Date of issue:
April 2026

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IOGP S-745, Supplementary Specification to IEC 60034-1 for High-voltage Synchronous Machines, First Edition, April 2024

ADDENDUM 1

This addendum (Version 1.01) replaces Edition 1.0 published in April 2024.

NOTE: In addition to the updates listed below, minor editorial/typographical amendments may have been made.

List of updates

Clause/subclause	Description
1	Figure 15 amended Subclause 1.2 amended
2	References IEC 60034-14:2018, IEC 60034-15:2025, IEC 60034-27-4:2018, IEC 60034-29, IEC TS 60034-32:2016, IEC 60204-1:2016, IEEE 421.5:2016, IEEE 1110:2019 and IEEE 1799:2022 added
8.1	Replacement of first paragraph amended Addition to subclause amended
8.6	New subclause 8.6.2.3.2 replacement
9.1	New addition to subclause (after third one) including new NOTE
Table 16	Table amended
11.1	New addition to subclause (after replacement of fourth paragraph) Second addition to subclause amended
Table 26	Third column heading amended
11.3.5	New subclause 11.3.5.3 added Subclause 11.3.5.3 * renumbered to 11.3.5.4
11.4.2.2	New subclause 11.4.2.2.3 including subclauses 11.4.2.2.3.1 through 11.4.2.2.3.11
Table 27	Table amended with new row "Removable drain plug"
11.4.2.3	New subclauses 11.4.2.3.6, 11.4.2.3.7 and 11.4.2.3.8 added
11.4.4	New NOTE 1 and NOTE 2 added Subclause 11.4.4.2 amended New subclause 11.4.4.3 added (and subsequent subclauses renumbered accordingly) New subclauses 11.4.4.7 through 11.4.4.11 added
11.4.5	Subclause 11.4.5.14 amended New subclauses 11.4.5.16 and 11.4.5.17 (including NOTE) added
11.4.7	New subclauses 11.4.7.11 and 11.4.7.12 added
11.4.8	New subclauses 11.4.8.4 and 11.4.8.5 added

List of updates *(continued)*

Clause/subclause	Description
11.4.9.2	Subclause 11.4.9.2.3 amended
11.4.16	Subclause 11.4.16 heading amended Subclause 11.4.16.1.2 amended Subclause 11.4.16.3 amended
11.4.17.1	Subclause 11.4.17.1.1 amended
11.4.17.3	New subclause 11.4.17.3.7 added
11.4.17.4	Subclause 11.4.17.4.4 amended New subclause 11.4.17.4.5 added
11.4.18	Subclause 11.4.18.2 amended Subclause 11.4.18.7 amended New subclauses 11.4.18.13 and 11.4.18.14 added (and subsequent subclauses renumbered accordingly) New subclause 11.4.18.18 added

* Clause/subclause number from Edition 1.0.

International Association of Oil & Gas Producers

SPECIFICATION

IOGP S-745J

April 2026

Version 1.01

ADDENDUM 1 TO FIRST EDITION (APRIL 2024)

Supplementary Specification to IEC 60034-1 for High-voltage Synchronous Machines

NOTE This version (S-745J) of the specification document provides the justification statements for each technical requirement, but is otherwise identical in content to S-745.

JIP33 JOINT INDUSTRY PROGRAMME

Revision history

VERSION	DATE	PURPOSE
1.01	April 2026	Addendum 1
1.0	April 2024	First Edition

Acknowledgements

This IOGP Specification was prepared by a Joint Industry Programme 33 Standardization of Equipment Specifications for Procurement organized by IOGP with support by the World Economic Forum (WEF).

Foreword

This specification was prepared under Joint Industry Programme 33 (JIP33) "Standardization of Equipment Specifications for Procurement" organized by the International Oil & Gas Producers Association (IOGP) with the support from the World Economic Forum (WEF). Companies from the IOGP membership participated in developing this specification to leverage and improve industry level standardization globally in the oil and gas sector. The work has developed a minimized set of supplementary requirements for procurement, with life cycle cost in mind, resulting in a common and jointly agreed specification, building on recognized industry and international standards.

Recent trends in oil and gas projects have demonstrated substantial budget and schedule overruns. The Oil and Gas Community within the World Economic Forum (WEF) has implemented a Capital Project Complexity (CPC) initiative which seeks to drive a structural reduction in upstream project costs with a focus on industry-wide, non-competitive collaboration and standardization. The CPC vision is to standardize specifications for global procurement for equipment and packages. JIP33 provides the oil and gas sector with the opportunity to move from internally to externally focused standardization initiatives and provide step change benefits in the sector's capital projects performance.

This specification has been developed in consultation with a broad user and supplier base to realize benefits from standardization and achieve significant project and schedule cost reductions.

The JIP33 work groups performed their activities in accordance with IOGP's Competition Law Guidelines (November 2020).

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Introduction

The purpose of the IOGP S-745 specification documents is to define a minimum common set of requirements for the procurement of high-voltage synchronous machines in accordance with IEC 60034-1, Edition 14.0, February 2022, Rotating electrical machines – Part 1: Rating and performance, for application in the petroleum and natural gas industries.

The IOGP S-745 specification documents follow a common structure (as shown below) comprising a specification, also known as a technical requirements specification (TRS), a procurement data sheet (PDS), an information requirements specification (IRS) and a quality requirements specification (QRS). These four specification documents, together with the purchase order, define the overall technical specification for procurement.

JIP33 Specification for Procurement Documents
Supplementary Technical Requirements Specification (TRS)

This specification is to be applied in conjunction with the supporting PDS, IRS and QRS as follows.

IOGP S-745: Supplementary Specification to IEC 60034-1 for High-voltage Synchronous Machines

This specification defines technical requirements for the supply of the equipment and is written as an overlay to IEC 60034-1, following the IEC 60034-1 clause structure. Clauses from IEC 60034-1 not amended by this specification apply as written. Modifications to IEC 60034-1 defined in this specification are introduced by a description that includes the type of modification (i.e. *Add*, *Replace* or *Delete*) and the position of the modification within the clause.

NOTE Lists, notes, tables, figures, equations, examples and warnings are not counted as paragraphs.

IOGP S-745D: Procurement Data Sheet for High-voltage Synchronous Machines (IEC)

The PDS defines application-specific requirements. The PDS is applied during the procurement cycle only and does not replace the equipment data sheet. The PDS may also include fields for supplier-provided information required as part of the purchaser's technical evaluation. Additional purchaser-supplied documents may also be incorporated or referenced in the PDS to define scope and technical requirements for enquiry and purchase of the equipment.

IOGP S-745L: Information Requirements for High-voltage Synchronous Machines (IEC)

The IRS defines the information requirements for the scope of supply. The IRS includes information content, format, timing and purpose to be provided by the supplier, and may also define specific conditions which invoke information requirements.

IOGP S-745Q: Quality Requirements for High-voltage Synchronous Machines (IEC)

The QRS defines quality management system requirements and the proposed extent of purchaser conformity assessment activities for the scope of supply. Purchaser conformity assessment activities are defined through the selection of one of four generic conformity assessment system (CAS) levels on the basis of evaluation of the associated service and supply chain risks. The applicable CAS level is specified by the purchaser in the PDS or in the purchase order.

The specification documents follow the editorial format of IEC 60034-1 and, where appropriate, the drafting principles and rules of ISO/IEC Directives Part 2.

The PDS and IRS are published as editable documents for the purchaser to specify application-specific requirements. The TRS and QRS are fixed documents.

The order of precedence of documents applicable to the supply of the equipment, with the highest authority listed first, shall be as follows:

a) regulatory requirements;

b) contract documentation (e.g. purchase order);

c) purchaser-defined requirements (e.g. PDS, IRS and QRS);

d) this specification;

e) IEC 60034-1.

1 Scope

Add new subclause

1.1 Scope boundaries/configurations

The scope boundary/configuration and the rating specification and range of the machine covered by this specification are in accordance with Table 23, Figure 14 and Figure 15.

Justification

This requirement indicates the change in scope in comparison with IEC 60034-1. It aligns with the scope of this specification as defined in the framing proposal.

Add new Table 23

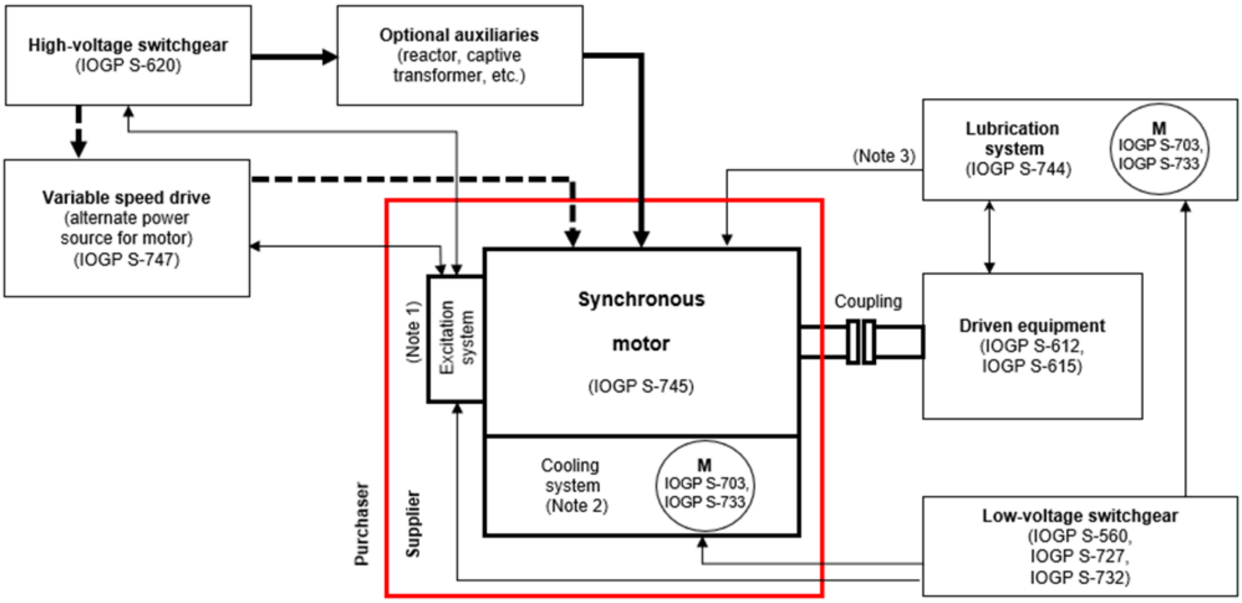
Table 23 – Scope boundaries

Parameter	Details
Voltage	Above 1 kV and up to 15 kV 50 or 60 Hz
Synchronous machine power	500 kVA and above
Speed	Up to 3 000 rpm for 50 Hz Up to 3 600 rpm for 60 Hz
Speed with variable speed drive	From 0 up to 3 000 rpm for 50 Hz From 0 up to 3 600 rpm for 60 Hz
Excitation system	Brushless
Stator windings	Form wound
Motor power source	DOL, VSD types (VSI, CSI, LCI)
Location	Onshore, LNG vessel, offshore installations (topside and FPSO)
Environment	Non-hazardous, hazardous

Justification

This table indicates the change in scope in comparison with IEC 60034-1. It aligns with the scope of this specification as defined in the framing proposal.

Add new Figure 14



Note 1 The excitation panel is part of the excitation system and located as per project requirements.

Note 2 The cooling system motor is optional.

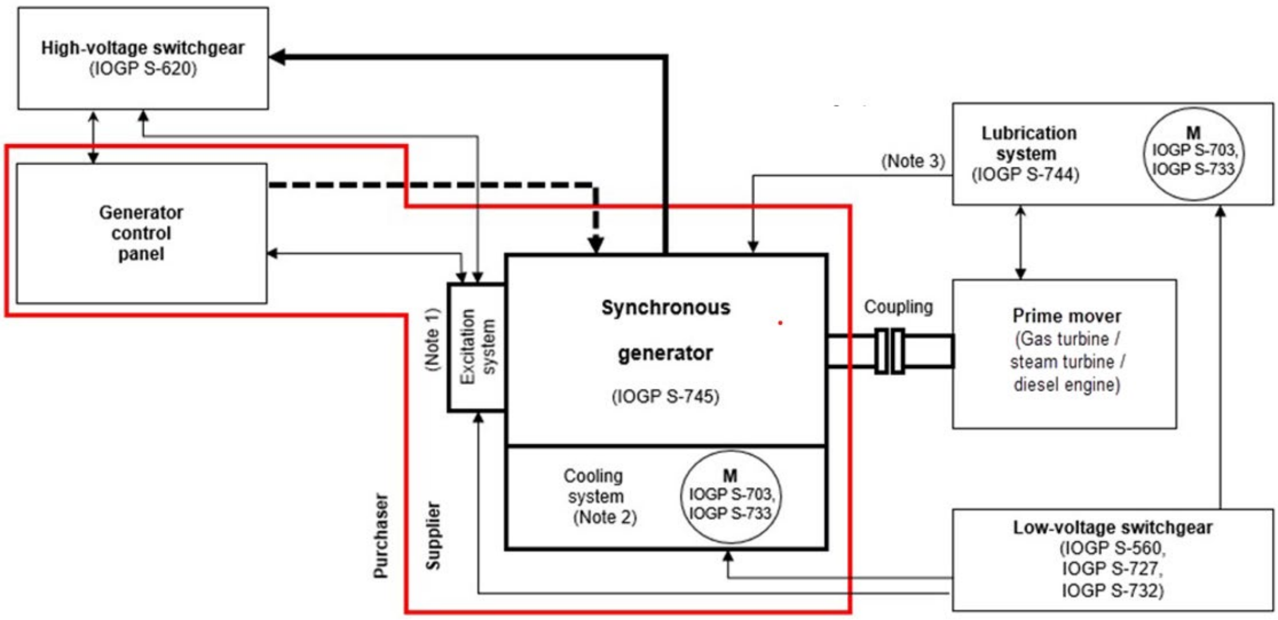
Note 3 The lubrication system could be independent or shared with the driven equipment as per project requirements.

Figure 14 – Scope boundary diagram – Synchronous motor

Justification

This figure indicates the change in scope in comparison with IEC 60034-1. It aligns with the scope of this specification as defined in the framing proposal.

Add new Figure 15



Note 1 The excitation panel is part of the excitation system and located as per project requirements.

Note 2 The cooling system motor is optional.

Note 3 The lubrication system could be independent or shared with the driven equipment as per project requirements.

Figure 15 – Scope boundary diagram – Synchronous generator

Justification

This figure indicates the change in scope in comparison with IEC 60034-1. It aligns with the scope of this specification as defined in the framing proposal. Diesel engine driven HV generators are not excluded from this specification for the purpose of essential power generators.

Add new subclause

1.2 Exclusions

The scope of this specification excludes super synchronous motors.

Justification

This requirement indicates the change in scope in comparison with IEC 60034-1. It aligns with the scope of this specification as defined in the framing proposal. This specification deals with converter fed motors. Diesel engine driven HV generators are not excluded from this specification for the purpose of essential power generators. There is limited need for super synchronous motors (special high starting torque synchronous motors).

2 Normative references

Add to first paragraph

The following publications are referred to in this document, the PDS (IOGP S-745D) or the IRS (IOGP S-745L) in such a way that some or all of their content constitutes requirements of this specification.

Add to clause

ANSI/NEMA MG 1, *Motors and Generators*

API Standard 546:2022, *Brushless Synchronous Machines—500 kVA and Larger*

API Standard 670, *Machinery Protection Systems*

BS 4999-140, *General requirements for rotating electrical machines — Part 140: Specification for voltage regulation and parallel operation of a.c. synchronous generators*

IEC 60034-2-1:2014, *Rotating electrical machines – Part 2-1: Standard methods for determining losses and efficiency from tests (excluding machines for traction vehicles)*

IEC 60034-4-1:2018, *Rotating electrical machines – Part 4-1: Methods for determining electrically excited synchronous machine quantities from tests*

IEC 60034-7, *Rotating electrical machines – Part 7: Classification of types of construction, mounting arrangements and terminal box position (IM Code)*

IEC 60034-8:2007+AMD1:2014 Edition 3.1 CSV, *Rotating electrical machines – Part 8: Terminal markings and direction of rotation*

IEC 60034-14:2018, *Rotating electrical machines - Part 14: Mechanical vibration of certain machines with shaft heights 56 mm and higher - Measurement, evaluation and limits of vibration severity*

IEC 60034-15:2025, *Impulse voltage withstand levels of form-wound stator coils for rotating a.c. machines*

IEC 60034-18-41:2014+AMD1:2019 Editions 1.1 CSV, *Rotating electrical machines – Part 18-41: Partial discharge free electrical insulation systems (Type I) used in rotating electrical machines fed from voltage converters – Qualification and quality control tests*

IEC 60034-18-42:2017+AMD1:2020 Edition 1.1 CSV, *Rotating electrical machines – Part 18-42: Partial discharge resistant electrical insulation systems (Type II) used in rotating electrical machines fed from voltage converters – Qualification tests*

IEC TS 60034-25:2022, *Rotating electrical machines – Part 25: AC electrical machines used in power drive systems – Application guide*

IEC 60034-27-1, *Rotating electrical machines – Part 27-1: Off-line partial discharge measurements on the winding insulation*

IEC 60034-27-3, *Rotating electrical machines – Part 27-3: Dielectric dissipation factor measurement on stator winding insulation of rotating electrical machines*

IEC 60034-27-4:2018, *Measurement of insulation resistance and polarization index of winding insulation of rotating electrical machines*

IEC 60034-29, *Rotating electrical machines – Part 29: Equivalent loading and superposition techniques – Indirect testing to determine temperature rise*

IEC TS 60034-32:2016, *IEEE Guide for Testing Turn Insulation of Form-Wound Stator Coils for Alternating-Current Electric Machines*

IEC 60072-2, *Dimensions and output series for rotating electrical machines – Part 2: Frame numbers 355 to 1000 and flange numbers 1180 to 2360*

IEC 60079 (all parts), *Explosive atmospheres*

IEC 60092-101, *Electrical installations in ships – Part 101: Definitions and general requirements*

IEC 60204-1:2016, *Safety of machinery – Electrical equipment of machines – Part 1: General requirements*

