DRAFT STANDARD

Maritime utility connections - High voltage offshore connection (HVOC) systems

Norsk Elektroteknisk Komite
Mustads vei 1
0283 Oslo

Telephone:
Fax:
Email:
Website: www.nek.no

NEK

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National Foreword

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NEK NSPEK 413 has been prepared by committee NK 18: Elektriske installasjoner om bord i skip og flyttbare og faste innretninger i petroleumsvirksomheten, which mirrors IEC technical committee TC 18: Electrical installations of ships and of mobile and fixed offshore units. It is a Norwegian specification (NSPEK).

This document has been prepared to express the consensus of a defined group, which, in accordance with NEK RET1:2025, can be a committee, a forum, or a working group appointed by NEK.

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Introduction

The intention of this specification is to define requirements that support, with the application of suitable operating practices, efficiency and safety of connections by compliant ships to compliant high voltage *(3.13)* offshore power and charging installations through a compatible grid-to-ship connection. This specification provides guidance on offshore power and charging solutions for hybrid or fully electric offshore vessels, such as Service Operation Vessels (SOVs) and Commissioning Service Operation Vessels (CSOVs).

With the support of sufficient planning, cooperation between ship and offshore facilities, and appropriate operating procedures and assessment, compliance with the requirements of this specification is intended to allow different ships to connect to *High Voltage Offshore Connection (HVOC)* (3.14) systems at different locations within the Norwegian continental shelf and the continental European and UK waters.

This provides the benefits of standard, straightforward connection with minimal need for adaptation and adjustment at different locations that can satisfy the requirement to connect for as long as practicable during offshore deployment.

Ships that do not apply this specification may find it unsafe or impossible to connect to compliant offshore supplies.

The need for power and charging solutions to larger vessels offshore is driven by the offshore energy sector's ambition to remove carbon emissions and reduce environmental impact from supporting vessels. By ensuring that vessels have access to a power supply with sufficient capacity for supplying electrical power to electric propulsion, auxiliary *loads* (3.15), and battery charging, the sector targets zero emission operations.

Continuous electrification of vessels in this segment need to be supported by increasing number of facilities supplying power to vessels. Increasing the number of available shore-connection installations ashore, and the prospect of power supply available offshore and in green anchorage zones close to shore, are elements that support the overall goal of emissions reduction and sustainability.

Interoperability between vessels and the various available connection points are crucial to ensure fast, robust, safe and cost-effective solutions. Additionally, interoperability between offshore solutions and shore connection solutions, built to comply with international recognized standards, is critical to avoid duplication of infrastructure on board of the vessels.

This specification is intended to address mainly the safety and effectiveness of HVOC *(3.14)* systems with a minimum level of requirements that would standardize on one solution. This specification includes the requirement to complete a detailed compatibility assessment for each combination of ship and *offshore supply facility* (3.17) prior to a given ship arriving to connect to a given supply for the first time.

Annex A includes cabling recommendations that can be used in HVOC systems.

Key principles

Here are some of the key terms that are essential for a proper understanding of the content.

term	**description**
Normative text	Text that contains requirements, recommendations, and permissions.
Informative text	Text that supports the understanding or use of the document, or provides contextual information about the content, background, or relationship to other documents.
Note	Used to provide additional information intended to make the text in the document easier to understand or use.
National note	Used to provide relevant supplementary information, e.g., about Norwegian conditions and applicable regulations. National notes are prepared by NEK.
Annex – Normative	Contains additional normative text related to one or more parts of the document.
Annex – Informative	Contains additional information to support the understanding or use of the document; may include optional provisions that are not required to claim compliance with the entire document.
Shall	A requirement that is not optional, if compliance with the document is to be claimed.
Should	A recommendation that indicates a possible choice or method considered particularly suitable, without necessarily excluding others.
May	Indicates permission, possibility, or the option to do something.
Can	Indicates possibility or capability, which, depending on context, should be understood either as an expected or conceivable outcome, or as the suitability or quality required to do or achieve something specific.
NOTE These terms are based on CENELEC Internal Regulations Part 3 (IR3), which applies in cases of doubt or ambiguity.	

