

Medium Voltage Equipment Used on Subsea Production Systems

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Medium Voltage Equipment Used on Subsea Production Systems

1 Scope

This Recommended Practice (RP) is applicable to the design, fabrication, testing, installation, and operation of Subsea Power Systems. The scope includes single phase and three phase systems from 3 kVac to 69 kVac (refer to 3.1.4). It covers subsea installed electrical power equipment and the connections between the equipment.

This RP does not include DC power systems, though they may be included in future revisions.

For any conflicting requirements between this standard and specific component standards listed in [Section 2](#) of this specification with regards to analysis, design test and qualification, the requirements of the specific component standard shall apply.

2 Normative References

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any addenda) applies."

API Specification 17E, *Specification for Subsea Umbilicals*

API Standard 17F, *Standard for Subsea Production and Processing Systems*

API Recommended Practice 17H, *Remotely Operated Tools and Interfaces on Subsea Production Systems*

API Recommended Practice 17N, *Recommended Practice on Subsea Production System Reliability, Technical Risk, and Integrity Management*

API Recommended Practice 17P, *Recommended Practice for Subsea Structures and Manifolds*

API Recommended Practice 17V, *Recommended Practice for Analysis, Design, Installation, and Testing of Safety Systems for Subsea Applications*

API Recommended Practice 17X, *Recommended Practice for Subsea Pump Module Systems*

IEC 60038, *Standard Voltages*

IEC/IEEE 61886.1, *Subsea equipment - Part 1: Power connectors, penetrators and jumper assemblies with rated voltage from 3 kV ($U_{max} = 3,6 \text{ kV}$) to 30 kV ($U_{max} = 36 \text{ kV}$)*

IEC/IEEE 61886.2, *Subsea Equipment – Part 2: Power Transformers*

IEEE 3002.2 – 2018, *Recommended Practice for Conducting Load-Flow Studies and Analysis of Industrial and Commercial Power Systems*

IEEE 3002.3 – 2018, *Recommended Practice for Conducting Short-Circuit Studies and Analysis of Industrial and Commercial Power Systems*

IEEE 3002.7 – 2018, *Recommended Practice for Conducting Motor-Starting Studies and Analysis of Industrial and Commercial Power Systems*

IEEE 3002.8 – 2018, *Recommended Practice for Conducting Harmonic Studies and Analysis of Industrial and Commercial Power Systems*

IMCA D 045, *Code of Practice for the Safe Use of Electricity Underwater*

IMCA D 079, *Subsea Power Cables*

UN Manual of Tests and Criteria, Sixth Revised Edition

3 Terms, Definitions, Acronyms, and Abbreviations

3.1 Terms and Definitions

For the purposes of this document, the following terms and definitions apply.

3.1.1

extended factory acceptance test

EFAT

Test conducted to verify that the specified requirements, for a set of interfacing products, have been fulfilled.

3.1.2

Energy efficiency

Relates the output of an activity to its energy input, for a given service. The efficiency of a system in electronics and electrical engineering is defined as useful power output divided by the total electrical power consumed (a fractional expression), typically denoted by the Greek small letter eta (η).

3.1.3

lifecycle

That of a subsea development that includes design, manufacture through commissioning, operations, intervention, and decommissioning.

3.1.4

Medium Voltage

For the purposes of this document, Medium Voltage is defined as follows:

IEEE 3 kVac to 69 kVac

IEC 1.8 / 3 (3.6) kVac to 38 / 69 (72.5) kVac

3.1.5

Pre-deployment test

Test conducted to verify that the specified requirements, for a product that is ready for deployment, are still fulfilled.

3.1.6

validation testing

Confirmation that the operational requirements for a specific use or application have been fulfilled, through the provision of objective evidence.

3.1.7

verification testing

Confirmation that specified design requirements have been fulfilled, through the provision of objective evidence.