IEC 60423:2007, *Conduit systems for cable management – Outside diameters of conduits for electrical installations and threads for conduits and fittings*

IEC 60529:1989+AMD1:1999+AMD2:2013 Edition 2.2 CSV, *Degrees of Protection Provided by Enclosures (IP Code)*

IEC 60751, *Industrial platinum resistance thermometers and platinum temperature sensors*

IEC 61000-6-2, *Electromagnetic compatibility (EMC) – Part 6-2: Generic standards – Immunity standard for industrial environments*

IEC 61000-6-4, *Electromagnetic compatibility (EMC) – Part 6-4: Generic standards – Emission standard for industrial environments*

IEC 61800-2:2021, *Adjustable speed electrical power drive systems – Part 2: General requirements – Rating specifications for adjustable speed AC power drive systems*

IEEE 115:2019, *IEEE Guide for Test Procedures for Synchronous Machines Including Acceptance and Performance Testing and Parameter Determination for Dynamic Analysis*

IEEE 421.5:2016, *IEEE Recommended Practice for Excitation System Models for Power System Stability Studies*

IEEE 522, *IEEE Guide for Testing Turn Insulation of Form-Wound Stator Coils for Alternating-Current Electric Machines*

IEEE 1110:2019, *IEEE Guide for Synchronous Generator Modeling Practices and Parameter Verification with Applications in Power System Stability Analyses*

IEEE 1255, *IEEE Guide for Evaluation of Torque Pulsations During Starting of Synchronous Motors*

IEEE 1799:2022, *IEEE Recommended Practice for Quality Control Testing of External Discharges on Stator Coils, Bars, and Windings*

ISO 1680, *Acoustics — Test code for the measurement of airborne noise emitted by rotating electrical machines*

ISO 12944-1, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 1: General introduction*

ISO 12944-2, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 2: Classification of environments*

ISO 21940-11 AMD 1, *Mechanical vibration — Rotor balancing — Part 11: Procedures and tolerances for rotors with rigid behaviour AMENDMENT 1 — First Edition*

ISO 21940-12, *Mechanical vibration — Rotor balancing — Part 12: Procedures and tolerances for rotors with flexible behaviour*

ISO 21940-32, *Mechanical vibration — Rotor balancing — Part 32: Shaft and fitment key convention*

Delete from clause

IEC 60034-8:2007, *Rotating electrical machines – Part 8: Terminal markings and direction of rotation*

IEC 60034-8:2007/AMD1:2014, *Amendment 1 Rotating electrical machines – Part 8: Terminal markings and direction of rotation*

IEC 60034-18-41:2014, *Rotating electrical machines – Part 18-41: Partial discharge free electrical insulation systems (Type I) used in rotating electrical machines fed from voltage converters – Qualification and quality control tests*

IEC 60034-18-41:2014/AMD1:2019, *Amendment 1 Rotating electrical machines – Part 18-41: Partial discharge free electrical insulation systems (Type I) used in rotating electrical machines fed from voltage converters – Qualification and quality control tests*

IEC 60034-18-42:2017, *Rotating electrical machines – Part 18-42: Partial discharge resistant electrical insulation systems (Type II) used in rotating electrical machines fed from voltage converters – Qualification tests*

IEC 60034-18-42:2017/AMD1:2020, *Amendment 1 Rotating electrical machines – Part 18-42: Partial discharge resistant electrical insulation systems (Type II) used in rotating electrical machines fed from voltage converters – Qualification tests*

IEC TS 60034-25:2014, *Rotating electrical machines – Part 25: AC electrical machines used in power drive systems – Application guide*

Replace Clause 3 title with

3 Terms, definitions and abbreviated terms

Add new subclause 3.0 to start of clause

3.0 Abbreviated terms

AVR automatic voltage regulator

Ex explosive atmosphere

FAT factory acceptance test

HMI human-machine interface

IRS information requirements specification

LSZH * low smoke zero halogen

MOV * metal oxide varistor

MRB * manufacturer's record book

MTTR * mean time to repair

PDS procurement data sheet

PE protective earthing

PMG permanent magnet generator

QRS quality requirements specification

RTD resistance temperature device

TRS technical requirements specification

VDR * voltage dependent resistor

VPI vacuum pressure impregnated

* Cited in IOGP S-745J only.

Add new term 3.38

3.38
critical speed
shaft rotational speed at which a machine component (e.g. shaft, rotor) is in a state of resonance

Add new term 3.39

3.39
maximum continuous operating speed
highest rotational speed at which the motor, as-built and tested, is defined for continuous operation, expressed as revolutions per minute [min^{-1}]

Add new term 3.40

3.40
minimum continuous operating speed
lowest rotational speed at which the motor, as-built and tested, is defined for continuous operation, expressed as revolutions per minute [min^{-1}]

4 Duty

4.2 Duty types

4.2.9 Duty type S9 – Duty with non-periodic load and speed variations

In second sentence of fourth paragraph, replace "IEC TS 60034-25:2014" with

IEC TS 60034-25:2022

Justification

Edition 4.0 (2022) supersedes Edition 3.0 (2014).

4.2.10 Duty type S10 – Duty with discrete constant loads and speeds

In second sentence of last paragraph, replace "IEC TS 60034-25:2014" with

IEC TS 60034-25:2022

Justification

Edition 4.0 (2022) supersedes Edition 3.0 (2014).

5 Rating

5.5 Rated output

5.5.2 AC generators

In first paragraph, replace "volt-amperes (VA)" with

kilovolt-amperes (kVA)

Justification

The high-voltage generator power rating is expressed in kVA, which is consistent with supplier catalogues, international standards and industry practices.

5.5.3 Motors

Replace "watts (W)" with

kilowatts (kW)

Justification

The high-voltage motor power rating is expressed in kW, which is consistent with supplier catalogues, international standards and industry practices.

5.5.4 Synchronous compensators

Replace "volt-amperes (VA)" with

kilovolt-amperes (kVA)

Justification

The rating of the high-voltage machine used as synchronous compensator is expressed in kVA, which is consistent with supplier catalogues, international standards and industry practices.

5.6 Rated voltage

5.6.2 AC generators

In third paragraph, replace "7.3" with

7.4

Justification

This incorrect reference is a carryover from the previous edition where the reference was to subclause 7.3 which in the current edition is subclause 7.4. This is understood to be a typographical error.

5.7 Preferred combinations of voltages and outputs

Add new NOTE

NOTE For synchronous machines, the minimum rated output is 500 kVA for rated voltage 1 kV and above.

5.8 Machines with more than one rating

In second sentence of last paragraph, replace "7.3" with

7.4

Justification

This incorrect reference is a carryover from the previous edition where the reference was to subclause 7.3 which in the current edition is subclause 7.4. This is understood to be a typographical error.

Add new subclause

5.9 Efficiency

Synchronous machines shall have minimum efficiency in accordance with Table 24.

Justification

Synchronous machines have better efficiencies than induction motors due to reduced rotor losses. However, defining minimum efficiency requirements demonstrates JIP33's intent to reduce carbon emissions and capitalize on new technologies to ensure that environmental considerations have been addressed. IEC 60034-30-1 defines IE3 (international efficiency standard) as premium efficiency for low-voltage motors, however high voltage does not have an equivalent definition for efficiency. Table 24 has been developed from existing operator values. Testing requirements for single-speed machines are as per IEC 60034-2-1. For converter duty motors, testing is performed with a sinusoidal sine wave supply as per single-speed motors to provide a benchmark of efficiency. It is acknowledged that the converter supply has an adverse effect on efficiency, however this requirement ensures that testing can be standardized.

Add new Table 24

Table 24 – Minimum efficiency of synchronous machine

Machine configuration	Minimum efficiency value %
2 poles	98,0
4 poles	97,5
6 poles / 8 poles	> 97,0

Justification

Synchronous machines have better efficiencies than induction motors due to reduced rotor losses. However, defining minimum efficiency requirements demonstrates JIP33's intent to reduce carbon emissions and capitalize on new technologies to ensure that environmental considerations have been addressed. IEC 60034-30-1 defines IE3 (international efficiency standard) as premium efficiency for low-voltage motors, however high voltage does not have an equivalent definition for efficiency. Testing requirements for single-speed machines are as per IEC 60034-2-1. For converter duty motors, testing should be performed with a sinusoidal sine wave supply as per single-speed motors to provide a benchmark of efficiency. It is acknowledged that the converter supply has an adverse effect on efficiency, however this requirement ensures that the testing can be standardized. IEC 60034-30-3 (Rotating electrical machines Part 30-3: Efficiency classes of high voltage AC motors (IE code)) is being developed and is still in draft version and until the time it is officially published, the values in Table 24 are a minimum threshold to comply with.

6 Site conditions

Add new subclause

6.8 Degree of ingress protection

The minimum degree of ingress protection for a synchronous machine shall be as specified in Table 25 and in accordance with IEC 60034-5.

Justification

The degree of ingress protection for machines is governed by the location of installation and the environmental conditions to which the machines are exposed such as "indoor", "outdoor – onshore" and "outdoor – offshore (fixed/floating)". IEC 60034-5 adequately covers the protections taken against respective environmental conditions.

Add new Table 25

Table 25 – Minimum degree of ingress protection based on the location of the installation

Installation environment	Minimum degree of ingress protection	
	Machine	Terminal box
Indoor	IP44	IP55
Outdoor – coastal and onshore	IP55	IP55
Outdoor – offshore / open deck	IP56	IP56

Justification

This table lists the minimum degree of ingress protection used in the industry based on the location of installation of the machine. The individual parts on the machine such as the terminal box and bearing housing may have a higher degree of protection as required.

8 Thermal performance and tests

8.1 Thermal class

Replace first paragraph with

The machine insulation system shall be minimum thermal class 155 (F) without exceeding thermal class 130 (B) temperature rise for the machine rated output at the maximum reference coolant temperature.

Justification

Insulation system class F, class B temperature rise is an industry-recognized cost-effective specification facilitating increased motor life by improved winding insulation quality. This insulation specification is acknowledged by manufacturers as the most commonly requested for industrial motors. Therefore, it is compliant with the minimum specification philosophy of JIP33. The use of class F insulation with class B temperature rise gives products a safety margin of 25 °C. This can be exploited to increase the loading of the machine for limited periods to operate at higher ambient temperatures or altitudes, or with greater voltage and frequency tolerances. It can also be exploited to extend insulation life. Manufacturers qualify insulation systems by means of functional tests as defined in IEC 60034-18-1:2022, 4.5. The maximum ambient air temperature may not be the same as the reference coolant temperature.

Add to subclause

For converter duty motors, the machine insulation system shall be minimum thermal class 155 (F) without exceeding thermal class 130 (B) temperature rise within the entire operating load envelope at the maximum reference coolant temperature.

Justification

This requirement defines the performance standard, for converter duty motors, which is commonly used throughout the industry, however IEC 60034-1 does not provide a performance requirement on temperature rise limits for converter duty motors. Manufacturers qualify insulation systems by means of functional tests as defined in IEC 60034-18-1:2022, 4.5. The maximum ambient air temperature may not be the same as the reference coolant temperature.

Add new NOTE 3

NOTE 3 Machine insulation systems include all windings of stator, rotor, exciter and permanent magnet generator (PMG), where provided.

8.6 Determination of winding temperature

8.6.1 Choice of method

Delete second paragraph (including NOTE)

Justification

It is common to use the resistance method for determination of the stator winding temperature for motors over 5 MW, therefore this paragraph introduces unnecessary restrictions to testing and is removed. The resistance method measures the average conductor temperature as opposed to the embedded temperature detector (ETD) which measures the temperature outside the main wall insulation (in an assumed hot spot area). The conductor temperature is higher than what the ETD is measuring. It is basically the hottest temperature in the winding that is of interest (determining the thermal lifetime of the winding), but this is not possible to measure. IEC 60034-1 allow a higher temperature rise by the ETD method compared to the resistance method, but if the resistance method (average conductor temperature) is giving a higher temperature rise than the ETD method, this does not make sense. The proposal to standardize the resistance method is based on experience and consistent with IOGP S-704.

Delete third paragraph

Justification

This paragraph has been deleted to ensure that there is no conflict in requirements as this is now covered by an optional requirement in IOGP S-704D.

8.6.2.3.2 Short stopping time

Replace subclause with

The short stopping time shall be determined by the following steps.

a) Obtain the initial resistance reading after stabilization of the measuring device and within 120 s of switching off power.

b) Take additional readings at 30 s intervals over a period of 5 min following the first reading.

c) Calculate the resistance value at the time of switching off power by means of extrapolation.

d) Use the resistance value at the time of switching off power to confirm the winding temperature.

e) Measure the resistance between the same windings for all readings.

Justification

This paragraph and Table 6 leaves room for inconsistency as the temperature value is accepted when measured within time delay in Table 6. The inconsistent results are due to a drop in the winding temperature between 5K and 10K when measured or extrapolated within 120 s after shut-down as compared to the value extrapolated to t = 0. The steps in this paragraph replacement standardize the procedure for measurement of winding resistance across suppliers and entire product range. This procedure makes the measurements comparable and accurate. Hence, this paragraph has been replaced and Table 6 has been deleted. This requirement aligns with IEC 60034-2-1:2024, 5.7.1, paragraph 5 for extrapolation to measure winding resistance at t = 0.

9 Other performance and tests

9.1 Routine tests

Add to subclause

A "soft foot" check in accordance with API Standard 546:2022, 6.3.1.15 shall be made prior to mechanical running tests.

Justification

The "soft foot" check ensures that the machine mounting is of a defined pre-agreed standard and that the mounting arrangement does not have an adverse effect on the results of the machine vibration test. This requirement aligns JIP33 with API Standard 546:2022, 6.3.1.15.

Add to subclause

For flooded lubrication systems, factory tests shall be carried out using the specified lube oil viscosity with the oil temperature maintained within the range of operating values recommended by the manufacturer.

Justification

This requirement ensures that testing parameters are as close to the operating conditions on site as possible. This excludes the possibility of using other parameters in the testing facility, either for convenience or to optimize testing results.

Add to subclause

During vibration severity tests, the lube oil inlet temperature shall be adjusted to the maximum temperature permitted by the lubrication system design.

Justification

This requirement ensures that vibration levels are tested at the maximum of lube oil temperature and that the recorded vibration values do not exceed maximum allowable levels. This requirement aligns in principle with API Standard 546:2022, 6.3.1.6.

Add to subclause

If the machine is equipped with permanently installed shaft vibration sensors, the following data shall be plotted (Bode plots) during coastdown from maximum continuous operating speed to 10 % of the rated speed:

a) synchronous vibration amplitude, one per revolution;

b) overall vibration amplitude;

c) phase angle versus speed.

NOTE If the machine is subject to a temperature rise test, one plot shall be for cold machine (stable no-load condition) and one plot for hot machine.

Justification

This requirement provides fingerprint for new machines at the manufacturer's test bed condition. It is a useful reference in case of vibration issues during string test or commissioning. The plot can identify critical speeds (if present) and fingerprint for cold and hot machine for comparison.

Add to subclause

When bearing modification or replacement is undertaken during testing, bearing-related tests shall be repeated to reassess the bearing performance.

Justification

Bearing modification or replacement can affect the performance of the motor, whether adversely or positively. This requirement ensures that relevant tests are repeated to reassess the bearing performance after bearing modification or replacement has taken place.

Add new NOTE

NOTE Cosmetic repairs such as removal of scratches that do not otherwise affect motor performance are not a reason for retesting.

Table 16 – Tests for synchronous machines assembled and tested in the manufacturer's factory

Replace Table 16 with

Test No.	Test description [g]	Reference standard	Remarks
Routine tests			
1	Visual inspection	Approved drawings and documents	
2	Air-gap measurement between stator and rotor of main machine and exciter	API Standard 546:2022, 4.4.7.2.4	In-process test or test during factory acceptance test (FAT)
3 [d]	Measurement of ohmic resistance of exciter, rotor and stator windings referred to 25 °C	IEC 60034-2-1:2014, 5.7.1	
4	Measurement of insulation resistance of stator windings	IEC 60034-27-4: 2018	Test also carried out post withstand voltage test
5 [d]	Check of phase sequence/direction of rotation and terminal markings	IEC 60034-8:2014, 6.7	Including excitation system
6	No-load characteristic and losses	IEC 60034-4-1:2018, 6.4	
7	Short-circuit characteristics and losses	IEC 60034-4-1:2018 6.5	
8	Verification of magnetic centre and end play (where sleeve bearings are provided)	API Standard 546:2022, 4.4.9.3	
9 [d]	Withstand voltage test for stator, rotor, exciter armature, exciter field and PMG (if applicable)	IEC 60034-1:2022, 9.2	
10	Measurement of insulation resistance of insulated bearings	IEEE 115:2019, 4.6.4	
11	Measurement of electrical and mechanical run-out	IEC 60034-14:2018, Clause 9 API Standard 546:2022, 6.3.3	Refer to API Standard 546 for test procedure and IEC 60034-14 for acceptance criteria
12 [d]	No-load excitation current at rated voltage by open-circuit test	IEC 60034-1:2022	
13	Functional tests of auxiliary devices and controls	Manufacturer's standard	Including control panels in scope of supply
14	Withstand voltage tests on resistance temperature devices (RTDs)	IEC 60034-1:2022, 9.2	
15	Insulation resistance tests on RTDs and space heaters where applicable	IEC 60204-1:2016, 18.3	
16	Vibration test at no load	IEC 60034-14:2018, Clause 8 and Clause 9	
17	Rotor earth fault detection test	Manufacturer's standard	If applicable
18	Bearing oil tightness test		