Maritime utility connections - High voltage offshore connection (HVOC) systems

1 Scope

This specification include provisions for the design, installation, operation, maintenance and testing of HVOC systems for transfer of electric power to hybrid and battery electric vessels, for the purpose of supplying electrical power to the vessel's battery for charging, electric propulsion for positioning, and/or auxiliary loads.

This specification is applicable to:

— installations on board the ship and on the offshore supply facility including offshore-to-ship connection and interface equipment,

— ships requiring 1 MVA or more or ships with HVOC capability,

— alternating current (AC) power transfer,

— SOVs and CSOVs, and intended to sufficiently address other ship types,

— in principle both autonomous and manned ships, but focuses on manned ships,

— transformers/reactors,

— frequency convertors,

— ship distribution systems,

— protection, control, monitoring, interlocking and power management systems, and

— communication between equipment on offshore supply facility and ship.

The specification is not applicable for:

— *low voltage* (3.16) solutions (e.g for lighter vessels),

— direct current (DC) power transfer,

— inland navigation vessels;

— electrical power supply during docking periods, for example dry docking and other out-of-service maintenance and repair,

— shore power connection, although this may have considerations which are associated to HVOC, and

— systems to be operated by an *ordinary person* (3.18).

Additional or alternative requirements can be imposed by national administrations or the authorities within whose jurisdiction the ship is intended to operate or by the owners or authorities responsible for an offshore power supply or distribution system.

NOTE High Voltage Shore Connection systems are covered by IEC/IEEE 80005-1.

2 Normative references

The following referenced documents contain text which fully or in part is part of the requirements in the specification. For dated references, only the edition cited applies. For undated references, the latest edition of the cited document applies (including amendments).

NEK IEC 60034 (all parts), *Rotating electrical machines*

NEK IEC 60050, *International Electrotechnical Vocabulary (IEV Electropedia)*

NEK IEC 60076 (all parts), *Power transformers*

NEK IEC 60079 (all parts), *Explosive atmospheres*

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

NEK IEC 60092-201, *Electrical installations in ships – Part 201: System design – General*

NEK IEC 60092-301, *Electrical installations in ships – Part 301: Equipment – Generators and motors*

NEK IEC 60092-350, *Electrical installations in ships - Part 350: General construction and test methods of power, control and instrumentation cables for shipboard and offshore applications*

NEK IEC 60092-354, *Electrical installations in ships – Part 354: Single- and three-core power cables with extruded solid insulation for rated voltages 6 kV (Um = 7,2 kV) up to 30 kV (Um = 36 kV)*

NEK IEC 60092-360, *Electrical installations in ships - Part 360: Insulating and sheathing materials for shipboard and offshore units, power, control, instrumentation and telecommunication cables*

NEK IEC 60092-376, *Electrical installations in ships - Part 376: Cables for control and instrumentation circuits 150/250 V (300 V)*

NEK IEC 60092-503, *Electrical installations in ships – Part 503: Special features – AC supply systems with voltages in the range of above 1 kV up to and including 15 kV*

NEK IEC 60092-504, *Electrical installations in ships – Part 504: Automation, control and instrumentation*

NEK IEC 60146-1 (all parts), *Semiconductor convertors – General requirements and line commutated convertors*

NEK IEC 60204-11, *Safety of machinery – Electrical equipment of machines – Part 11: Requirements for HV equipment for voltages above 1 000 V a.c. or 1 500 V d.c. and not exceeding 36 kV*

NEK IEC 60228, *Conductors of insulated cables*

NEK IEC 60332-1-2, *Tests on electric and optical fibre cables under fire conditions – Part 1-2: Test for vertical flame propagation for a single insulated wire or cable – Procedure for 1 kW pre-mixed flame*

NEK IEC 60364-4-41, *Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric shock*

