unbalance	Motor Manufacturer
48	Incomplete Sequence or Locked Rotor	Motor Manufacturer
49	Thermal Image (by Current Sensors)	Motor Manufacturer
49RTD	High Temperature (by Temperature Sensors) (2)	Motor Manufacturer
49RTD	High Temperature of Cooling Liquid (by temperature sensors) (3)	Motor Manufacturer
51LR	AC inverse time overcurrent (locked rotor)	Motor Manufacturer
66	Starts/Hour & Time Between Starts	Motor Manufacturer
87M	Differential Current (4)	Motor Manufacturer

Notes:
1) 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) For submersible motors with direct temperature monitoring;
3) For submersible motors with indirect temperature monitoring;
4) Only for 11 kV motors and above. CTs for self-balanced differential protection shall be supplied installed in the Power Terminal Box.

4.5.2 SURGE PROTECTION

4.5.2.1 Motor windings with rated voltage above 1 kV shall comply with the impulse voltage withstand levels defined by IEC 60034-15.

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

4.5.2.3 For motors with rated voltage above 1 kV and less than 11 kV, surge arresters and surge capacitors shall be used if required by electrical studies. Motors designed to withstand higher impulse voltage levels than that required by motor's rated voltage, according to the values indicated in IEC 60034-15, are acceptable to replace surge arresters and surge capacitors.

4.5.2.4 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.

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

4.5.2.6 Ex certification of the Power Terminal Box, if applicable, shall consider the surge arrester and surge capacitors.

4.5.2.7 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.

4.5.2.8 Motor manufacturer shall inform the temperature inside the Power Terminal Box, in which surge arrester and surge capacitors are installed, at steady state and at full load condition.

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

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

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

4.5.2.12 The connection leads from the motor cables power supply to the capacitors and arresters shall be at least 107 mm². These cable 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. In addition, if these cables cross Zone 0 or Zone 1 hazardous area, they shall be armoured type.

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 and materials.

b) Motor technical catalogue.

c) Preliminary dimensional drawing and technical information for the fluid cooling unit.

d) 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.

e) 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.

f) Permissible torque-frequency curve for motors fed from VSD.

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

h) 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;

i) Painting method (for the terminal boxes).

j) Applicable Standards, Codes and Rules.

k) Tests List.

l) Spare parts list, including code numbers and unit price.

m) Mean Time to Repair (MTTR).

n) Electrical cable catalogue including elements, dimensions and materials of the cross section and electrical parameters (inductance, capacitance and resistance) of the cable between motor terminals and power terminal box.

o) Number of coils in series and in parallel and number of turns per coil of the stator winding (for form-wound stators).

p) Total length per phase of the electric cable winding for cable-wound stators.

q) Thickness of the main and turn insulation of the stator winding for form-wound stators.

r) Electrical cable catalogue including elements, dimensions and materials of the cross section and electrical parameters (inductance, capacitance and resistance) for cable-wound stators.

s) Detailed procedure (execution/step by step) for the following activities:
- motor windings terminations and output cable sealing;
- Y (or delta) connection of the windings;
- end-windings bracing and supports.

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

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

g) List of standards applicable to design, manufacturing and testing.

h) Drawing(s), specifications of fluid cooling system.

i) Drawing(s), specifications and data-sheet for bearings.

j) Drawing of identification plate.

k) Speed-torque and speed-current curves at 100 % and 80 % rated voltage.

l) Speed-power factor curve.

m) 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 % rated voltage);
- running overload (cold and hot conditions).

n) 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.

o) Negative-sequence capability curve.

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

q) Coils connections scheme for medium-voltage motors (informing, for each phase, the number of coils in series and in parallel and the how they are placed into the slots) for form-wound stators.

r) Complete winding data presented on a form as shown in Annex G of API 541 for medium-voltage form-wound stator windings. 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.

s) Detailed windings configuration showing the number of parallel and total length of cables per phase for cable-wound stator.

t) Detailed procedure (execution/step by step) for the following activities:
- motor windings terminations and output cable sealing;
- Y (or delta) connection of the windings;
- end-windings bracing and supports.

u) Detailed position of the temperature sensors.

v) 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.

w) Detailed information about fluid cooling system, including calculation report and fluid flow and pressure data.

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

y) Conformity certificates with valid dates (for type tests) for Terminal Boxes and accessories certified for installation in hazardous areas, according to INMETRO *Portaria* nº 115, March 21st, 2022.

z) Identification plates.

aa) 3D model files.

bb) Detailed description of the equipment, including all accessories.

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

dd) List of risks related to changing or override of protections and safety devices.

ee) List of risks related to use of equipment out of design conditions.

ff) Procedures during emergency conditions.

gg) 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) Cooling fluid system maintenance plan.

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) As built and certified version for all documents cited in items 5.2.

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

6.1.2 For tests of the set motor-pump, see requirements of SPECIFICATION FOR SEA WATER LIFT PUMP AND START SEA WATER LIFT PUMP.

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 4.

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

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

6.1.7 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.

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

6.2 TESTS LIST

6.2.1 TESTS DURING THE MANUFACTURING PROCESS

6.2.1.1 Tests required during the manufacturing process for form-wound and cable-wound stator windings are indicated in Table 2 and in Table 3, respectively.

6.2.1.2 For form-wound stator windings, as presented in Table2, tests are split in components, that is, sample coils, stator, and rotor.

6.2.1.3 For the sample coils tests required in Table 2, 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 impregnation process (VPI or Resin Rich).

Table 2 – Tests to be performed during the manufacturing process (for form-wound windings).