Table 16 *(continued)*

Test No.	Test description [g]	Reference standard	Remarks
Performance tests [e]			
1	Locked rotor current test	IEC 60034-4-1:2018, 6.24	Test for single-speed motor
2	Locked rotor torque test	IEEE 115:2019, 8.2.2	Test for single-speed motor
3	Temperature rise test	IEC 60034-1:2022, Clause 8 or IEC 60034-29 [a]	
4	Sleeve bearing inspection	API Standard 546:2022, 6.3.2	
5	Determination of efficiency at 100 %, 75 % and 50 % load at rated power factor	IEC 60034-2-1:2014, Clause 7	
Special tests [f]			
1	Rated rotor temperature vibration test (i.e. heat run test)	API Standard 546:2022, 6.3.5.2	Alternately testing (procedure, purpose, etc.) to be agreed between purchaser and manufacturer
2	Measurements of shaft voltage at no-load	IEC 60034-1:2022, 9.14	
3	Bearing temperature rise at no-load	API Standard 546:2022, 6.3.2	
4	Tests for the construction of no-load V curve	API Standard 546:2022, 6.3.5.1.1	
5	Noise level at no load	ISO 1680:2013	
6	Measurement of moment of inertia	Manufacturer's standard	
7	Measurement of torque and current as function of speed during starting	IEEE 115:2019, 8.3 IEEE 1255:2000	
8	Dielectric dissipation test (tan δ) on stator windings	IEC 60034-27-3:2016	Test performed with stator winding installed in frame
9	Partial discharge test on complete stator	IEC 60034-27-1:2017 IEC 60034-27-2:2023	Test performed with stator winding installed in frame
10	Stator external discharge test	IEEE 1799:2022	In process test
11	Sealed winding conformance test	ANSI/NEMA MG 1	In process test
12	Unbalanced response test	API Standard 546:2022, 6.3.5.3	
13	Bearing housing natural frequency test	API Standard 546:2022, 6.3.5.4	
14	Stator core test	API Standard 546:2022, 6.3.4.1	In process test
15	Surge comparison test on complete stator assembly	IEEE 522	In process test
16	Sample coil test	API Standard 546:2022, 6.3.4.2, IEC 60034-15:2025, IEC 60034-27-1:2017, IEC 60034-27-3:2016	
17 [h]	Sudden short-circuit test	IEC 60034-4-1:2018, 6.11	
18	Heat exchanger performance verification test	API Standard 546:2022, 6.3.5.5	

Table 16 *(continued)*

Test No.	Test description [g]	Reference standard	Remarks
19	Hydrostatic pressure test of heat exchanger tubing devices [d]	Design code [c]	
20	Generator control panel functional test	Manufacturer's standard	Tests (e.g. procedure, purpose) to be agreed between purchaser and manufacturer
21	Generator waveform analysis	IEC 60034-1:2022, 9.11	
22	Rotor impedance test at rated frequency for the machine (stator frequency)	Manufacturer's standard	
23 [h]	Test for determination of unsaturated negative-sequence reactance $X_{(2)}$	IEC 60034-4-1:2017, Table 1	
24 [h]	Test for determination of unsaturated zero-sequence reactance $X_{(0)}$	IEC 60034-4-1:2017, Table 1	
25 [h]	Test for determination of direct-axis open circuit time constant τ'_{do}	IEC 60034-4-1:2017, Table 1	
26	End winding impact test (Experimental modal analysis)	IEC TS 60034-32:2016, 5.2	
27	Overspeed test	IEC 60034-1:2022, 9.7	

[a] IEC 60034-29 shall be used as the reference standard where testing to IEC 60034-1 is restricted due to the limitations of the test facilities.

[b] Heat exchanger testing is performed at the heat exchanger manufacturer's premises.

[c] Heat exchanger design code should be confirmed by the supplier.

[d] Tests listed in the original table.

[e] Where one or more than one identical motor is purchased, the listed performance tests are carried out on at least one motor. However, the need for the performance tests and the number of motors to be tested may be agreed between the purchaser and the manufacturer.

[f] The special tests required to be performed in IOGP S-745D shall be specified.

[g] Tests shall be performed with project-specific sensing, monitoring and protection devices mounted on the machine.

[h] Quantities corresponding to both unsaturated and saturated state of the machine shall be derived from tests. When sudden short-circuit test cannot be performed at rated armature voltage, tests at 30 %, 50 % and 70 % of rated armature voltage shall be performed. Saturated quantities shall be found by extrapolation method.

Justification

The original Table 16 in IEC 60034-1 has minimal test requirements that cover all motors whereas the revised content of Table 16 has tests exclusively for high-voltage synchronous machines, including additional routine tests as well as special tests specified by the purchaser. For high-voltage synchronous machines in the oil and gas industry, special/additional tests are performed to verify that the required performance criteria are met prior to the machine leaving the manufacturer's premises due to the following reasons.

- *High-voltage machines are typically regarded as high value items.*
- *High-voltage machines are used in systems where, if they do not perform as required, it could have a severe financial consequence to the end user.*
- *In most cases, high-voltage machines are engineered equipment to some extent and therefore, all test criteria are verified before acceptance by the purchaser.*
- *Logistically, any remedial work required once the high-voltage machine is on site can be complex.*
- *These routine tests provide a performance benchmark that can be compared to test results post-installation at site and throughout the design life of the high-voltage machine.*

IEC 60034--1 recommends several tests and extrapolation when sudden short-circuit test cannot be performed at rated voltage. Tests at 30 %, 50 % and 70 % and extrapolation have been a standard simplified method for the industry for this type of synchronous machines for a long time. Both saturated and unsaturated quantities are needed for electrical system analysis.

9.2 Withstand voltage test

In eighth paragraph, replace "7.3" with

7.4

Justification

This incorrect reference is a carryover from the previous edition where the reference was to subclause 7.3 which in the current edition is subclause 7.4. This is understood to be a typographical error.

10 Information requirements

10.3 Rating plate

Replace first sentence of first paragraph with

Rating and marking plates shall be made from 316L stainless steel.

Justification

Stainless steel rating plates are a readily available standard offering and a proven solution to issues experienced using other methods. For example, industry experience shows that illegibility due to other types of marking plates causes problems such as delayed troubleshooting.

Replace second sentence of first paragraph with

The information included on rating and marking plates shall be stamped or engraved.

Justification

This is a common user requirement to prevent machine information from getting lost over time due to wear and tear. This is a tried, tested and proven industry practice which ensures that the information remains attached to the equipment during its operational life. Although this information is also made available in other associated documents of the equipment, the relevant information is available with the equipment. This requirement is included in most operator specifications but not stated in IEC 60034-1.

In first sentence of second paragraph, replace "The rating plate(s) shall preferably be mounted on the frame of the machine" with

The rating and marking plates shall be attached to a non-removable part of the motor frame with stainless steel 316L fasteners

Justification

As per 10.3, first sentence of first paragraph, this requirement ensures that the fasteners are of the same durability as the rating plate. By ensuring that the rating and marking plates are attached to a non-removable part, there is no chance of the part being mistakenly reattached to a different unit or misplaced during maintenance or breakdown activities.

10.4 Information content

10.4.1 General

In first sentence of first paragraph, replace "10.4.5" with

10.4.6

Justification

Subclause 10.4.6, named "Optional information" in IEC 60034-1, has been renamed "Additional information" in this specification and the list of items included in this subclause has now been added to the list of information to be provided as applicable (i.e. to the list of items subject to the requirement in 10.4.1). It is necessary to include information related the cooling method, converter capability, torque capability, impulse voltage insulation class (IVIC) level and rated power factor on the rating plate specifically as these are more critical machines. Bearing and bearing lubrication information is required for bearing replacement on-site. This is beneficial on the nameplate when maintenance is being performed on site as there is no need to look for the documentation. The mixing of lubricants could damage a bearing.

Delete third sentence of first paragraph

Justification

Items in 10.4.6 are optional in the standard IEC 60034-1, whereas as per this overlay specification, these items are additional information. Hence this requirement text is redundant and need to be deleted.

In first sentence of second paragraph, replace "jj)" with

kk)

Justification

This requirement results from the addition of new list item kk) in 10.4.6.

10.4.2 Minimum information requirements

Replace list item j) with

j) Efficiency at full load.

Justification

The original text in this subclause 10.4.2, item j) specifies efficiency class (IE codes) for motors within the scope of IEC 60034-30-1 and IEC 60034-30-2. However, for high-voltage synchronous machines, Table 24 specifies the minimum efficiency values. Subclause 10.4.2, item j) is replaced to specify the efficiency value achieved at full load during the factory acceptance test as part of the minimum information requirements on the nameplate for the machines.

Replace list item k) with

k) The total mass of the machine.

Justification

This replacement provides the total mass of the machine for lifting operations and the assessment of the equipment/effort for lifting.

Replace subclause 10.4.6 title with

10.4.6 Additional information

Replace list item gg) with

gg) On a separate rating plate, the types of the bearings, bearing sizes, clearance, bearing insulation, shaft and housing fit for drive end and non-drive end bearings, type of lubricant, minimum and maximum allowable quantity of lubricant, maximum and minimum oil temperature/pressure/flow rate for flood lubricated bearings and oil viscosity.

Justification

This information on bearings is beneficial for maintenance staff during predictive/preventive maintenance activities and provides a means for instant and reliable verification while at site without the need for equipment documentation.

Add new list item kk)

kk) For machines used in hazardous areas, the equipment marking on a separate nameplate applied to Ex Equipment and/or Ex Components in accordance with IEC 60079.

Justification

By marking the equipment in accordance with IEC 60079, the manufacturer confirms that the equipment/components are manufactured, successfully tested and certified for use in accordance with the applicable requirements of the relevant standards.

11 Miscellaneous requirements

11.1 Protective earthing of machines

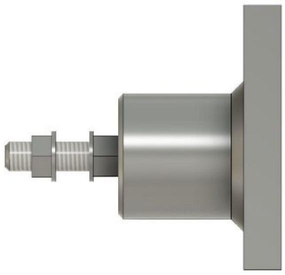
Replace fourth paragraph with

The machine shall have two diagonally opposite earthing bosses with M12 internal threads, fitted externally on the machine frame.

Justification

This requirement drives industry standardization on earthing externally. These earthing bosses are rounded metal parts with internal threads (typically M12) welded on the machine surface for external earth connections as per Justification Figure a and Justification Figure b.

Justification Figure a



Justification Figure b

Add to subclause

When the corrosivity category is C4 or greater, the two diagonally opposite fitted earthing bosses shall be made of 316L stainless steel and welded to the machine frame.

Justification

This requirement provides the material of bosses to prevent corrosion for higher corrosivity categories.

Add to subclause

The machine shall have means for connecting all conducting external cable sheaths and protective earthing cables inside every terminal box.

Justification

This requirement drives industry standardization on earthing externally and internally. It also provides full optionality for instances where the machine is used in a different application. This requirement ensures termination of all earthing connections.

Add to subclause

The earthing boss shall be permanently marked with the symbol  (IEC60417-5019) to indicate protective earth.

Justification

This requirement is in line with the identification of components on the equipment in accordance with IEC 60417. The marking highlights the purpose of the component and prompts to leave clear access for termination/connection at site.

Add to subclause

The machine shall have bonding straps across joints within or between the machine frame components.

Justification

Bonding straps ensure that earth continuity is provided across the complete motor assembly. This is especially critical across joints where gaskets are installed. Bonding straps prevent stray current sparking in the enclosure during start up.

Add new subclause

11.3 Performance criteria

11.3.1 Single-speed motor starting, re-starting and re-acceleration

11.3.1.1

For motors without specific starting requirements, the locked rotor current inclusive of the tolerance shall be lower than five times the rated current.

Justification

Maximum starting currents are defined to ensure that electrical power systems are not adversely affected. This requirement ensures consistency in electrical supply design. It is acknowledged that the values may be higher for high-efficiency machines and this has been considered while developing the requirement. Establishing the locked rotor current of the motor enables the motor cable sizing and ensures that the upstream/downstream busbars do not experience excessive under voltage during motor starting. Five times has been defined as this value can be generally complied by the manufacturers as their standard offering and this value also corresponds to API Standard 546:2022, 4.2.4.4.

11.3.1.2

The motor shall be designed for direct-on-line starting across full line voltage in accordance with Table 26.

Justification

When a motor is subjected to frequent starting, it cannot be loaded at its rated output because of thermal starting losses in the windings. Table 26 establishes the minimum requirements to ensure consistency for these parameters across the industry. These parameters are the current industry standard and compliance with these are already the norm.

Add new Table 26

Table 26 – Number of re-starts of motors

Starting condition	Status	Minimum number of consecutive starts [a]
With the initial temperature at or below the maximum ambient temperature	Cold	3
With the initial temperature above the maximum ambient temperature but not exceeding the maximum rated operating temperature	Hot	2
[a] The motor should coast to rest between consecutive starts.		

Justification

A motor subjected to frequent starting cannot be loaded at its rated output because of thermal starting losses in the windings. Minimum requirements should be specified to ensure consistency for these parameters across the industry. These parameters are well established and compliance with these are already the norm. Given this, no significant cost adders are anticipated. The values in the table are the current industry standard.

11.3.1.3

Motors shall be designed and constructed for a lifetime minimum of 5 000 full voltage starts.

Justification

Though 1 000 starts per year is the industry standard and provides assurance on the design life of the motor, such a requirement does not qualify to be an essential minimum requirement. Such large motors are not started/stopped so frequently and do not need these severe design requirements. Instead, a more practical approach in line with API Standard 546:2022, 4.2.4.1 is considered a better essential minimum requirement for motor design.

11.3.1.4

The motor shall start direct-on-line and accelerate with the rated load at 80 % of the rated voltage applied at the motor terminals.

Justification

The 80 % value allows for upstream system deviations and voltage drop in conductors from the point of supply to the motor location typically incurred in the oil and gas industry. The 80 % value is particularly prevalent in island networks and also aligns with API Standard 546:2022, 4.2.3.1.

11.3.1.5

The locked rotor withstand time under hot condition shall be greater than the time required to accelerate the specified driven load at 80 % of rated voltage at the motor terminals plus 5 s.

Justification

This requirement ensures that there is a sufficient amount of time between the acceleration time of the specified load and the locked withstand time under hot condition. This margin adequately ensures that the motor protection devices operate and isolate the motor prior to damage occurring due to overheating of motor windings.

11.3.1.6

Inclusive of the negative tolerance, the accelerating torque of the motor at the rated frequency with 80 % of the rated voltage applied at the motor terminals shall be at least 10 % of the full load torque at any point.

Justification

This requirement provides assurance that there is a defined margin between the load requirements and the capability of the motor to ensure that the torque at the driven load is sufficient.

11.3.2 Transient air gap torques

The rotor shaft and active iron core systems shall withstand a two-phase short-circuit current at the motor terminals for 0,2 s.

Justification

This requirement addresses the capability of the rotor shaft and active iron systems to withstand a two-phase short-circuit current that is considered to be the most adverse fault type. This is a fundamental requirement that is not addressed by IEC 60034-1.

11.3.3 Pulsating torques

11.3.3.1

For motors driving pulsating loads such as reciprocating compressors, the minimum value of the pull-out torque at 80 % of the rated voltage shall be more than the peak value of the pulsating torque.

Justification

The pull-out torque is the value where the motor is pulled out of synchronous state with the rotating magnetic field. If the pulsating loads exerted by the load on the motor do not exceed the 80 % of the pull-out torque threshold, it does not impact the synchronous state and continue to operate uninterruptedly.

11.3.3.2

The inertia of the motor driving equipment requiring variable torque during each revolution shall restrict the stator current variation to 40 % of the motor rated current.

Justification

This requirement ensures that there is sufficient inertia present in the rotor and the shaft to maintain rotation where there is variable torque such that the stator current does not exceed 40 % of the full load current. It ensures that unnecessary overheating of the motor does not occur. This ultimately reduces the design life of the motor and prevents reliability issues due to overheating that causes harm to the winding insulation.

11.3.4 Critical speed

11.3.4.1

For single-speed machines, the lateral natural frequencies that result in resonance amplification of vibration amplitudes shall fall outside the band of synchronous speed ± minimum 15 %.

Justification

Rotating shafts deflect during rotation. The mass of the rotating object causes deflection that creates resonant vibration at certain speeds known as the critical speeds. If the speed, as a result of the forced surge frequency, is the same as the lateral natural frequency of the system, resonance can occur. The magnitude of deflection depends upon the following:

- *stiffness of the shaft and its support;*
- *total mass of shaft and attached parts;*
- *balance of the mass with respect to the axis of rotation;*
- *amount of damping in the system;*
- *foundation design of motor mounting area.*

In view of these influencing parameters, this requirement ensures that the lateral natural frequencies fall outside the safe band enveloping the operational speed and that the measurable margin is defined as 15 %, which is adequately distant to not cause resonance.

NOTE Well-damped resonances with an amplification factor less than 2.5 are not considered critical speeds.

Justification

This note provides the clarification for critical speeds with well-damped resonances with amplification factors.

11.3.4.2

For converter duty motors, the lateral natural frequencies that result in resonance amplification of vibration amplitudes shall fall outside the band of operating speed range ± minimum 15 %.

Justification

Converter duty motors stabilizing at many speeds throughout the operating envelope are more likely to encounter critical speeds than a single-speed motor. To prevent resonance and thereby vibrations, this requirement ensures that the lateral natural frequencies or the critical speeds fall outside the entire operational speed range and that the safe margin practically is ± minimum 15 % as per industry practice.

11.3.5 Noise

11.3.5.1

The sound pressure level of the machine operating at rated speed and no load when fed with sinusoidal supply voltage, measured in any direction at a distance of 1 m, shall be less than 85 dB(A).

Justification

Noise regulations are part of health and safety at the workplace in industry and are legally binding, especially by countries as part of the national law. Limiting the noise level to which operating personnel are exposed reduces the harmful effects of noise on hearing. The permissible maximum noise level value along with the use of hearing protection corresponding to a daily or weekly average noise exposure is typically restricted to 85 dB(A). Considering the rating and size of the machines, if an upper limit is not specified, the noise from the equipment can cause detrimental effect to operating personnel. ISO 1680:2013, Clause 4 indicates that rotating electrical machines can be fed by network supply (sinusoidal) or a converter. Though the scope of this specification also covers converter duty motors, the testing conducted with sinusoidal supply is the normal practice.

11.3.5.2

Machines shall meet the noise limits by design without implementing corrective measures.

Justification

Noise abatement measures can camouflage machine deficiencies and seem to have fulfilled the stated noise limit requirement. The exclusion is explicitly stated as these noise abatement measures can have an undesirable effect on the performance of the motor and impede access during maintenance activities.

11.3.5.3

Noise abatement measures implemented to meet the noise limits shall be indicated on the drawings for approval by the purchaser.