3.2 Acronyms and Abbreviations

AC	alternating current
AUV	autonomous Underwater Vehicle
CT	current transducer

DC	direct current
EFAT	extended factory acceptance test
EMC	electromagnetic compatibility
FAT	factory acceptance test
FMECA	failure mode, effects, and criticality analysis
IR	insulation resistance
MGR	main ground reference
MV	medium voltage
OEM	original equipment manufacturer
OPEX	operational expenditure
QRA	quantitative risk assessment
RAM	reliability, availability, and maintainability
ROT	remotely operated tool
ROV	remotely operated vehicle
RP	recommended practice
SIT	system integration test
SSU	subsea switchgear unit
SUTA	subsea umbilical termination assembly
TBD	to be determined
TCC	time-current characteristics
THD	total harmonic distortion
VSD	variable speed drive
VT	voltage transducer

4 System Requirements

4.1 General

During system design, the following functionality should be considered:

- flexibility with respect to electrical load situations (power and communication);
- electrical system robustness;
- seawater ingress and material compatibility;
- subsea intervention;
- human factors;
- lifecycle attributes, such as reliability, maintainability, manufacturability, usability, obsolescence management, and cyber-security risk assessment;
- ease of deployment;
- safety and emergency shutdown.

4.1.1 Flexibility with Respect to Electrical Load Situations (Power and Communication)

The system should be built to accommodate a large variation in electrical loads to allow for flexibility regarding future expansion.

The communication system should be built to function on both primary and backup communications (where applicable), within a large range of communications load variations. The communications systems should be robust with respect to failure modes.

4.1.2 Monitoring of Water Content in Dielectric Oil

Oil-filled and pressure-compensated units (e.g. subsea transformers, switchgear, and VSDs) should include instrumentation to monitor water ingress (or moisture content). If fitted, the instrumentation shall indicate the water content over time to provide advanced warning about degradation of the dielectric fluid properties

4.1.3 Subsea Intervention

Intervention systems may be operated by divers, ROV, ROT, AUV or other subsea vehicle. The design of subsea interfaces shall be in accordance with API Recommended Practice 17H.

Retrievable components should fulfill the following principles:

- Disconnection of lifting devices used during installation should be executed according to the intervention strategy. A backup system to release lifting devices may be provided.
- Minimize the amount of time the installation vessel is tethered to the equipment via lifting rigging after successful installation
- Have position indicators on all subsea actuated connections
- Be installable within a defined practical weather window that is consistent with the specific type of installation equipment and vessel being used
- require a minimum number of special installation tools
- facilitate fully reversible sequential installation techniques/operations

It is recommended that retrievable medium voltage components be designed to provide the following functionality to facilitate efficient intervention:

- suitable viewing positions for observations during running, connection and operation of tools, modules, and equipment
- suitable landing area, attachment points, or a combination thereof, where it is necessary to carry out manipulative tasks
- protection for sensitive components/items on the subsea structure that can be damaged by the intervention system
- bucket(s) designed for easy replacement of acoustic transponder(s) (acoustic shielding and potential snagging should be avoided).
- easy operation of all mechanisms in accordance with the defined intervention strategy.
- any special equipment or arrangements installed on the subsea structure that requires the application of torque during an operation designed to use a API Recommended Practice 17H torque tool interface.

- anodes and other construction details located such that they do not represent any obstruction or snagging point for the selected intervention system.
- tools, modules, and retrievable equipment having adequate running clearance to any part of the structure, adjacent module, or equipment.
- for guideline less operations, provision of positive restrictions, such as guide funnels or bumper beams, to avoid impact between adjacent equipment.

4.1.4 Lifecycle Attributes such as Reliability, Maintainability, Manufacturability, and Usability

Reliability, maintainability, manufacturability, and usability are the factors that affect run-time behavior, system design, and user experience. They represent areas of concern that have the potential for applicationwide impact across layers and tiers. Lifecycle attributes should be defined by the end user.