NEK IEC 60502-2, *Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um= 1,2 kV) up to 30 kV (Um= 36 kV) – Part 2: Cables for rated voltages from 6 kV (Um= 7,2 kV) up to 30 kV (Um= 36 kV)*

NEK IEC 60793-2-10, *Optical fibres - Part 2-10: Product specifications - Sectional specification for category A1 multimode fibres*

NEK IEC 60811, *Electric and optical fibre cables - Test methods for non-metallic materials - Part 602: Physical tests - Separation of oil in filling compounds*

NEK IEC 60909, *Short-circuit currents in three-phase AC systems - Part 3: Currents during two separate simultaneous line-to-earth short circuits and partial short-circuit currents flowing through earth*

NEK IEC 61140, *Protection against electric shock - Common aspects for installation and equipment*

NEK IEC 61363-1, *Electrical installations of ships and mobile and fixed offshore units – Part 1: Procedures for calculating short-circuit currents in three-phase a.c.*

NEK IEC 61936-1, *Power installations exceeding 1 kV a.c. – Part 1: Common rules*

NEK IEC 60947-5-1, *Low-voltage switchgear and controlgear – Part 5-1: Control circuit devices and switching elements – Electromechanical control circuit devices*

NEK IEC 62061, *Safety of machinery - Functional safety of safety-related control systems*

NEK IEC 62271-200, *High-voltage switchgear and controlgear – Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*

NEK IEC 62613-1, *Plugs, socket-outlets and ship couplers for high-voltage shore connection systems (HVSC-Systems) – Part 1: General requirements*

NEK IEC 62613-2, *Plugs, socket-outlets and ship couplers for high-voltage shore connection systems (HVSC-Systems) – Part 2: Dimensional compatibility and interchangeability requirements for accessories to be used by various types of ships*

NEK IEC/IEEE 80005 (all parts), *Utility connections in port*

NS-EN ISO 13849-1, *Safety of machinery - Safety-related parts of control systems - Part 1: General principles for design*,

IEEE Std C37.2™, *IEEE Standard for Electrical Power System Device Function Numbers, Acronyms, and Contact Designations*

IEEE Std C37.20.2™, *IEEE Standard Definitions for AC (52 kV and below) and DC (3.2 kV and below) Switchgear Assemblies*

IEEE Std 519™, *IEEE Standard for Harmonic Control in Electric Power Systems*

IEEE Std 1580™, *IEEE Recommended Practice for Marine Cable for Use on Shipboard and Fixed or Floating Facilities*

IEEE Std 1662™, *IEEE Recommended Practice for the Design and Application of Power Electronics in Electrical Power Systems*

IMO, *International Convention for the Safety of Life at Sea (SOLAS)*

3 Terms, definitions and abbreviations

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

IEC maintain terminological databases for use in standardization at IEC 60050 International Electrotechnical Vocabolary (Electropedia) www.electropedia.org.

AC Alternating Current

CENELEC	Comité Européen de Normalisation Électrotechnique (European Committee for Electrotechnical Standardization)
DC	Direct Current
CSOV	Commissioning Service Operation Vessel
CTV	Crew Transfer Vessels
SOV	Service Operation Vessel

3.1
automatic protective operation
operating mode in which all functions of the protective equipment are performed without action of a human operator

3.2
basic protection
protection against electric shock under normal conditions

[SOURCE: IEV 195-06-01]

3.3
cable management system CMS
all equipment, including a device that limits cable *tension* (3.28), designed to control, monitor, handle and stow the flexible cables, for power and control, and their connection devices

3.4
cable reel
a device comprising a flexible cable or cord attached to a reel, so constructed that the cord can be wound onto the reel

[SOURCE: IEV 442-03-15]

3.5
control station
assembly of one or more control switches fixed on the same panel or located in the same enclosure

Note 1 to entry: A control station panel or enclosure may also contain related equipment, e.g., potentiometers, signal lamps, instruments, etc.