Justification

Noise abatement measures can camouflage machine deficiencies and seem to have fulfilled the stated noise limit requirement. The exclusion is explicitly stated as these noise abatement measures can have an undesirable effect on the performance of the motor and impede access during maintenance activities.

11.3.5.4

Noise measurements shall be in accordance with ISO 1680.

Justification

ISO 1680 is the recognized reference for noise measurement by most manufacturers and for noise requirements in the oil and gas industry. This requirement ensures consistency going forward, especially with new manufacturers.

Add new subclause

11.4 Design criteria

11.4.1 General

11.4.1.1

Machines shall be designed and constructed for a minimum service life of 25 years excluding parts subjected to wear and tear.

Justification

The machine is expected to provide a minimum useful service life of 25 years in the specified environmental conditions. However, the expectation of minimum useful service life considers that the manufacturer's recommended maintenance activities are performed as per the maintenance plan. High value assets such as the machine include an expected service life as part of the asset integrity plan.

11.4.1.2

The machine shall be designed for continuous operation of at least six years, excluding oil change of self-lubricated sleeve bearings.

Justification

Operating companies may have a turnaround period ranging from four to six years and machines are expected to operate without interruption for this duration. Major scheduled maintenance is an activity that is performed during the turnaround time that further extends the period of operation and provides an expected service life of 25 years. However, oil change of self-lubricated sleeve bearings is an activity that needs to be performed as per the supplier's recommendations to ensure the expected service life of the bearings.

11.4.1.3

The machine shall be constructed with components, materials and design features that have proven service in the industry for at least two years.

Justification

This requirement ensures that if the product proposed by the manufacturer is not of a proven design, the purchaser is made aware of this such that they can evaluate the need for any additional steps, measures or activities to be undertaken. Typically, this is not an issue, but without this requirement, there is nowhere else in this specification that causes the manufacturer to make the purchaser aware of this.

11.4.2 Enclosure design

11.4.2.1 General

11.4.2.1.1

The machine enclosure shall have a low point drain hole with a removable plug.

Justification

Typically, drain holes are provided in the enclosure of machines for egress of moisture/condensation from within the housing. These drain holes have removable plugs and following the manufacturer's guidelines, they ensure that the degree of ingress protection is maintained.

11.4.2.1.2

Drain plugs shall be accessible with the machine installed in service position.

Justification

This requirement facilitates maintenance activities associated with draining the motor without dismantling any of the parts or components. In some cases, this can require the removal of the coupling guard for ease of access.

11.4.2.2 Mounting

11.4.2.2.1

The machine mounting arrangement shall be in accordance with IEC 60034-7.

Justification

The reference to IEC 60034-7 is for the most commonly used mounting methods across suppliers and in industry-wide applications. This requirement standardizes the definition of mounting and provision for installation on the baseplate for driven equipment. It also ensures that machines can be replaced and upgraded. The choice of mounting is as per application / driven equipment specifications and manufacturers' design needs.

11.4.2.2.2

Frame supports shall be provided with two vertical pilot holes for the installation of alignment dowels.

Justification

This requirement provides an efficient method for future motor alignment following initial alignment. Once the initial alignment has been successfully completed, the dowels can be installed to facilitate a fast method of locating the motor. This is as per API Standard 546:2022, 4.4.2.11.

11.4.2.2.3 Mounting surfaces and alignment

11.4.2.2.3.1

Mounting surfaces shall be machined to a finish of at least 6,3 μm arithmetic average roughness (Ra).

Justification

This requirement ensures a minimum criterion for frame mount surface in accordance with API Standard 546:2022, 4.4.2.8. a). For high-voltage synchronous machines, it is critical to have this addressed to provide required performance throughout the design life of the machine. This basic requirement contributes to the successful performance of the machine from initial set-up through the complete design life of the machine.

11.4.2.2.3.2

Mounting surfaces shall be machined within a flatness of 40 μm per linear meter of the mounting surface.

Justification

This requirement ensures a minimum criterion for frame mount surface in accordance with API Standard 546:2022, 4.4.2.8. c). For high-voltage synchronous machines, it is critical to have this addressed to provide required performance throughout the design life of the machine. This basic requirement contributes to the successful performance of the machine from initial set-up through the complete design life of the machine.

11.4.2.2.3.3

Mounting surfaces shall be in the same horizontal plane within 125 μm.

Justification

This requirement ensures a minimum criterion for frame mount surface in accordance with API Standard 546:2022, 4.4.2.8. b). For high-voltage synchronous machines, it is critical to have this addressed to provide required performance throughout the design life of the machine. This basic requirement contributes to the successful performance of the machine from initial set-up through the complete design life of the machine.

11.4.2.2.3.4

The upper machined or spot faced surface shall be parallel to the mounting surface.

Justification

This requirement ensures a minimum criterion for frame mount surface in accordance with API Standard 546:2022, 4.4.2.8. f). For high-voltage synchronous machines, it is critical to have this addressed to provide required performance throughout the design life of the machine. This basic requirement contributes to the successful performance of the machine from initial set-up through the complete design life of the machine.

11.4.2.2.3.5

Mounting planes shall be parallel to each other within 0,17 mm per metre.

Justification

This requirement ensures a minimum criterion for frame mount surface in accordance with API Standard 546:2022, 4.4.2.8. d). For high-voltage synchronous machines, it is critical to have this addressed to provide required performance throughout the design life of the machine. This basic requirement contributes to the successful performance of the machine from initial set-up through the complete design life of the machine.

11.4.2.2.3.6

Horizontal machine mounting planes shall be parallel to the horizontal plane through the bearing centreline within 0,17 mm per metre.

Justification

This requirement ensures a minimum criterion for frame mount surface in accordance with API Standard 546:2022, 4.4.2.8. e). For high-voltage synchronous machines, it is critical to have this addressed to provide required performance throughout the design life of the machine. This basic requirement contributes to the successful performance of the machine from initial set-up through the complete design life of the machine.

11.4.2.2.3.7

The mounting surface on a vertical machine shall be machined perpendicular to the centreline of the machine.

Justification

This requirement ensures a minimum criterion for frame mount surface in accordance with API Standard 546:2022, 4.4.2.9. For high-voltage synchronous machines, it is critical to have this addressed to provide required performance throughout the design life of the machine. This basic requirement contributes to the successful performance of the machine from initial set-up through the complete design life of the machine.

11.4.2.2.3.8

The mounting surface on a vertical machine shall not deviate from the perpendicular plane by more than 0,17 mm per metre.

Justification

This requirement ensures a minimum criterion for frame mount surface in accordance with API Standard 546:2022, 4.4.2.9. For high-voltage synchronous machines, it is critical to have this addressed to provide required performance throughout the design life of the machine. This basic requirement contributes to the successful performance of the machine from initial set-up through the complete design life of the machine.

11.4.2.2.3.9

Hold-down bolt holes shall be drilled perpendicular to the mounting surfaces of the machine.

Justification

This requirement ensures a minimum criterion for frame mount surface in accordance with API Standard 546:2022, 4.4.2.8. g). For high-voltage synchronous machines, it is critical to have this addressed to provide required performance throughout the design life of the machine. This basic requirement contributes to the successful performance of the machine from initial set-up through the complete design life of the machine.

11.4.2.2.3.10

Hold-down bolt holes shall be machined or spot faced to a diameter of at least three times that of the bolt hole.

Justification

This requirement ensures a minimum criterion for frame mount surface in accordance with API Standard 546:2022, 4.4.2.10. For high-voltage synchronous machines, it is critical to have this addressed to provide required performance throughout the design life of the machine. This basic requirement contributes to the successful performance of the machine from initial set-up through the complete design life of the machine.

11.4.2.2.3.11

Frame supports shall be provided with two vertical pilot holes for the installation of alignment dowels.

Justification

This requirement provides an efficient method for future machine alignment following initial alignment. Once the initial alignment has been successfully completed, the dowels can be installed to facilitate a fast method of locating the machine. This is as per API Standard 546:2022, 4.4.2.11.

11.4.2.3 Frame

11.4.2.3.1

Frame numbers and fixing dimensions shall be in accordance with IEC 60072-2.

Justification

This requirement reduces variants and ensures that any machine outside of the scope of IEC 60072-2 is assessed by the purchaser to ensure that it is acceptable prior to order placement. Any design outside of the scope of IEC 60072-2 is likely to be unproven and/or can have characteristics or features for which the purchaser requires more information before order placement.

11.4.2.3.2

The machine frame and add-on assemblies inclusive of terminal box covers heavier than 25 kg shall be provided with lifting lugs or lifting eyebolts.

Justification

This requirement facilitates safe lifting for installation, removal and refitting of the equipment and heavier frame-mounted add-on assemblies including terminal boxes. Without this requirement, non-compliance with HSE norms followed in the industry can happen.

11.4.2.3.3

Foot-mounted machines shall be provided with vertical jacking provisions and, when a soleplate is included in the scope of supply, with horizontal jacking provisions.

Justification

This requirement enables a safe and standard means of alignment of the machine with the coupled equipment during installation.

11.4.2.3.4

Where a corrosivity category of C4 or greater is specified, the selection of hardware used on the frame shall be in accordance with Table 27.

Justification

ISO has defined six corrosivity categories (i.e. C1 - very low, C2 - low, C3 - medium, C4 - high, C5 - very high, CX - extreme) based on a one-year corrosion mass loss or penetration of steel, zinc, copper and aluminium coupons. Environmental conditions contribute directly to the occurrence of corrosion and are therefore accounted for in this specification. The effects of corrosion and the rate at which they occur are consequences of the choice of material, exposure to environmental conditions (both severity and duration) and operational conditions. Where a category greater than C3 is specified, the selection of hardware is done in accordance with these environment conditions to meet the life cycle requirements. This requirement ensures that the equipment can withstand the environmental conditions and meet the life cycle requirement. Table 27 compiles a preferred selection of material from most manufacturers for corrosivity category of C4 or greater.

Add new Table 27

Table 27 – Selection criteria for hardware used on frame

Hardware type	Hardware material
External screws, bolts, nuts and washers of a thread diameter less than or equal to 10 mm	316L stainless steel
External screws, bolts, nuts and washers with a thread diameter greater than 10 mm	Hot-dip galvanized
Cooling air inlet protection mesh	316L stainless steel
Removable drain plug	316L stainless steel

Justification

ISO has defined six corrosivity categories (i.e. C1 - very low, C2 - low, C3 - medium, C4 - high, C5 - very high, CX - extreme) based on one-year corrosion mass loss or penetration of steel, zinc, copper, and aluminium coupons. Environmental conditions contribute directly to the occurrence of corrosion. The effects of corrosion and the rate at which they occur are consequences of the choice of material, exposure to environmental conditions (both severity and duration), and operational conditions.
This table considers environmental factors in the selection of hardware in order to meet the life cycle requirements. It also compiles a preferred option of material from most manufacturers for corrosivity category of C4 or greater.

11.4.2.3.5

Machines with a frame size 630 and above shall have removable inspection covers for the following:

– where applicable, inspection of coil end turns, exciter, synchronizing controls and rotor windings;

– inspection of air gap in at least three positions located 90° apart.

Justification

This requirement substantially reduces the time taken to perform the routine inspection by providing designated borescope inspection facilities for the inspection of the air gap and coil end turns, the exciter, synchronizing controls, and rotor windings as applicable. It also ensures that inspection can be performed throughout the lifetime of the machine, which facilitates the early detection of abnormalities and corresponding proactive corrective actions to reduce downtime. This requirement also provides alignment with API Standard 546:2022, 4.1.10.

NOTE The provision of inspection covers is not possible in all situations and deviations, if any, are brought to the attention of the purchaser.

11.4.2.3.6

The frame of the assembled machine shall be free from structural resonance between 40 % and 60 % range of the operating speed.

Justification

Structural resonance is caused when the forcing frequency in an assembled machine coincides with the natural frequency of the structural frame, which results in high vibration of the frame. This is not an issue with cast frames but it has been a problem for larger machines with fabricated frames. The design ensures that the natural frequency of the assembled machine system does not coincide with the natural frequency of the frame between 40 % and 60 % range of the operating speed and differ by at least ±15 % from one and two times the running-speed frequency and by at least ±15 % from one and two times the electric power frequency. During the design stage, finite element analysis (FEA) can be performed on the fabricated frame design to verify that structural resonances are kept away from 0.5x operating speed. If FEA shows resonance on one or more of the above conditions and in the range mentioned, the frame design can be modified to move the resonance outside of this range. This helps the frame to achieve an infinite fatigue life due to the forcing frequencies where the peak vibration occurs. The FEA report can be reviewed during the factory acceptance test (FAT), or more commonly, the purchaser accepts the declaration that the FEA results confirm that the frame design is compliant. Operators have experienced failures/damages to the machine frame as well as to terminations (cable glands). This requirement text standardizes the design criteria across the suppliers.

11.4.2.3.7

The frame of the assembled machine shall be free from structural resonance within ± minimum 15 % around speed frequency, twice speed frequency, power frequency and twice power frequency.

Justification

Structural resonance is caused when the forcing frequency in an assembled machine coincides with the natural frequency of the structural frame, which results in high vibration of the frame. This is not an issue with cast frames but for larger machines with fabricated frames, it has been a problem. The design ensures that the natural frequency of the assembled machine system does not coincide with the natural frequency of the frame between 40 % and 60 % range of the operating speed and differ by at least ±15 % from one and two times the running-speed frequency and, by at least ±15 % from one and two times the electric power frequency. During the design stage, FEA can be performed on the fabricated frame design to verify that structural resonances are kept away from 0.5x operating speed. If FEA shows resonance on one or more of the above conditions and in the range mentioned, the frame design can be modified to move the resonance outside of this range. This helps the frame to achieve an infinite fatigue life due to the forcing frequencies where the peak vibration occurs. The FEA report can be reviewed during the FAT, or more commonly accept the declaration that the FEA results confirm that the frame design is compliant. Operators have experienced failures/damages to the machine frame as well as to terminations (cable glands). This requirement text standardizes the design criteria across the suppliers.

11.4.2.3.8

The magnitude of the vibration on the machine frame, including the main terminal boxes, excluding the bearings, shall not exceed 4.5 mm/s (RMS) in any direction.

Justification

Structural resonance is caused when the forcing frequency in an assembled machine coincides with the natural frequency of the structural frame, which results in high vibration of the frame. This is not an issue with cast frames but for larger machines with fabricated frames, it has been a problem. The design ensures that the natural frequency of the assembled machine system does not coincide with the natural frequency of the frame between 40 % and 60 % range of the operating speed and differ by at least ±15 % from one and two times the running-speed frequency and, by at least ±15 % from one and two times the electric power frequency. During the design stage, FEA can be performed on the fabricated frame design to verify that structural resonances are kept away from 0,5x operating speed. If FEA shows resonance on one or more of the above conditions and in the range mentioned, the frame design can be modified to move the resonance outside of this range. This helps the frame to achieve an infinite fatigue life due to the forcing frequencies where the peak vibration occurs. The FEA report can be reviewed during the FAT, or more commonly accept the declaration that the FEA results confirm that the frame design is compliant. This 4.5 mm/s RMS as the limit for vibration has been in the purchase specification of multiple operators since long without any pushback from the suppliers. Operators have experienced failures/damages to the machine frame as well as to terminations (cable glands). This requirement text standardizes the design criteria and defines the upper limit for the vibration on the machine frame along the axis of the shaft centerline as the acceptance criteria across the suppliers.

11.4.2.4 Surface finish

11.4.2.4.1

For onshore applications, the protective paint system corrosivity category shall be at least C3 in accordance with ISO 12944-2.

Justification

This requirement specifies the surface finish in relation to the environmental conditions in which the machine is located and drives standardization among operating companies. Therefore, it allows the purchaser to specify environmental conditions from the listed categories in accordance with ISO 12944-2 in the PDS for the selection of the appropriate protective paint system. ISO 12944-2 defines corrosivity categories and these definitions align with several manufacturer's options. C3 as the default choice for onshore applications in the PDS sets the essential minimum requirement for the equipment across suppliers.

11.4.2.4.2

For offshore exterior applications, the protective paint system corrosivity category shall be CX in accordance with ISO 12944-2.

Justification

This requirement specifies the surface finish in relation to the environmental conditions in which the machine is located and drives standardization among operating companies. Therefore, this requirement allows the purchaser to specify environmental conditions from the listed categories in accordance with ISO 12944-2 in the PDS for the selection of the appropriate protective paint system. ISO 12944-2 defines corrosivity categories and these definitions align with several manufacturer's options. C3 as the default choice for onshore applications and CX as the default choice for offshore exterior applications in the PDS sets the essential minimum requirement for the equipment across suppliers. A higher option is selectable dependent on environmental conditions. CX for offshore is aligned with IOGP S-715.

11.4.2.4.3

The protective paint system durability category shall be at least "medium" in accordance with ISO 12944-1 for all locations.

Justification

This requirement specifies the surface finish in relation to the environmental conditions in which the machine is located and drives standardization among operating companies. Therefore this requirement allows the purchaser to specify environmental conditions from the listed categories in accordance with ISO 12944-2 in the PDS for the selection of the appropriate protective paint system. For durability, "medium" is the default option as this is considered the lowest reasonable selection for the oil and gas industry (both onshore and offshore) and aligns with the default offering from most manufacturers. More onerous options are available in the PDS, if required.

11.4.3 Cooling

11.4.3.1 General

11.4.3.1.1

Machine cooling shall be selected from the cooling methods listed in Table 28, in accordance with IEC 60034-6 and the specified degree of ingress protection.

Justification

Limiting the method of cooling to Table 28 ensures consistency, provides alignment with IEC 60034 (all parts) and drives standardization among motor manufacturers.

Add new Table 28

Table 28 – Machine cooling method

Cooling method	Code
Frame surface cooled machine using surrounding medium with self-circulation of secondary coolant	IC4A1A1
Machine with an integral heat exchanger using surrounding medium with self-circulation of secondary coolant	IC5A1A1
Machine-mounted heat exchanger using surrounding medium with self-circulation of secondary coolant	IC6A1A1
Machine-mounted heat exchanger using remote medium with self-circulation of primary coolant	IC7A1W7
Machine-mounted heat exchanger using surrounding medium with self-circulation of primary coolant	IC8A1W7

Justification

Limiting the method of cooling to this table ensures consistency, provides alignment with IEC 60034 (all parts) and drives standardization among motor manufacturers.