Component	Test	T	R	S	Test Procedure and Acceptance Criteria
Sample coils	Impulse voltage withstand test (1) (4)		x		IEC 60034-15
	Dielectric dissipation test (tan δ and Δ tan δ) (4)				IEC 60034-27-3
	Partial discharge (4)		x		IEC 60034-27-1 Limits by note 2
Stator	Stator core test (4)		x		API 541
	Surge test before impregnation and coils connections (4)		x		IEEE 522
	Surge test after impregnation (4)		x		IEEE 522
	Partial discharge (4)		x		IEC 60034-27-1 Limits by note 3
	Sealed winding conformance test (Spray Test) (4)		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 (4)		x		IEC 60034-32
	Blackout test (corona) (4)		x		IEEE 1799
Rotor	Balancing		x		ISO 21940-11

Notes: 1) Impulse voltage withstand test shall be carried out for main insulation and interturn insulation as required by IEC 60034-15.

2) The Largest Repeatedly Occurring PD Magnitude (Qm 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, shall be less than or equal to 8 ηC (or 80 mV) for phase-to-ground rated voltage.

3) The Largest Repeatedly Occurring PD Magnitude (Qm 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, 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.

4) Only applicable to motors with rated voltage above 1 kV.

6.2.1.4 For cable-wound stator windings, as presented in Table 3, tests are also split in the phases of the stator winding assembling, that is, samples of cable, cable joints and splices, cables inserted into the slots prior to the neutral connection and after neutral connection. For tests to be performed on samples of cable, cable joints and splices, at least, 3 (three) samples of each (cable, cable joint and splice) shall be submitted to the tests.

Table 3 – Tests to be performed during the manufacturing process (for cable-wound windings).

Phase	Test	T	R	S	Test Procedure and Acceptance Criteria
Samples of Cable, Cable Joints and Splices	Conductor examination		x		IEC 60092-350
	Measurement of thickness of insulation		x		IEC 60092-350
	Measurements of thickness of non-metallic sheaths		x		IEC 60092-350
	Measurement of external diameter		x		IEC 60092-350
	Electric resistance of conductors		x		IEC 60092-350
	Insulation resistance test		x		IEC 60092-350
	Voltage Test		x		IEC 60092-350
Cable-wound Stator prior to neutral connection	Electric resistance of conductors		x		IEC 60092-350
	Insulation resistance test		x		IEC 60034-27-4
	Partial Discharge (1)		x		IEC 60092-350
	Surge Test (1)		x		IEEE 522

Phase	Test	T	R	S	Test Procedure and Acceptance Criteria
Cable-wound Stator after neutral connection	Electric resistance of conductors		x		IEC 60092-350
	Insulation resistance test		x		IEC 60034-27-4
	Partial Discharge (1)		x		IEC 60092-350
	Surge Test (1)		x		IEEE 522
Rotor	Balancing			x	ISO 21940-11

Note: 1) Only applicable to motors with rated voltage above 1 kV.

6.2.2 FINAL ACCEPTANCE TESTS

6.2.2.1 Final Acceptance Tests list are indicated in Table 4 and they refer to form-wound and cable-wound stator windings.

Table 4 – Tests to be performed with the motor final assembled (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 voltage withstand 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)(3)	x			IEC 60034-1
Performance test at rated frequency at 100%, 75% and 50% of load (4)(5)	x			IEC 60034-2-1
Vibration tests (6)(7)		x		IEC 60034-14 (7)
Overspeed test		x		IEC 60034-1
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
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 pull-up and breakdown torques and their relative slips			x	IEC 60034-2-1
Measurement of loss tangent (tan δ and Δ tan δ) of insulation (9)			x	IEC 60034-27-3
Verification of degree of enclosure protection (IP)	x			IEC 60034-5

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 indirect temperature windings monitoring, temperature rise test shall consider temperature sensors directly installed at the winding hottest points (to be removed after the factory tests) in order do have a correlation with the temperature of cooling fluid.

4) 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.

5) Performance test to include determination of power factor, efficiency, current balance and slip.

6) For converter-fed motors, vibration tests shall be performed for the whole operational speed range and during coast down.

7) If vibration sensors are required, they shall be used during tests, forming the basis for acceptance.

8) Test procedure and acceptance criteria shall be changed from IEC 60034-14 to API 541 when so requested in the motor Project Documentation.

9) Only applicable to motors with rated voltage above 1 kV.

7 DESIGN REVIEW

7.1 GENERAL

7.1.1 Submersible induction motor manufacturer shall provide detailed technical information about the equipment in specific design review meetings with PETROBRAS for both, low and medium-voltage induction motors.

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) number of starts allowed;

e) inertia of the machine and coupled equipment;

f) stator winding and winding insulation system;

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

h) shaft design stress, short circuit torques;

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

j) bearing and seal details;

k) lubricating fluid system;

l) minimum test list;

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

n) data for performance of electrical power system studies by the purchaser;

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

p) installation and commissioning procedures;

q) 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
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
NEMA	National Electrical Manufacturers Association
PCM	Material Purchase Order
PD	Partial Discharge
PDEV	Partial Discharge Extinction Voltage
PDIV	Partial Discharge Inception Voltage
Qm	Largest Repeatedly Occurring PD Magnitude
RM	Material Requisition
R	Routine Test
RTD	Resistance Temperature Detector
S	Special Test
t_a	Acceleration time
T_b	Breakdown torque
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
VSD	Variable Speed Drive
VPI	Vacuum Pressure Impregnation