For information on subsea reliability, refer to API Recommended Practice 17N.

4.1.5 Obsolescence Management

For information on obsolescence management, refer to API Standard 17F.

4.1.6 Cybersecurity Risk Assessment

A risk assessment should be performed in accordance with IEC 62443 Industrial Automation and Control Systems Security to assess the system's level of cybersecurity risk and preparedness.

4.1.7 Safety and Emergency Shutdown

Systems shall be designed for safe operation and be able to shut down production in a safe and efficient manner that complies with API Recommended Practice 17V and all regulatory and specified requirements.

4.2 Analysis Requirements

4.2.1 General

The design and operation of MV subsea power systems require several studies to assist in the evaluation of the initial and future system performance, system reliability, safety, and potential future expandability.

The power delivery system operation under fault conditions shall be defined, and this shall be the basis for the requirements for fault detection and protections systems to be used.

Maximum and minimum electrical fault levels shall be calculated throughout the network with the aim to design fault detection and protection systems.

Voltage levels throughout the distribution system shall be calculated in all foreseen operating conditions (e.g. maximum and minimum load), with consideration for equipment design tolerances and tolerances on the power supply parameters of the host facility.

The following studies shall be completed for MV systems:

a) Load Flow

- These studies determine the voltage, current, active, and reactive power, and power factor in a power system.

b) Cable Ampacity

- These studies calculate the current carrying capacity (ampacity) of power cable in topside and subsea installations.
- c) Short-circuit
 - These studies determine the magnitude of the potential currents flowing in a power system at various times after a fault occurs
- d) Protective Device Coordination
 - These studies determine or verify the clearing characteristics such as fuses, circuit breakers and relays used in the protective scheme. They are also needed to determine the protective device settings that will provide selective fault isolation.
- e) Stability
 - These studies determine or measure the ability of a power system, containing two or more synchronous machines, to continue to operate after a change occurs. Stability should be determined for both steady-state and transient conditions.
- f) Motor-starting
 - These studies determine speed, slip, electrical output torque, load current and terminal voltage at discrete time intervals from locked rotor to full speed
- g) Harmonic Analysis
 - This study is used to predict distortion levels caused by the addition of a new harmonic load. A harmonic study shall be performed to assess the harmonic content (THD and single harmonics) throughout the power delivery network, with the aim to investigate the presence of disturbances or resonance phenomena.
- h) Transformer Analysis
 - These analyses determine design parameters associated with subsea transformers such as premagnetization, taps, and boost factor. For details of the required analyses refer to IEC/IEEE 61886-2.
- i) Reliability
 - These studies are used to determine system reliability and availability and select an acceptable system design for subsea application. A FMECA of the overall system shall be performed. When specified by the end user, FMECA shall also be performed on components within the system. The output of the FMECA shall demonstrate that the fault mechanisms are understood, and the detection and protection mechanisms are suited to the requirements.
- j) Grounding
 - Ground fault studies provide insight into required equipment ratings (e.g. transient over voltages and short circuit currents levels), protection settings (e.g. fault clearing duration) and ensure safe passage of fault currents.
 - Requirements for grounding with personnel in the water needs very detailed consideration and is out of the scope of this document; refer to IMCA D 045 and IMCA D 079 for more information.
- k) Switching Transients
 - A transient system analysis shall be performed to assess the following conditions as a minimum:

- transients during energization of system;
- transients during de-energization of system;
- transients during dynamic events (such as load switching), including all potential inrush phenomena;
- transients during fault condition;
- transient conditions following fault elimination.

Single Line Diagrams with specific rating information shall be generated for each project, similar to IEEE 3002.2, Figures 1 through 9. Figures with output data for each component shall also be generated similar to IEEE 3002.2, Figures 16, 17, and 18.

[Figures 1](#) through [4](#) indicate the typical subsea power systems that are currently deployed. System components shall be as needed to complete the system design requirements.