11.4.3.1.2

The operating frequency, or frequencies for converter duty motors, and operating frequency multiples of the machine shall not trigger the natural frequency of vibration of any cooling system components.

Justification

The cooling components could be add-on components (e.g. heat exchanger, externally mounted fans). This requirement ensures that the natural frequency of any add-on components is not triggered by the operating frequency or its multiples, resulting in unwarranted vibration and damages (e.g. cracks and/or breakages to the machine).

11.4.3.2 Air-cooled heat exchangers

11.4.3.2.1

Cooling air tubes shall be accessible for cleaning without removal of the exchanger assembly.

Justification

Regular cleaning of cooling tubes is important to maintain the heat removing capability. Restriction to access or any cumbersome means to access the exchanger tube ends prevents regular cleaning, thereby posing inadequate cooling and the possibility of failure.

11.4.3.2.2

A three-wire Pt-100 temperature sensor shall be provided to monitor the heat exchanger outlet air temperature.

Justification

This requirement provides a temperature monitoring facility that alerts the user when the performance of the heat exchanger is outside its normal operating values. By identifying deficiencies in a timely manner, prolonged equipment outages can be prevented and machine damage can be minimized.

11.4.3.2.3

Air-cooled heat exchangers shall be in accordance with API Standard 546:2022, 4.4.10.8.

Justification

API Standard 546:2022, 4.4.10.8 adequately covers the selection of tube material for the exchanger design.

11.4.3.3 Water-cooled heat exchangers

11.4.3.3.1

Water-cooled heat exchangers shall be provided with low point drains and air release vents.

Justification

This requirement ensures that maintenance can be performed with minimal disruption/outage time and coolant sampling can be done, if required. The low point drains also ensure that the entire cooling medium is drained out of the system, which helps to flush the system. This air release facility is imperative for releasing the trapped air from the cooling system when topping up with the cooling medium.

11.4.3.3.2

Water-cooled heat exchangers shall have provision for leakage or condensation collection and drainage of coolant.

Justification

While it is acknowledged that water leakage should not occur, it is accepted that from time to time, water leakage can be possible. This requirement addresses the need for a secondary defence to prevent the water from coming into contact with vulnerable machine components, and for the water to be contained within a designated area. This facilitates the identification of any leakages and provides a facility for removing the leaked coolant in a controlled manner. This requirement helps prevent aggravated failure and ultimately prolonged equipment outages.

11.4.3.3.3

Water-cooled heat exchangers shall be provided with 20 % spare tubes.

Justification

This requirement provides additional capacity to allow for failure of tubes over the design lifetime of the machine. Replacing damaged tubes can in some cases be a complex process that requires a complete outage of the heat exchanger and therefore of the machine. By providing spare capacity (tubes) to allow for plugging of damaged tubes, the machine can continue to operate with minimal disruption for extended periods of time with the same cooling capability. This requirement uses 20 % spare tubes instead of 10 % since the repair/replacement of tubes is cumbersome, costlier and impractical (at times) when compared to providing an additional 10 % spare tubes by default. The probability of the need for undertaking a repair/replacement of tubes of the exchanger becomes remote when 20 % spare tubes are provided since the failed tubes can be plugged and forgotten as there are adequate spares. This spare quantity would generally last for the life cycle of the exchanger. Providing 20 % spare tubes does not impact the exchanger size and is a preferred alternative for reducing exchanger repair/maintenance over the life cycle.

11.4.3.3.4

Water-cooled heat exchanger tube bundles shall have provisions for plugging and isolating the leaking tubes.

Justification

This requirement ensures faster resolution of leakage problems since replacing damaged tubes can in some cases be a complex process that requires a complete outage of the heat exchanger and therefore of the machine. By plugging and isolating the damaged tubes, the machine can continue to operate with minimal disruption for extended periods of time.

11.4.3.3.5

Water-cooled heat exchangers shall be in accordance with API Standard 546:2022, 4.4.10.8.

Justification

API Standard 546:2022, 4.4.10.8 adequately covers the selection of tube material for the exchanger design.

11.4.3.3.6

When the required parameters on the water side are not available from the purchaser, cooling water system design criteria shall be in accordance with API Standard 546:2022, Table 7.

Justification

There could be a situation when the required parameters for the exchanger design are not available and the fall back is the parameters of API Standard 546:2022, Table 7. This requirement sets common default criteria instead of an arbitrary chosen value for manufacturers in the absence of a required value.

11.4.4 Stator windings

11.4.4.1

Winding coils shall be of a form-wound, fully vacuum pressure impregnated (VPI) construction.

NOTE 1 The main stator windings can be form-wound design based on mica and epoxy subject to owner approval.

NOTE 2 A resin rich system can be acceptable subject to owner approval.

Justification

Form wound designs are desirable for medium-voltage and high-voltage applications wherein the ability to provide better turn-to-turn insulation and greater mechanical strength results in a more reliable machine, with relatively minor sacrifices in performance and cost. Applications that use continuous, repeated surge loads to the machine are usually best served with a form wound design. The surge loads result in magnetic reactions in the windings, particularly in the end turns of the stator, that tend to deform the windings or even break them over time. With a rigid, heavily braced design in case of form winding, the impact of these mechanical stresses can be more easily mitigated. The VPI process provides an insulation system with high dielectric strength, mechanical resilience, chemical and moisture resistance, and good thermal capabilities. Also, the solvent-free resins used in the VPI process are the non-reactive components of the formulation that have a very high initial boiling point and non-flammable properties making it safer.

11.4.4.2

For machines 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.

Justification

Electric field grading or field stress grading is the technique of effective and reliable distribution of the electric field within or around the winding coils. A reliable field stress grading system prevents partial discharge in the air gaps between the surfaces of winding coils and the winding ends / overhang region. These areas have increased electric field leading to corona discharges or partial discharges. Partial discharges deteriorate the winding insulation system, leading to failures of machine windings. The field stress grading systems cater to two parts namely the slot area using a conductive armour tape and the winding overhang region using a stress grading tape. The conductive armour tape used is made of carbon black embedded in a fibre-glass tape and prevents slot discharges. The stress grading tape is a semi-conductive tape made of finely woven polyester glass fabric impregnated evenly with an electrically semi-conductive varnish containing silicon carbide. These tapes are suitable for the main wall insulation and overhang of high-voltage winding coils and bars using VPI and resin rich technology. The reliability of the field stress grading system in the winding overhang region is important to the life of insulation due to the high electrical stress and the proximity of adjacent winding coils.

11.4.4.3

For machines with a rated voltage of 6 kV and above, field stress grading tape shall be used for anti-corona protection.

Justification

Electric field grading or field stress grading is the technique of effective and reliable distribution of the electric field within or around the winding coils. A reliable field stress grading system prevents partial discharge in the air gaps between the surfaces of winding coils and the winding ends / overhang region. These areas have increased electric field leading to corona discharges or partial discharges. Partial discharges deteriorate the winding insulation system, leading to failures of motor windings. The field stress grading systems caters to two parts namely the slot area using a conductive armour tape and the winding overhang region using a stress grading tape. The conductive armour tape used is made of carbon black embedded in a fibre-glass tape and prevents slot discharges. The stress grading tape is a semi-conductive tape made of finely woven polyester glass fabric impregnated evenly with an electrically semi-conductive varnish containing silicon carbide. These tapes are suitable for the main wall insulation and overhang of high-voltage winding coils and bars using VPI and resin rich technology. The reliability of the field stress grading system in the winding overhang region is important to the life of insulation due to the high electrical stress and the proximity of adjacent winding coils.

11.4.4.4

Winding coils shall have uniform insulation levels rated for line-to-line voltage.

Justification

This requirement ensures that the insulation thickness is consistent throughout the stator windings all along its length, otherwise it may be argued that the insulation level is met just by demonstrating its thickness at a single location and may not be consistent at another location.

11.4.4.5

Winding connections, except those completed in the main terminal box, shall be brazed using a silver-based brazing material.

Justification

Historical data confirms that wherever these connections have been crimped, only those connections fail. Brazing or soldering is also deployed as it is proven to provide a connection that is stronger over time. While the results of brazing are superior, the practicalities of brazing that can cause damage to the insulation can be challenging due to the high temperature involved. Therefore manufacturers were consulted to understand the adopted industry practice for winding connections (manufacturers were also consulted during the development of IOGP S-704, first revision). Based on the manufacturers' responses, the requirement is considered feasible and acceptable for standardization.

11.4.4.6

The windings of the machine shall be star connected.

Justification

When the stator winding in STAR configuration is connected to high voltage, the phase current remains the same as the line current, but the phase voltage reduces to $V_{ph} = V_{line}/1.732$, which means that the insulation requirement from the phase winding will be less. Though as per 11.4.4.3, the winding coils should have uniform insulation levels rated for line-to-line voltage to ensure that the insulation thickness is consistent throughout the stator windings all along its length. Thus, the phase voltage applied on the winding coils with insulation levels rated for line-to-line voltage will further reduce the stress thereby furthering the life of the insulation system of the winding. The six ends of the stator windings are brought out into the terminal boxes (three ends to the main terminal box and three ends to the neutral terminal box). For differential protection, when required, either full differential or self-balancing scheme is arranged with the six ends of the stator windings as applicable. This requirement, along with the data sheet element for neutral connection, ensures that the terminal boxes are adequately sized for all six ends of the stator windings. For generators, neutral grounding and earth-fault protection can be provided.

11.4.4.7

Winding coils shall be tightly wedged in stator slots prior to vacuum pressure impregnation.

Justification

Current through the stator windings create lot of electromagnetic forces during steady state and transient operation. If windings are not tightly wedged prior to VPI, these forces cause movement, abrasion and premature failure of the stator winding insulation system. Moreover, such inadequately tight wedges remain unnoticed after VPI until a failure occurs.

11.4.4.8

The stator winding system including end windings, connections and circuit rings shall be securely and uniformly supported and braced in the radial and circumferential directions.

Justification

Current through the stator windings creates a lot of electromagnetic forces, especially on the free hanging ends of stator winding . These forces cause end winding movement which damages the winding insulation. The likelihood of damage increases as the insulation ages and becomes more brittle. Rigid supports and uniform bracing prevent excessive movement of end windings during steady state operation, motor starting and power system transients.

11.4.4.9

The terminal lead extensions from the stator winding to the terminal box shall be braced and supported securely in a manner that allows for thermal expansion and movement during starting, and prevent chafing.

Justification

Current through the terminal lead extensions creates electromagnetic forces on the leads during starting and power system transients. The leads also experience vibration forces during normal operation. These forces cause terminal lead movement which can damage some of the lead insulation. The likelihood of damage increases as the insulation ages and becomes more brittle. Since one end of the terminal leads is connected to the stator core assembly and the other end is connected to the terminal box, the leads experience differential movement as the stator core assembly experiences thermal expansion and contraction. The design of the terminal leads coupled with the method of supporting and bracing the terminal leads needs to prevent chafing and withstand this differential movement to prevent insulation cracking and failure.

11.4.4.10

The terminal lead extensions from the stator winding to the terminal box shall be insulated, and separated from terminal leads and surfaces of different potential.

Justification

Current through the terminal lead extensions creates electromagnetic forces on the leads during starting and power system transients. The leads also experience vibration forces during normal operation. These forces cause terminal lead movement which can damage some of the lead insulation. Additionally, the terminal leads when uniformly spaced and supported prevent movement of terminal lead extensions during steady state operation, machine starting and power system transients. The lack of air gap between the surfaces of each terminal lead extension and the earth (terminal box enclosure) that have difference in potential leads to partial discharges. Partial discharges deteriorate the insulation on the terminal leads, leading to failures in the machine. Hence, this requirement ensures that the terminal lead extensions from the stator winding routed internally up to the terminal box are properly insulated and separated between terminal leads and surfaces with different potential.

11.4.4.11

Magnetic stator slot wedges shall not be used.

Justification

The mechanical strength of magnetic slot wedges is too weak for critical large synchronous machines. This requirement prevents the use of magnetic slot wedges as it can lead to premature stator failure.

11.4.5 Rotor

11.4.5.1

The shaft of the rotor shall be manufactured from a single piece of heat-treated forged steel.

Justification

This requirement ensures that the torsional strength of the rotor shaft is not compromised and is uniform throughout the shaft length. This also aligns with API Standard 546:2022, 4.4.5.1.2. Shafts made of hot-rolled round steel are most common in small and medium-sized motors. Hot rolling is a mill process that involves rolling the carbon structural steel at a high temperature (typically at a temperature over 1 700 °F) that is above the recrystallization temperature of the steel. When the steel material is above the recrystallization temperature, it can be shaped and formed easily, and be made in much larger sizes. The block diameter is selected in accordance with the maximum diameter of the shaft anywhere along its length plus the machining allowance. Therefore, the amount of cutting is relatively large. Hot rolling improves the following:

- *toughness and strength;*
- *ductility;*
- *resistance to vibration and shock;*
- *formability;*
- *weldability.*

Forged shafts are preferred for larger shaft diameters. The forged steel has high mechanical strength and the general shape of the stepped shaft can save raw materials and cutting time, but forged shafts are more expensive than hot-rolled shafts. The advantages of forging include the following.

- *It is generally tougher than alternative manufacturing techniques.*
- *The nature of forging excludes the occurrence of porosity, shrinkage, cavities and cold pour issues.*
- *The tight grain structure of forgings makes it mechanically strong. There is less need for expensive alloys to attain high-strength components.*
- *The tight grain structure offers great wear resistance without the need to make products "super hard".*

11.4.5.2

Where shaft keys are provided, rotors shall be balanced with a half-key fitted in the shaft keyway in accordance with IEC 60034-14 and ISO 21940-32.

Justification

Rotor shaft construction and balancing requirements ensure consistency across operators and manufacturers with a minimum specification. The rotor shaft is balanced in accordance with IEC 60034-14:2018, Clause 7 with the keyway in accordance with ISO 21940-32. This requirement is generally the default for manufacturers but is currently not covered in IEC 60034-1.

11.4.5.3

Rotors shall be balanced to restrict the residual unbalance below the permissible limit determined by the specified balance quality grade.

Justification

As part of the rotor balancing, ensuring minimum residual unbalance is a good start to achieve low vibration values in a completely assembled machine. Setting the limits for residual unbalance based on balance grade G 2,5 is the typical industry practice for large motor unbalance. This requirement allows the purchaser to procure machines with lower residual unbalance magnitudes by pointing to a PDS element that specifies the required balancing grade to determine the permissible limits for residual unbalance.

11.4.5.4

Rotors with rigid shaft characteristics shall be balanced in accordance with ISO 21940-11.

Justification

The balance grade is defined to ensure consistency. ISO 21940-11:2016, Table 1 defines the actual requirement and level of accuracy required. The applicable category is "Electric motors and generators (of at least 80 mm shaft height), of maximum rated speeds above 950 r/min". ISO 21940-11 also describes the balancing process. The maximum shaft vibration and run out limits are specified in the PDS.

11.4.5.5

For converter duty motors with rigid shaft characteristics, the maximum vibration magnitude limits shall be applicable throughout the defined speed range.

Justification

The balance grade is defined to ensure consistency. ISO 21940-11:2016, Table 1 defines the balancing quality grades for typical machinery categories. The applicable category is "Electric motors and generators (of at least 80 mm shaft height), of maximum rated speeds above 950 r/min". ISO 21940-11 also describes the balancing process. This requirement supplements 11.4.5.4 by stating that the maximum vibration magnitude is applicable not only for the maximum rated speed but for the entire defined speed range for a converter duty motor. The maximum shaft vibration and run out limits are specified in the PDS.

11.4.5.6

Rotors with flexible shaft characteristics shall be balanced at rated speed in accordance with ISO 21940-12.

Justification

Balancing rigid shafts is performed at a speed that is not considered critical, however this is not the case for a flexible shaft machine. This type of rotor is balanced at a low speed where the rotor does not flex. Correction for unbalance is made, then the speed is gradually increased and the unbalance is corrected in stages until the rated/operating speed of the rotor is reached. This requirement ensures that the rotor does not flex in the entire range up to the rated speed. The maximum shaft vibration and run out limits are specified in the PDS.

11.4.5.7

For converter duty motors with flexible shaft characteristics, the maximum vibration magnitude limits shall be applicable throughout the defined speed range.

Justification

When balancing rigid shafts, it is a given that balancing is performed at a speed that is not considered critical, however, this is not the case for a flexible shaft machine. This type of rotor is balanced at a low speed where the rotor does not flex. Correction for unbalance is made, then the speed is gradually increased and the unbalance is corrected in stages until the rated/operating speed of the rotor is reached. This requirement ensures that the rotor does not flex in the entire range up to the rated speed. This requirement supplements 11.4.5.7 by stating that the maximum vibration magnitude is applicable not only for the maximum rated speed but for the entire defined speed range for a converter duty motor. The maximum shaft vibration and run out limits are specified in the PDS.

11.4.5.8

For machines with sleeve bearings, the rotor shall be permanently marked to be visible in operation and standstill position with the magnetic centre and limits of permissible shaft axial movement.

Justification

This requirement facilitates the monitoring of bearing performance and condition when the machine is in use. It provides the user with the ability to identify a bearing malfunction in the early stages and reduces the chances of bearing failure becoming catastrophic.

11.4.5.9

Shaft extensions shall be in accordance with IEC 60072-2.

Justification

IEC 60072-2 ensures that dimensions are uniform across manufacturers. This requirement ensures that the machine is replaceable and interchangeable.

11.4.5.10

The proximity probe sensing areas on the rotor shaft shall be concentric with the bearing journal, free from stencil and scribe marks and from surface discontinuity.

Justification

The contactless probes enable maintenance-free long-term measurements in industrial environments. The application of these probes requires the measurement surfaces on the shaft to be specially machined. Ideally, these surfaces should be round, cylindrical and concentric with the rotational axis. The measurement surfaces are usually located close to each bearing journal. Imperfections in the surfaces appear in the probe response and result in measurement error. API Standard 546:2022, 4.4.5.1.6 specifies the preparation of the rotor sensing area to prevent measurement errors/issues. Activities such as metallizing, sleeving or plating on the measurement area during rotor sensing surface introduce variation in metal properties/characteristics and result in measurement errors/issues. IEC 60034-1 does not specify the requirements related to the preparation of the rotor sensing area. Hence, compliance with API standards ensures standardization and the elimination of measurement errors/issues due to surface anomalies.

11.4.5.11

The proximity probe sensing areas on the rotor shaft shall not be metallized, sleeved or plated.

Justification

The contactless probes enable maintenance-free long-term measurements in industrial environments. The application of these probes requires the measurement surfaces on the shaft to be specially machined. Ideally, these surfaces should be round, cylindrical and concentric with the rotational axis. The measurement surfaces are usually located close to each bearing journal. Imperfections in the surfaces appear in the probe response and result in measurement error. API Standard 546:2022, 4.4.5.1.6 specifies the preparation of the rotor sensing area to prevent measurement errors/issues. Activities such as metallizing, sleeving or plating on the measurement area during rotor sensing surface introduces variation in metal properties/characteristics and result in measurement errors/issues. IEC 60034-1 does not specify the requirements related to preparation of rotor sensing area. Hence, compliance in accordance with API standard ensures standardization and ensure the elimination of measurement errors/issues due to surface anomalies.

11.4.5.12

The proximity probe sensing areas on the rotor shaft shall achieve a surface finish of maximum of 0.8 μm arithmetic average roughness.

Justification

The contactless probes enable maintenance-free long-term measurements in industrial environments. The application of these probes requires the measurement surfaces on the shaft to be specially machined. Ideally, these surfaces should be round, cylindrical and concentric with the rotational axis. The measurement surfaces are usually located close to each bearing journal. Imperfections in the surfaces appear in the probe response and result in measurement error. API Standard 546:2022, 4.4.5.1.6 specifies the preparation of the rotor sensing area to prevent measurement errors/issues. Activities such as metallizing, sleeving or plating on the measurement area during rotor sensing surface introduces variation in metal properties/characteristics and result in measurement errors/issues. IEC 60034-1 does not specify the requirements related to preparation of rotor sensing area. Hence, compliance in accordance with API standard ensures standardization and ensure the elimination of measurement errors/issues due to surface anomalies.

11.4.5.13

The electrical and mechanical runout of the rotor shaft supported on v-blocks shall be measured at least every 10° of rotation on each probe location with the rotor rotated through the full 360°.

Justification

Suppliers often demonstrate the compliance but do not provide elaborate measurements and the associated report of the test. The test results form the baseline data for any future investigation related to vibration issues. Hence, the electrical and mechanical runout readings of the rotor shaft measured at least every 10° of rotation with the rotor rotated through the full 360° when supported on v-blocks must be recorded. Similarly, the electrical and mechanical runout readings of the rotor shaft in the assembled machine should be measured at least every 10° of rotation with the rotor rotated through the full 360° at slow roll speed (200 rpm to 300 rpm). These test results of electrical and mechanical runout for the full 360° at each probe location have to be part of the documentation in the manufacturer's record book (MRB).

11.4.5.14

When proximity probes are provided, the electrical and mechanical runout of the rotor shaft in the assembled machine shall be measured at slow roll speed (200 rpm to 300 rpm).

Justification

This requirement ensures alignment with API Standard 546:2022 for rotor dynamics and avoids wrongly mixing runout in v-blocks and slow roll run-out.

11.4.5.15

Rotor balance corrections shall be in accordance with API Standard 546:2022, 4.4.6.3.2.

Justification

Operators have experienced suppliers adopting non-standard material and processes for rotor balance corrections since it is not explicitly addressed in the specification. API Standard 546:2022, 4.4.6.3.2 adequately address the rotor balance correction requirements, hence this requirement eliminates the ambiguity and a possible dispute.

11.4.5.16

Components on the rotor assembly shall not be repaired by plating, plasma spray, metal spray, impregnation and welding unless approved by the purchaser.

Justification

Operators have experienced that the absence of this requirement has led to disputes between purchasers and suppliers as suppliers repair/rectify damages on the components of the rotor assembly during manufacturing (assembly/testing) using processes that do not address heat stress relieving which cause defects later. Suppliers adopt non-standard materials and processes for rotor component repairs when explicitly not addressed in the specification. This requirement eliminates the ambiguity and a potential dispute between purchasers and suppliers.

11.4.5.17

The rotor winding insulation system shall be adequately rated for expected overvoltages or provided with overvoltage protection.

NOTE Overvoltage protection can be via bypass thyristors, varistors or a discharge resistor.

Justification

This requirement provides set of minimum integrity requirements for rotor field winding for synchronous machines.

11.4.6 Terminals

Terminal bushings and post insulators shall be made of cycloaliphatic epoxy resin material.

Justification

Cycloaliphatic epoxy resin is a low viscosity, low molecular weight epoxy resin designed for use in high-voltage outdoor electrical applications because it achieves crack-free components with excellent mechanical and electrical properties with high uniformity. Cycloaliphatic epoxy resins are alternatives to standard bisphenol epoxies because they have superior resistance to moisture and ultraviolet (UV), better colour and gloss stability, excellent electrical properties, high heat deflection temperature and high compression strength. High compression strength and other qualities of cycloaliphatic epoxy resin make the insulators from these epoxy resins reliable for many years of service. This requirement aligns with API Standard 546:2022, 5.1.1.

11.4.7 Terminal boxes

11.4.7.1

The main terminal box shall be made of fabricated steel with a thickness greater than or equal to 3 mm.

Justification

This requirement is not covered in IEC 60034-1 and ensures that terminal boxes are made of a material and of a thickness that aligns with the operating life of the machine body. The specified thickness is consistent with the manufacturer's standard offerings and aligns with API Standard 546:2022, 4.4.1.1.

11.4.7.2

Main and neutral terminal boxes shall have terminal markings and the direction of rotation in accordance with IEC 60034-8.

Justification

IEC 60034-8 provides a letter designation to the terminals for the connection diagram of the machine windings. This requirement provides a standard method for terminal markings and the direction of rotation that is commonly understood by suppliers and users.

11.4.7.3

Where provided, threaded cable gland entries shall have a metric thread in accordance with IEC 60423:2007, Table 1.

Justification

This requirement ensures that terminal box gland entries are consistent with no variation in thread size/pitch across manufacturers.

11.4.7.4

Cable entries shall be fitted with blanking devices to retain the ingress protection rating of the machine during transportation and storage.

Justification

This requirement ensures that the intended ingress protection rating is maintained during transportation and storage and until the installation of cables is completed.

11.4.7.5

Where single-core power cables are specified, the gland plate and multi-cable transit frame shall be made of non-magnetic material.

Justification

Where single-core cables are used for each phase, the magnetic flux does not cancel out as it does in the case of a three-core cable. This causes the individual cable magnetic flux to produce eddy current circulation in the metallic plate, causing overheating of the gland plate. Hence, the gland plate or multi-cable transit frame is made of non-magnetic material to prevent eddy current and heating. Though this phenomenon is widely recognized, it is not specified in IEC 60034-1, hence this requirement.

11.4.7.6

Where provided, the neutral terminal box shall be located on the opposite side of the main terminal box.

Justification

Mounting the neutral terminal box (which would typically be required for current transformers with full differential protection scheme) opposite the line conductor terminal is standard practice among manufacturers. Moreover, it is not practical to locate both large terminal boxes on one side and locating one on either side achieves the best balance in order to provide convenient access for installation, testing and maintenance.

11.4.7.7

For non-Ex db main terminal boxes, a corrosion-resistant pressure-relief diaphragm shall be incorporated in the terminal box.

Justification

Safety and integrity of high-voltage terminal boxes during internal faults are ensured by deliberately incorporating a weak spot within the terminal box. In normal operation, the cable box is adequately sealed and maintains the integrity and enclosure protection level. In the event of an internal fault, a relatively modest rise in pressure within the box ruptures the pressure-relief diaphragm and relieves the energy, preventing damage to the terminal box. The location of the pressure-relief diaphragm is also important as during the rupture of the diaphragm, the pressure is released away from where any personnel could be present. Also, the corrosion resistance property ensures that environmental effects do not affect the integrity of the diaphragm.

11.4.7.8

The discharge of the pressure-relief diaphragm shall be located on the back panel of the terminal box and directed towards the machine frame.

Justification

Safety and integrity of high-voltage terminal boxes during internal faults are ensured by deliberately incorporating a weak spot within the terminal box. In normal operation, the cable box is adequately sealed and maintains the integrity and enclosure protection level. In the event of an internal fault, a relatively modest rise in pressure within the box ruptures the pressure-relief diaphragm and relieves the energy preventing damage to the terminal box. The location of the pressure-relief diaphragm is also important as during the rupture of the diaphragm, the pressure is released away from where any personnel could be present.

11.4.7.9

The bottom of the terminal box shall be higher than the mounting surface of the machine.

Justification

This requirement ensures that the machine mounting base is the lowest point and that terminal boxes can remain installed on the machine housing even during transport and storage. This requirement ensures that the machine can be installed on the base frame without any additional structural assembly required to elevate the lowest point of the machine up to or above the base frame level. When stated upfront, this requirement helps the manufacturer to choose the tilt and orientation of the terminal box at the initial stage.

11.4.7.10

Machine auxiliaries and instruments shall be wired to separate auxiliary terminal boxes mounted on the side of the machine.

Justification

This requirement ensures that the number of auxiliary terminal boxes is in accordance with the segregation of signals and that the location of these boxes on the machine housing and routing of wiring are determined uniformly by all manufacturers. This requirement rules out the possibility of manufacturers combining auxiliary terminal boxes.

11.4.7.11

The terminals forming a terminal block shall be arranged and positioned in an accessible manner for carrying out external cabling, testing, inspection and maintenance, following the termination of cables.

Justification

This requirement improves maintenance and construction efficiency.

11.4.7.12

Terminal blocks for different voltages shall be segregated.

Justification

This requirement ensures safe and correct connections, preventing short-circuit and potential damage, and supports safe fault tracing and maintenance work.

11.4.8 Fans

11.4.8.1

Separable fans shall be permanently indexed angularly and axially.

Justification

Rotors need to be removed for many maintenance operations. If fan impellers are mounted external to the rotor end shields, the fans are removed as part of the rotor removal process. It is important to maintain the same relative position between the rotor and the fan when the fan is reinstalled such that the rotor balance is maintained. Keying or screwing to the rotor shaft is a simple and accurate method of ensuring this alignment.

11.4.8.2

Independently mounted fan impellers shall be keyed or shrink fitted to the rotor shaft.

Justification

Incorrect fitting can dislodge the fan from the shaft, resulting in a dangerous situation. This requirement ensures locking by keyed arrangement or shrink fit and prevents such dangerous situations from occurring.

11.4.8.3

Machines with unidirectional fans shall have a permanently affixed label with an arrow indicating the direction of rotation.

Justification

Where a unidirectional fan is provided, the engraved arrow helps the installer of the fan to confirm the orientation for which the fan should be installed, ensuring it operates as per the design. The arrow is also a check for the direction of rotation of the driver to ensure the phase sequence of the power cables.

11.4.8.4

Where a corrosivity category greater than C3 has been specified, fan impellers external to the stator end shields shall not be made of aluminium.

Justification

This requirement ensures that fan impellers are made of a material that lasts for the lifetime of the machine.

11.4.8.5

Fan impellers shall not be made of plastic.

Justification

This requirement ensures that fan impellers are made of a material that lasts for the lifetime of the machine.

11.4.9 Bearing and Lubrication

11.4.9.1 Bearing insulation

11.4.9.1.1

Bearings shall be electrically insulated.

Justification

Bearing currents occur when there is an induced voltage, on the motor shaft, that is high enough to overcome the breakdown voltage on the bearing lubricant. Shaft voltages cause either of the following:
- *current to flow directly from the shaft, through a bearing, then through the motor or load frame and then into the ground;*
- *current to circulate from one side of the shaft, through a bearing, through the motor frame, back into the opposite bearing, and then back into the shaft. Insulated bearings prevent premature bearing failures caused by stray bearing currents.*

11.4.9.1.2

When insulated bearings are used, a shaft grounding system shall be provided at the drive end of the rotor shaft.

Justification

When insulating both bearings, it is 100 % effective in stopping the circulating current. However, the voltage on the shaft of the machine would then rise to a maximum and would seek a path to the ground through the attached equipment. This situation could also put the coupled equipment bearings a risk. Therefore, a means of providing a path to the ground is installed to discharge these shaft voltages. The shaft grounding provides a means of discharging these shaft voltages.

NOTE If an insulated coupling has been specified, a shaft grounding system is provided at the non-drive end of the rotor shaft.

11.4.9.1.3

The bearing housing shall bear a prominent label to indicate the use of insulated bearings.

Justification

The caution label on the bearing housing states that no action causes the bearing insulation to be bridged by any conductive connection. This requirement also cautions for appropriate replacement spares and compliance with procedures as recommended by the manufacturer to maintain the integrity of bearing insulation.

11.4.9.2 Sleeve bearings

11.4.9.2.1

Sleeve bearings shall be spherical seated and self-aligning.

Justification

On spherical seated self-aligning sleeve bearings, the outer rings get press fit into housings. This requirement allows the fracture to remain closed and prevents the rotation of the outer ring under heavy rotational or oscillating loads. Inner rings may have interference or clearance fits on shafts depending on the application. To facilitate the mounting of bearings of this design, the ends of pins or shafts and the edges of housing bores have a lead chamfer of 10° to 20°. These bearings can be more easily pressed into position and there is little risk of damage to mating surfaces caused by skewing of the bearing. This ultimately facilitates a more efficient bearing replacement, with less opportunity to damage the bearing housing faces, which minimizes additional machine downtime.

11.4.9.2.2

Replacement of sleeve bearing liners, pads and shells shall be possible without disassembly of the lower half of the end bells, plates and ductwork or without disassembly of the coupling on the machine.

Justification

This requirement enables rectification work to be performed on sleeve bearings with minimal disruption and outage time.

11.4.9.2.3

A permanently installed jacking oil system shall only be installed if premature babbitt wear cannot be avoided without hydrostatic jacking.

Justification

This requirement ensures that a jacking oil system is only applied where needed.

11.4.9.2.4

Self-lubricated sleeve bearings shall be provided with an oil level indicator.

Justification

This requirement provides lubrication level monitoring to ensure that maintenance activities can identify a low oil level without performing intrusive maintenance. This allows trends to be easily monitored if increased oil usage or any leakage occurs.

11.4.9.2.5

Sleeve bearings with a ring lubricating system shall permit the visual inspection of oil ring operation while the machine is running.

Justification

Visual inspection while the machine is running provides the user with a non-intrusive means of ensuring that the lubrication system is operating properly on a regular basis. Some manufacturers recommend checking oil ring operation daily.

11.4.9.2.6

For flooded lubrication systems with a lube oil re-circulation circuit, a flow indicator shall be provided in the lube oil return lines.

Justification

This requirement provides lubrication oil flow monitoring to ensure that maintenance activities can identify low oil flow without performing intrusive maintenance.

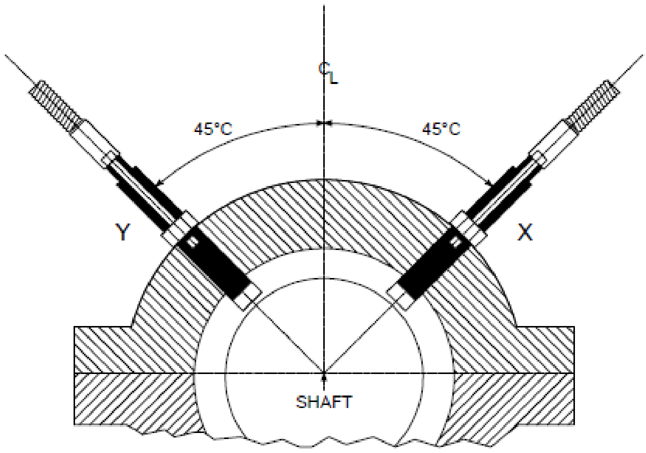
NOTE The terms "flooded lubrication" and "forced lubrication" may be used interchangeably.

11.4.9.2.7

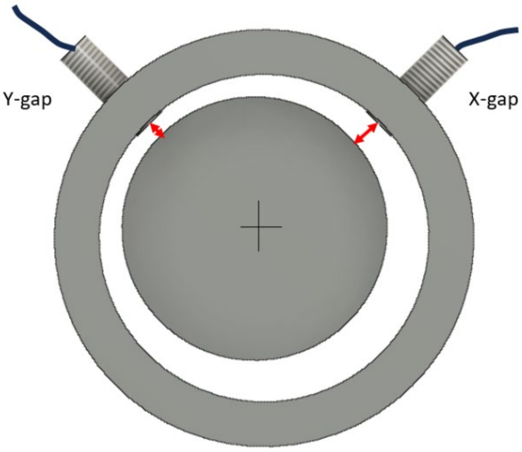
Machines shall have provision for two non-contacting vibration measurement proximity probes per sleeve bearing and one phase reference transducer in accordance with API Standard 670.

Justification

This requirement ensures that the machine is provided with a means for vibration measurement. API Standard 670 provides further definition on proximity sensor specification. Proximity probes are sensors that detect objects without coming into physical contact, thereby measuring the shaft displacement relative to the sleeve bearing housing. Typically, two proximity probes identified as X and Y are mounted per sleeve bearing at a 45-degree angle from vertical, thus being at a 90-degree angle apart from one another, as shown in Justification Figure c and Justification Figure d. The relative motion between the shaft and the probes generates varying eddy current flow that gives a proportional corresponding change in both the amplitude and phase of the signal. This signal is then interpreted as shaft displacement and runout. The phase reference transducer provides a relative reference point for the vibration readings from the proximity probes and helps with monitoring/diagnostics information such as filtered vibration amplitude, phase lag and speed.



Justification Figure c



Justification Figure d

11.4.9.2.8

Oil and bearing temperatures shall be in accordance with API Standard 546:2022, 4.4.7.1.14.

Justification

The bearing over-temperature is the most common cause of premature bearing failure and stating a maximum temperature provides alignment for industry requirements.

11.4.9.2.9

The flooded lubrication system shall have redundant oil pumps.

Justification

For large-capacity machines, lubrication is an important requirement for reliable operation. Hence, the lubrication system has a redundant oil pump to keep the oil flowing into the bearings. The topology (flooded lubrication or pressure/force lubrication) is dependent on the manufacturer's model/design, capacity of the machine, etc. Redundancy in oil pumps ensures improved reliability and availability.

11.4.9.2.10

The flooded lubrication system shall have provision for topping up the oil level while the machine is in operation.

Justification

This requirement ensures that a proper arrangement for topping up the oil level is provided in the event of a leakage in the lubrication system. This requirement also ensures that the provision for air venting is part of the design and that the top up location is easily approachable and safe for the activity. This requirement also ensures that the supplier can demonstrate the activity of topping up the oil level and that the purchaser can validate the ease of access to perform the topping up activity.

11.4.9.2.11

If the flooded lubrication system fails or is switched off, the machine shall rundown safely.

Justification

Oil reservoirs or rundown tanks are simple vessels used for the storage of oil above a certain height from the shaft centre line of the rotary equipment (e.g. motor, generator, pump, compressor). Bearings are critical parts of the rotating machine with a high level of sensitivity and even a small damage can ruin the bearing rapidly. The most probable cause of bearing damage is reduced lubrication or loss of lubrication. This situation is likely to happen in case of a power interruption when the method of flood lubrication or pressure lubrication is used. Another cause could be someone switching off the pump by mistake. To counter this situation, the oil reservoir or rundown tank supplies the lubrication oil to the bearings at the required flow rate and pressures until the equipment coasts down (runs down) and comes to a standstill. This arrangement keeps the bearing adequately lubricated and protects it from damage. Typically, the status of the oil level in the reservoir is used as a start permissive interlock in the equipment starting logic.

11.4.9.2.12

The flooded lubrication system of the motor shall be separate from the seal and lube oil system of the hydrocarbon gas compressor unless a dry gas seal system is provided that prevents the following:

– seal gas from entering the lube oil system;

– lube oil from penetrating the dry gas seals.

Justification

This requirement ensures that the lubrication oil system of the driver and driven machine is separate (i.e. if the driven machine is a gas compressor, the motor as a driver cannot share the lubrication oil system with the compressor lubrication system or seal oil system). An alternative method is to provide a dry seal gas system that prevents seal gas from entering the lube oil system and prevents the lube oil from entering the dry gas seals. These are mitigation measures to prevent cross-contamination. This is because the lubrication system can get contaminated by gas and cause an explosion when circulated into the motor lubrication system. Hence, in such cases, this requirement ensures that both systems are free of cross-contamination.

11.4.9.2.13

When low-speed barring is required, the machine bearing shall be lubricated irrespective of the specified lubrication system.

Justification

Low-speed barring requirement typically arises due to the motor driven equipment or the generator driving equipment influenced by equipment inertia. Hence, when in coupled state, the motor/generators also continue to run for a prolonged time until coast-down with starved lubrication, which is detrimental for the bearings. This requirement ensures that necessary provisions are implemented to provide adequate lubrication to bearings when low speed barring is required to safeguard the bearings.

11.4.10 Lateral analysis

When specified, lateral analysis shall be carried out for test floor and final site conditions in accordance with API Standard 546:2022, 4.4.6.2.1.

Justification

Lateral vibration of a shaft rotor is caused by instability, rotor mass, unbalance or other forces acting on the rotor. Lateral analysis simulates the rotating system, calculates the critical speeds, predicts vibration amplitudes and provides data that may result in additional measures applied by the manufacturer to reduce vibration risks. The analysis is also impacted by the foundation stiffness and damping. When the foundation data is significantly different between the test floor and final site conditions, additional analysis is done. The foundation data for the factory acceptance test is the manufacturer's test floor conditions and the foundation data for the site acceptance test is the final site conditions. This requirement specifies that lateral vibration and critical speed analysis is performed as this is not specified in IEC 60034-1. This requirement also aligns with API Standard 546:2022, 4.4.6.2.1.

11.4.11 Torsional analysis

When specified, torsional analysis shall be performed in accordance with API Standard 546:2022, 4.4.6.2.2.

Justification

This requirement defines how torsional vibration and critical speed analysis is performed as this is not specified in IEC 60034-1. This requirement also aligns with API Standard 546:2022, 4.4.6.2.2.

11.4.12 Monitoring and protection devices

11.4.12.1 General

11.4.12.1.1

External connections between machine-mounted devices and respective terminal boxes shall be routed in steel conduits clamped on the machine frame.

Justification

These mounted devices are small instrumentation devices (such as sensors, probes and transducers) that have flexible and thin connecting cable leads. This requirement ensures that these devices are grouped in accordance with signal category and wired to the respective auxiliary terminal boxes located on the machine frame. Since these devices are located all over the machine surface depending on their application, the connecting cable leads need to be routed on the machine surface up to the auxiliary terminal boxes safely. The safest way to protect the cables is to route them in a steel conduit that is fixed to the machine frame. Without this requirement, the manufacturer could adopt different means of routing that can be inconsistent and sometimes less safe than desired.

11.4.12.1.2

Each wire of the mounted device shall be connected to an individual terminal in the respective terminal box.

Justification

These mounted devices are small instrumentation devices (such as sensors, probes and transducers) that have flexible and thin connecting cable leads. As required, these devices are to be grouped in accordance with signal category and need to be wired to respective auxiliary terminal boxes located on the machine housing. The grouping of the signals is based on the signal types such as digital input/output, analog input/output, volt-free contact, voltage levels and interface systems (electrical, control and instrumentation, etc.). This requirement mandates that each wire of the device needs to be terminated in the terminal box, which ensures that the terminal boxes are adequately sized and provided with the required number of terminations. This ensures that all spare signal inputs are also wired up and connected to the respective systems.

11.4.12.1.3

Three-wire Pt-100 platinum resistance temperature sensors in accordance with IEC 60751 shall be used for temperature detection.

Justification

This requirement standardizes the use of three-wire Pt-100 sensors for temperature measurement. Though two-wire can also work, three-wire is better as the addition of a third wire, connected to one side of the measuring element, helps to compensate for lead resistance. To compensate for lead wire resistance, three-wire RTDs have a third wire that provides a measurement of the resistance of the lead wire and subtracts this resistance from the value read.

11.4.12.2 Winding temperature sensors

Two winding temperature sensors per phase shall be installed to detect the highest temperatures of the stator winding.

Justification

The intent of providing the temperature sensors is to capture the value of the highest temperature attained in any part of the machine. The prospective location is underneath the conductors at the bottom portion of the slot or on the conductors in the end winding portion. The other locations could be the core pack laminations or the pressure plates but the conductors at the bottom portion of the slot or on the conductors in the end winding portion are the most commonly identified as the hottest part and preferred installed locations for temperature sensors. Thus, each phase winding has two sensors that are placed 120° apart. This provides a fairly uniform temperature measurement value during normal operation.

11.4.12.3 Bearing temperature sensors

11.4.12.3.1

Two bearing temperature sensors per bearing shall be installed.

Justification

While it is appreciated that this requirement is not currently consistent across operators, the intention is to align them on machine protection devices. Bearings are the most common type of failure in high-voltage machines (e.g. 51 % of failure as specified by one of the participating manufacturers) and an excessive temperature is typically an early warning sign of this condition. By specifying this requirement, it helps standardization. Three-wire offers increased accuracy for temperature measurement compared to the standard two-wire offering. This requirement ensures the essential minimum for temperature measurements of bearing across all ranges of machines and for all manufacturers. Two bearing temperature sensors per bearing achieve redundancy and prevent stoppage of the machine in case of failure of one of the sensors.

NOTE Where space constraints prevent the installation of two independent bearing temperature sensors on the bearing housing, an alternative solution can be proposed.

11.4.12.3.2

Where bearing insulation is provided, the integrity of bearing insulation shall remain uncompromised on the installation of the temperature sensor.

Justification

For the installation of temperature measurement, the temperature sensors are installed in a mounting hole, drilled in the bearing housing which reaches the bearing outer race surface. The sensors are fitted very close to the bearing surface to get the most accurate reading. In this effort, this requirement ensures that the manufacturer exercises caution not to breach the integrity of the bearing insulation which is generally placed over the outer race of the bearing which is then the closest to the temperature sensor tip. The mounting provision is located such that under no circumstances, the installation of the sensor interferes with the bearing insulation but still measures the most accurate temperature present on the bearing surface.

11.4.12.4 Heat exchangers

11.4.12.4.1 Air-cooled heat exchangers

For air-cooled heat exchangers, a three-wire Pt-100 temperature sensor shall be provided to measure the temperature of the cooling air leaving the heat exchanger.

Justification

A temperature monitoring facility alerts the user when the performance of the heat exchanger is outside its normal operating values. By identifying deficiencies in a timely manner, prolonged equipment outages can be prevented and extreme motor damage can be prevented or minimized.

11.4.12.4.2 Water-cooled heat exchangers

11.4.12.4.2.1

For water-cooled heat exchangers, three-wire Pt-100 temperature sensors shall be provided to monitor the inlet and outlet air temperatures.

Justification

A temperature monitoring facility alerts the user when the performance of the heat exchanger is outside its normal operating values. By identifying deficiencies in a timely manner, prolonged equipment outages can be prevented and extreme motor damage can be prevented or minimized.

11.4.12.4.2.2

Water-cooled heat exchangers shall be provided with leakage detection.

Justification

A leakage detection facility can ultimately save time and cost by identifying deficiencies in a timely manner and can ultimately prevent prolonged equipment outage.

11.4.12.5 Partial discharge monitoring

11.4.12.5.1

Where stator winding partial discharge sensors are provided, the low voltage lead wires shall be connected to the terminals in a dedicated terminal box mounted on the machine frame.

Justification

This requirement ensures that personnel does not access the main high-voltage terminal box and be exposed to high-voltages to get access to the partial discharge sensor lead wire terminals. This is a safety consideration that is normal practice in the oil and gas industry.

11.4.12.5.2

Where stator winding partial discharge sensors are provided, the line conductor terminal box shall be sized to adhere to the installation requirements of the supplier of the sensors.

Justification

This requirement ensures that the size of the line conductor terminal box is adequate to accommodate the partial discharge sensing device as per the spacing and orientation recommendations of the supplier of the sensors. This requirement ensures that the sensor information is obtained before sizing the terminal box, which is not normal practice in general and later causes non-compliance with installation recommendations of the supplier of the sensors.

11.4.12.5.3

Where stator winding partial discharge sensors are provided for machines used in a hazardous area, the sensors shall have an independent hazardous area certification.

Justification

Generally, partial discharge measurement uses coupling capacitors or wide-band current transformers to acquire the partial discharge signals from the machine windings. These are normally used for safe area applications. Where partial discharge monitoring is required for machines installed in hazardous areas, these sensors are special, using Rogowski coils, and certified for use in both safe and hazardous areas. This requirement ensures that sensors are certified independently so that the entire installation is compliant with the area classification requirement.

11.4.13 Excitation system

11.4.13.1 General

The excitation system of the synchronous machine shall be of brushless type.

Justification

Excitation means the production of flux by passing current in the field winding. The arrangement or system used for the excitation of the synchronous machine is known as an excitation system. Direct current is used to excite the field winding of the rotor of the synchronous machine. Synchronous machines used to have AC exciters mounted on the shaft with the output of the AC exciter rectified and supplied through the brushes via the slip rings to the rotor winding of the synchronous machine. For larger synchronous machines, the excitation requirement, which is quite high, requires a conveying large amount of power through the slip ring contacts, which becomes impractical. Typically nowadays, synchronous machines use brushless excitation systems. A brushless exciter is a direct-coupled AC generator with the field circuit on the stator and the armature circuit on the rotor. The three-phase output of the AC exciter generator is rectified by solid-state rectifiers. The rectified output is connected directly to the field winding, thus eliminating the use of brushes and slip rings. The brushless excitation system requires less maintenance due to the absence of brushes and slip rings, and also reduces the power loss.

11.4.13.2 Components

11.4.13.2.1

The exciter shall be protected against over voltage.

Justification

Over voltage is detrimental for the exciter. However, devices used in the rotating rectifier assembly for rectification of the AC exciter supply to the field supply for the main exciter are more prone to failure due to over voltages. These devices have a defined rating (forward voltage, peak inverse voltage and current rating). The selected device has a current carrying capability along with a voltage withstand capability and an operating safety margin in accordance with the designed exciter and main field winding operating levels. Components such as voltage dependent resistors (VDRs) and metal oxide varistors (MOVs) are included to protect the devices. A diode failure detection circuit is included to alert the user about the failure. This requirement ensures that the probable or prospective cause for overvoltage failures is addressed.

11.4.13.2.2

The excitation system shall monitor and indicate failure of the rotating rectifier.

Justification

The devices used in the rotating rectifier assembly for rectification of the AC exciter supply to the field supply for main exciter have a defined rating (forward voltage, peak inverse voltage and current rating). The selected device has a current carrying capability along with a voltage withstand capability and an operating safety margin in accordance with the designed exciter and main field winding operating levels. Components such as VDRs and MOVs are included to protect the devices. A diode failure detection circuit is included to alert the user about the failure of diode, both for open circuit and short circuit conditions.

11.4.13.3 Controls

The excitation system controller shall be microprocessor based, with digital communication features and interface ports compatible with the specified protocol of the higher-level automation system.

Justification

Microprocessor-based devices are selected for their ability to offer better controls, flexibility in configuration, easier diagnostics and troubleshooting, and advanced monitoring and power metering functions. These functions are typically required in controllers to ensure the reliable operation of synchronous machines.

11.4.14 Anti-condensation heaters

11.4.14.1

Anti-condensation heaters provided around stator windings or within power terminal boxes shall keep the inside temperature 5 K above the ambient air temperature while the machine is not in operation.

Justification

This requirement measures the performance of the anti-condensation heaters. Without a value for temperature rise, there is no assurance that the heater is adequately specified to perform its duty.

11.4.14.2

Anti-condensation heaters shall be wired to terminals in a separate terminal box mounted on the machine frame.

Justification

A separate terminal box ensures that low-voltage and high-voltage terminations are in separate enclosures. It also ensures that personnel are not exposed to low-voltage live terminals when performing work on the main terminal box.

11.4.14.3

A warning label stating "External voltage source" shall be affixed on the cover of the anti-condensation heater terminal box.

Justification

The warning label warns personnel to isolate the low-voltage supply that is from a different source and/or different location from the main power source to the machine.

11.4.15 Additional requirements for converter duty motors

11.4.15.1

Converter duty motors shall be in accordance with IEC TS 60034-25.

Justification

The scope of this specification includes machines used in power drive systems. This requirement details additional considerations and requirements necessary to operate this arrangement. These additional requirements include temperature monitoring, bearing insulation, certification and testing.

11.4.15.2

The stated continuous motor output ratings for converter duty motors shall be in accordance with IEC 61800-2:2021, 5.3.3.

Justification

The continuous output rating as defined in IEC 61800-2:2021, 5.3.3 is defined in terms of motor shaft parameters as follows:

- *rated torque (M_N) [N·m];*
- *rated speed (N_N) [r/min];*
- *maximum rated speed (N_{NMax}) [r/min];*
- *minimum rated speed (N_{NMin}) [r/min];*
- *minimum speed (N_{Min}) [r/min];*
- *maximum rated safe speed (N_{SNMax}) [r/min]*
- *rated output power (P_{sN}) [kW].*

11.4.15.3

When specified, torsional analysis of converter duty motors shall be in accordance with IEC 61800-2:2021, 5.13.2 and API Standard 546:2022, 4.4.6.2.2.

Justification

This requirement defines how torsional vibration and critical speed analysis is performed as this is not specified in IEC 60034-1. This requirement also aligns with API Standard 546, 4.4.6.2.2 and, for the converter duty motor, it aligns with IEC 61800-2:2021, 5.13.2.

11.4.16 Machines intended for use in hazardous area

11.4.16.1 Certification

11.4.16.1.1

Machines and their mounted components shall be certified for the specified protection type in accordance with IEC 60079.

Justification

IEC 60079 specifies the general requirements for construction, testing and marking of Ex Equipment and Ex Components for the specified protection type and hazardous area. IEC 60079 provides guidelines for equipment grouping and equipment protection levels based on the gas group and temperature classification.

11.4.16.1.2

Machines for use in a hazardous area shall be provided with a certificate issued by a notified body or a certification body.

Justification

This requirement ensures that where it may be possible in accordance with IEC 60079 to self-certify the equipment, the certification is issued by a notified or certifying body as per oil and gas industry requirements and standard practice.

NOTE A manufacturer's declaration of conformity alone does not satisfy the requirement of 11.4.16.1.2.

11.4.16.2 Converter duty motors

For converter duty motors, the hazardous area certification shall cover the combined converter and motor over the speed/load operating range.

Justification

The combined testing of the converter and the motor is also known as a string test or combined test. The main intent is to understand the performance of the motor while in operation with the converter including the temperature rise of the motor, noise, etc. The converter supply is non-sinusoidal and causes an increased temperature rise in motor windings due to the harmonic content in the waveform, and it also causes increased noise. The hazardous area certification of the combined converter and motor ensures that the desired performance (surface temperature rise within limit, noise within limits, etc.) is achieved. However, this requirement does not mandate the use of project-specific drive to be used for the testing. The purchaser and the supplier typically align on project-specific testing procedures and testing logistics/arrangements.

11.4.16.3 Flameproof (type Ex db)

Machines with protection level Ex db shall have terminal boxes with protection level Ex eb.

Justification

This requirement aligns with the manufacturer's standard offering and minimal requirement philosophy. This addresses the ambiguity of Ex db machine terminal box classification which without this could be construed as Ex db in its entirety. Ex eb terminal boxes have the advantage to still comply with Zone 1 requirements, and provide a very cost-effective solution that facilitates easy maintenance, and allows cables with lugs to be easily handled and cable terminals to be easily accessed. A terminal box one size larger is possible with easy access and plenty of space to route and handle cables.

11.4.16.4 Pressurized (type Ex pxb and Ex pzc)

The pressurization unit shall provide the following status information:

- purge cycle in progress;
- purge cycle complete;
- pressurized;

– pressure low / pressure fail.

Justification

This requirement ensures that the essential minimum status information for the control system is provided irrespective of the make and model of the pressurization unit.

11.4.17 Additional requirements for synchronous generators

11.4.17.1 General

11.4.17.1.1

Three-phase synchronous generators with rated outputs of 10 MVA and above driven by steam turbines or combustion gas turbines and three-phase synchronous Mvar compensators with a rated output of 10 MVA and above shall be in accordance with IEC 60034-3.

Justification

IEC 60034-3 is a standard specific to large three-phase synchronous generators with rated outputs of 10 MVA and above driven by steam turbines or combustion gas turbines. IEC 60034-3 also supplements the basic requirements for rotating machines given in IEC 60034-1.

11.4.17.1.2

The overcurrent capability of the generator shall be in accordance with IEC 60034-3.

Justification

An overload on the generator is an abnormality which could be momentary or last for certain time. The cause of an overload can be starting large motors on the generator supply, fault in the electrical system or mechanical defects (stall, jam, etc.). Such abnormalities can cause overloading/overcurrent on the generator and the magnitude and duration can vary for every cause and occurrence. The capability of the generator in terms of its overload/overcurrent performance is the same as defined in IEC 60034-3 for generators above 10 MVA.

11.4.17.2 Excitation system

The field forcing capability of the excitation system shall allow the generator to provide a short-circuit current equivalent to three times the rated current for at least 10 s.

Justification

Generators generally produce fault current that is lower than the full load amperes of the machine as per the decrement curve. The excitation system gets the feedback of the generator terminal voltage to adjust the excitation voltage. During a fault, the generator terminal voltage falls and reduces the excitation voltage. Field forcing is a function in the automatic voltage regulator (AVR) that intentionally raises the excitation voltage of the machine during a fault and hence increases the fault current by 300 %. This is designed with the aim of operating the overcurrent protective devices. Without field forcing, the fault current just looks like load and a fault would persist indefinitely. The duration of 10 s in the requirement is aligned with API Standard 546:2022, 4.5.1.7.

11.4.17.3 Automatic voltage regulator (AVR)

11.4.17.3.1

The automatic voltage regulator (AVR) shall have manual and automatic control modes.

Justification

The generator terminal voltage, power factor and reactive power (VAr) flow are related to the excitation. Different control loops can be created in the control system by using power factor sensing or VAr sensing to control the power factor or VAr "flow" of the generator by varying excitation. The operator provides a power factor setpoint or a VAr setpoint, and the excitation control system adjusts the excitation voltage/current as required to maintain the desired power factor or VAr "flow". When this correction/adjustment of the excitation voltage/current is desired automatically to meet the set point value without any human intervention, an "auto" mode is selected and when the excitation voltage/current control is taken over by continuously adjusting the parameters manually, the selection mode is in "manual" mode.

11.4.17.3.2

The AVR shall have a set point adjustment range of ±10 % of the nominal generator output voltage at the rated load.

Justification

The generator terminal voltage, power factor and reactive power (VAr) flow are related to the excitation. Different control loops can be created in the control system by using power factor sensing or VAr sensing to control the power factor or VAr "flow" of the generator by varying excitation. The operator provides a power factor set point or a VAr set point, and the excitation control system adjusts the excitation voltage/current as required to maintain the desired power factor or VAr "flow". The set point is not a single value, it is a range for selecting the desired set point. This requirement could arise in various scenarios such as adjusting the terminal voltage due to increased loading of the generator, need for parallel operation with other generators, etc. Hence, the desired adjustable range as per the industry practice is ±10 % of the nominal generator output voltage rating at full load.

11.4.17.3.3

The AVR shall keep a steady state voltage regulation within ±0,5 % of the nominal generator output voltage from no load to rated load at power factors varying from 0,5 lag to unity.

Justification

This requirement specifies the capability of the AVR to maintain the generator terminal voltage within ±0,5 % when the load varies from no load to full load and the load power factor varies from 0,5 lag to unity. The accuracy class of the feedback elements and control system design all contribute to achieving the desired precision in the control of generator output voltage. The defined performance ensures steady parallel operation among generators.

11.4.17.3.4

The AVR shall have over-excitation protection.

Justification

This requirement specifies the need for protection to prevent an unwarranted over-excitation situation following an event of a loss of voltage reference signal. Without this requirement, the control system would misinterpret the loss of voltage reference and initiate an increase in the excitation, resulting in an unwarranted over-excitation state. With this requirement, the voltage sensing protection blocks the corrective action of adjusting the excitation in the event of loss of the voltage reference signal.

11.4.17.3.5

The AVR shall automatically switch to manual excitation without change in set-point upon failure of the AVR.

Justification

This requirement specifies the need for protection to prevent an unwarranted over-excitation or under-excitation situation following an event of failure of AVR controls in automatic mode. Without this requirement, the control system in a failure scenario would behave erratically and initiate either an increase or decrease in the excitation, resulting in an unwarranted over-excitation or under-excitation state. The feature of switching to manual mode is the best choice of corrective action that can happen in the event of failure of AVR in automatic mode. This action is also associated with audio and visual alarm to alert the operator to take over the control and monitoring/adjusting the parameters as required.

11.4.17.3.6

The power factor controller function in the AVR shall keep the power factor regulation within ±2,5 % of the set value of the power factor.

Justification

This requirement specifies the capability of the power factor controller function in the AVR to maintain the generator output power factor within ±2,5 % of the setpoint value. The accuracy class of the feedback elements and control system design all contribute to achieving the desired precision in the control of generator output power factor. The defined performance ensures steady parallel operation and load sharing among generators.

11.4.17.3.7

The AVR shall be insensitive to temperature changes and vibration.

Justification

This requirement ensures stable operation for the expected variation of power system environment and protection from potential over-voltages. For ambient temperatures between 0 and 50 deg C, the AVR current drift shall not exceed ±0,5 % of its setpoint.

11.4.17.4 Generator control and monitoring

11.4.17.4.1

The control panel shall have a double voltmeter, a double frequency meter synchroscope with rotating LED-type lamps, a timer, an auto-synchronizer and a synchro-check relay for synchronization in manual and automatic modes.

Justification

This requirement is a means of achieving synchronization between generators or with the utility grid either in automatic or manual mode. The generator control panel is provided with a synchro-check relay to ensure that the paralleling operation is safely accomplished within the tolerance band as verified by the synchro-check relay.

11.4.17.4.2

The control panel shall be equipped with local human-machine interface (HMI) for display of the single line diagram with operating status, operating parameter values, alarms, events and fault diagnostics.

Justification

The display of operating status, operating parameter values, alarms, events and fault diagnostics on the screen is an essential requirement for monitoring and troubleshooting of the generator control system. Though this information can be accessed from a laptop or a desktop computer, it is essential that the control panel has a screen to display the information for personnel in front of the panel.

11.4.17.4.3

The control panel shall have a microprocessor-based generator control and protection relay with a remote communication facility for transmission of alarms and data over the specified protocol.

Justification

Hardware on the control panel provides a communication functionality for remote connectivity so that the data of the generator control system can be transferred to any remotely located system and can also receive emergency commands from the automation system. The communication protocol and interface media are project specific and specified through the PDS elements.

11.4.17.4.4

The generator control panel shall include the following commands for operation/selection:

a) open generator circuit breaker;

b) close generator circuit breaker;

c) start synchronization;

d) speed control – raise/lower;

e) excitation voltage control – raise/lower;

f) push button for lamp test;

g) local/remote selector switch;

h) auto/manual synchronization switch;

i) isoch/droop selector switch;

j) AVR control mode.

Justification

This requirement ensures that the generator control panel provides a provision for initiating commands such as circuit breaker open/close, speed raise/lower, excitation raise/lower and a selection of mode of operation such as auto/manual and local/remote. These commands can be performed either by dedicated buttons or via HMI, which is very helpful during commissioning, standalone trials and manual operation. HMI is typically touch panel or operator panel with keypad, which provides alphanumeric text and/or graphical interfaces. The list of commands enable to control the frequency, the active power, the voltage mode selection and the reactive power loading in local control.

11.4.17.4.5

The following operating parameters shall as a minimum be visible from the generator control panel front:

a) generator current in each phase (L1, L2, L3);

b) generator phase voltage for each phase (L1-N, L2-N, L3-N);

c) generator line-line voltage (L1-L2, L2-L3, L3-L1);

d) generator frequency;

e) excitation current;

f) generator active power;

g) generator reactive power;

h) accumulated energy produced by the generator;

i) accumulated running hours for the generator.

Justification

This requirement specifies operator information needed for local generator control and maintenance.

11.4.18 Constructional requirements for control panel

11.4.18.1

The control panel for the machine excitation system, generator controls, and metering and protection system shall be floor mounted, free-standing and self-supporting steel cabinet enclosure.

Justification

The control panel is a critical section of the synchronous machine. This requirement ensures that the control components are located within a steel cabinet enclosure securely installed on the floor with necessary supports and fixtures. Typically, floor mounting arrangements are considered to be the most basic option for steel cabinet enclosures with control system for high-voltage synchronous machines.

11.4.18.2

The control panel shall have a degree of ingress protection of at least IP21 with doors closed for indoor locations and at least IP44 with doors closed for outdoor locations in accordance with IEC 60529.

Justification

The degree of ingress protection specifies the extent of protection provided by the panel against access to hazardous parts by personnel, against solid object ingress and water ingress. This requirement ensures that the specification needs are in line with common industry practice which is IP21 in accordance with TR3120 for low voltage control panels.

11.4.18.3

Live components and parts accessible with the control panel door open shall have a degree of ingress protection of at least IPXXB in accordance with IEC 60529.

Justification

The intent of this requirement is to protect personnel from hazard of electric shock. In case the panel door is opened for observation, troubleshooting, etc., this requirement ensures that any chance of accidental contact with the live exposed part of any internal components is prevented. Hence, suitable enclosure, shrouds or other protection by barriers is ensured using a degree of protection of at least IP XXB (i.e. openings greater than or equal to 12,5 mm or protected against access by finger) in accordance with IEC 60529.

11.4.18.4

The internal layout within the control panel shall permit operation and maintenance from the front only.

Justification

This requirement ensures that the layout design of the components within the panel is done with the aim to facilitate operation and ease of maintenance/repair of items from the front of the panel. This is more relevant in locations where there are space constraints and no additional space is required around the panel for operation, maintenance and repairs. Though access from the sides for the control panel is non-standard, this requirement specifies upfront the purchaser's objective to ensure the desired panel layout design.

11.4.18.5

The control panel doors shall be hinged with an opening of at least 110°.

Justification

This requirement ensures that there is unobstructed accessibility to the front of the control panel for service and maintenance in accordance with 11.4.18.4.

11.4.18.6

The control panel shall be equipped with a door stay to secure the hinged doors in the open position.

Justification

This requirement ensures that there is unobstructed accessibility to the front of the control panel for service and maintenance by keeping the hinged door wide open. This requirement also ensures that the locking arrangement of the door in the open position does not impede maintenance personnel while working. Though this requirement is currently implemented in panels installed on floating units, it is now increasingly requested in panels for onshore installations.

Justification Figure e

11.4.18.7

Insulation material of internal wires and cable trunking in the control panel shall be zero halogen and flame retardant, and have a low smoke index.

Justification

Zero halogen is a material classification widely used for wire insulation or cable sheath in the industry. Low smoke zero halogen (LSZH) is composed of thermoplastic compounds that emit less smoke and no halogen when exposed to a high heat source or fire. LSZH is specified to minimize the aftermath of a fire. The flame-retardant property prevents or inhibits an outbreak of fire and this has been specified to support industry fire prevention measures. This requirement minimizes impact during a fire, for equipment integrity, HSE and working environment, and is in accordance with IEC 60332 and IEC 60754.

11.4.18.8

The mounting height of push buttons, displays, and protection and metering devices on the control panel shall be less than 1 800 mm from the floor level.

Justification

Considering the ergonomics aspect from the perspective of an operating person with average height, this requirement ensures that operating components like push buttons, switches and display/monitoring devices such as HMI, protective relays with display readouts are not mounted above 1 800 mm from the floor level in the control panel. The recommended height is considered a comfortable height for the operator to reach out and also the preferred reading distance for a person of average height.

11.4.18.9

Wiring ends on terminals shall be labelled with alphanumeric character wire markers in accordance with the wiring diagram.

Justification

The labelling of wiring ends helps to identify the path between the connections, which is key for any troubleshooting. The identification of wiring connections is an important step in ensuring that the mean time to repair (MTTR) is minimized. To establish co-relation with the wiring diagram, the wiring ends are labelled with alphanumeric character wire markers in accordance with the wiring diagram. Proper identification of wires, connectors, terminals, etc. helps in restoring the wiring after a repair or replacement of components, printed circuit boards (PCBs), etc. without human error. The material of marker/identification ferrule is of insulating material since it is in close proximity to the live terminals.

11.4.18.10

Each wire for external control wiring shall be terminated on an individual terminal.

Justification

Proper planning of control terminals is important prior to wiring in a panel. Normally, it would be appropriate to assign one termination (wiring end) per end of the terminal, which helps in easy identification/labelling of the circuit and prevents loose connection. Systematic wiring in panels facilitates faster troubleshooting and ensures that the MTTR is minimized.

11.4.18.11

Terminals shall be segregated in accordance with the voltage levels and type of signals.

Justification

Segregation in accordance with the voltage level is important to ensure minimum interferences due to the induction effect. Also, analogue signals, especially analogue voltage signals, are grouped and wired separately from digital input/output signals to the respective terminal blocks. Proper segregation is achieved by the arrangement of components and associated wiring per voltage levels and type of signals involved.

11.4.18.12

The control panel shall be cooled by natural ventilation unless a component installed within the panel requires forced ventilation.

Justification

Typically, there are no major current carrying components in the panel to generate heat that is continuously kept away from the panel. Ventilation is a key design element to ensure proper cooling of devices and components in the system. Considering the amount of low heat generated, natural ventilation is the preferred cooling method to be adopted. However, the manufacturer can provide cooling fans if the specific components installed require such forced ventilation. When forced cooling is required for specific components in the panel, redundant panel cooling fans are provided to ensure the reliability of operation.

11.4.18.13

When dust filters are provided on louvers, filters shall be replaceable with ease during operation without power disconnection.

Justification

As a standardization for offshore and onshore, this requirement ensures avoiding the need to stop the machine to perform maintenance. This requirement is an extract from IEC 61892-3: 2019, 4.12 applicable for generator control panel supplier.

11.4.18.14

If the control panel is provided with a cooling fan, a dust filter shall be provided.

Justification

This requirement prevents suction of dust into sensitive equipment.

11.4.18.15

A main protective earth (PE) shall be provided with an extension on two sides of the control panel for external connections.

Justification

This protective earth (PE) conductor is used for terminating the earth wires from the components within the panel. The PE conductor runs across the entire panel and is linked or connected using jumper cables. The earth connection from system earth is connected at both ends of the panel to ensure that at least one earth loop remains healthy and connected when the other loop gets loose or disconnected. This provides improved safety and ensures that the least resistive path is available for earth fault current.

11.4.18.16

Metal parts of the control panel shall have electrical continuity and connection to the main protective earth.

Justification

The electrical continuity of metal parts of the panel provides the least resistive path to earth for any leakage current or fault current and protects personnel from shock hazard.

11.4.18.17

Proprietary components or hardware installed in the control panel for machine control systems shall be declared upfront.

Justification

This requirement ensures that the manufacturer informs the purchaser of any proprietary components or hardware considered in the scope of supply. Instances of components/hardware declared obsolete and closed down production by the supplier or are made to order have caused the equipment to be out of service for prolonged periods. The installation of alternative components/hardware has resulted in costly remedial work and is well documented within operator networks.

11.4.18.18

Components inside the control panel and door mounted components shall be labelled in accordance with the identifications given in the wiring diagrams.

Justification

This requirement enables safe maintenance by ensuring components are properly labelled and identified.

12 Tolerances

12.1 General

In NOTE 2, replace "IEC Guide 115:2021" with

IEC Guide 115:2023

Justification

Edition 3.0 (2023) supersedes Edition 2.0 (2021).

12.2 Tolerances on values of quantities

Table 22 – Schedule of tolerances on values of quantities

Add new NOTE 2

NOTE 2 For synchronous motors driven by variable frequency drive, locked rotor current and locked rotor torque tests are not required.

Justification

The variable speed drive provides a reduced voltage and frequency when starting the motor and limits the starting current. Any increase in the starting current or increased torque due to the locked rotor condition is monitored and protected by the variable frequency drive. Hence, the occurrence of a locked rotor condition is prevented before it can cause any damage to the motor. Hence, the withstand test is not required if it is already identified to be driven at all times by a variable frequency drive.

13 Electromagnetic compatibility (EMC)

13.1 General

Replace first paragraph with

The EMC requirements specified in Clause 13 shall apply to all electrical machines included in the scope of this specification.

Justification

The original paragraph restricts the applicability of Clause 13 to high-voltage machines (i.e. rotating electrical machines with rated voltages exceeding AC 1 000 V intended for operation and use in industrial environments). The replacement of this paragraph ensures the expansion of the applicability of these EMC requirements to all electrical machines covered by this specification.

13.2 Immunity

13.2.2 Machines incorporating electronic circuits

Add to subclause

Peripheral control and excitation equipment of synchronous machines (e.g. AVR, exciter, control panels) designed to be installed and operated in an industrial environment shall comply with immunity requirements in accordance with IEC 61000-6-2.

Justification

IEC 60034-1 restricts the application of this requirement to rotating electrical machines with rated voltages not exceeding 1 000 V AC or 1 500 V DC and is non-committal for high-voltage motors. This new paragraph covers high-voltage synchronous machines installed in an industrial environment for EMC compliance.

13.3 Emission

Add to subclause

Peripheral control and excitation equipment of synchronous machines (e.g. AVR, exciter, control panels) designed to be installed and operated in an industrial environment shall comply with emission requirements in accordance with IEC 61000-6-4.

Justification

IEC 60034-1 restricts the application of Clause 13 to rotating electrical machines with rated voltages not exceeding 1 000 V AC or 1 500 V DC and is non-committal with respect to high-voltage motors. This new paragraph covers high-voltage synchronous machines installed in an industrial environment for EMC compliance.

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Add to start of Bibliography

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