[SOURCE: IEV 441-12-08]

3.6
earth fault
occurrence of an accidental conductive path between a live part and the earth

[SOURCE: IEV 195-04-14]

3.7
emergency disconnection EDC
process, either activated from manually actuated control device, from *control station* (3.5), or automatically mechanically released in extreme over-*tension* (3.28) scenario, used to initiate an release of *ship connector* (3.24) and ship connection cable

3.8
emergency shutdown ESD
process, either activated from manually actuated control device, or manually or automatically from *control station* (3.5), used to open the *safety circuit* (3.22) and resulting in a shutdown of *HVOC* (3.14) supply

3.9
equipotential bonding
provision of electric connections between conductive parts, intended to achieve equipotentiality.

[SOURCE: IEV 195-01-10]

3.10
fail-safe
capable of preserving safety in the case of failure

Note 1 to entry: The safe conditions should be defined for the particular application.

[SOURCE: IEV 192-10-06]

3.11
fibre optics
the branch of optical technology concerned with the transmission of optical radiation through fibres made of transparent materials such as glass, fused silica, or plastic

[SOURCE: IEV 731-01-44]

3.12
hazardous area
area in which an explosive atmosphere is present, or can be expected to be present, in quantities such that special precautions for the construction, installation and use of equipment are required

Note 1 to entry: NEK IEC 60079-10-1, *Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres*, gives a classification of hazardous areas containing explosive gas atmospheres (see IEV 426-03-03, IEV 426-03-04 and IEV 426-03-05).

Note 2 to entry: NEK IEC 60079-10-2, *Explosive atmospheres – Part 10-2: Classification of areas – Explosive dust atmospheres*, gives a classification of hazardous areas containing explosive dust atmospheres (see IEV 426-03-23, IEV 426-03-24, and IEV 426-03-25).

[SOURCE: IEV 426-03-01]

3.13
high voltage HV
voltage exceeding the conventionally adopted limit for *low voltage* (3.16)

3.14
high voltage offshore connection HVOC
high voltage offshore connection systems for transfer of electric power to hybrid and battery electric vessels from the *offshore supply facility* (3.17) for the purpose of supplying electrical power to the vessel's battery for charging, electric propulsion for positioning, and/or auxiliary *loads* (3.15).

3.15
load
device intended to absorb power supplied by another device or an electric power system

[SOURCE: IEV 151-15-15]

3.16
low voltage LV
a set of voltage levels used for the distribution of electricity and whose upper limit is generally accepted to be 1 000 V for alternating current

[SOURCE: IEV 601-01-26, modified — The definition has been rephrased]

3.17
offshore supply facility
a supply facility located in, on, or under water, typically away from the coast

3.18
ordinary person
person who is neither a skilled person nor an instructed person

[SOURCE: IEV 195-04-03]

3.19
person in charge PIC
individual responsible for *HVOC* (3.14) system operations

3.20
pilot contact
contact of the *ship inlet* (3.26) and *ship connector* (3.24) which signals correct connection and which is a safety-related component

3.21
safety extra low voltage SELV
electric system in which the voltage cannot exceed the value of extra-low voltage:

— under normal conditions and

— under single fault conditions, including *earth faults* (3.6) in other electric circuits

[SOURCE: IEV 195-06-28]

3.22
safety circuit
normally closed interlocking circuit with *pilot contacts* (3.20) and safety devices that opens to shut down the *HVOC* (3.14) system in response to specific initiating events

3.23
safety relay
device that will open the circuit even under single fault conditions

Note 1 to entry: This may be achieved by the series connection of two relays from different manufacturers or the application of similar technology

[SOURCE: IEC/IEEE 80005-3]

3.24
ship connector
part of the *ship coupler* (3.25) intended to be attached to one flexible cable connected to the *offshore supply facility (3.17)*, and to be connected to the *ship inlet* (3.26)

Note 1 to entry: See Figure 5.

3.25
ship coupler
means enabling the connection of a flexible cable to the ship, consisting of two parts: a *ship connector* (3.24) and *ship inlet* (3.26).

Note 1 to entry: See Figure 5.

Note 2 to entry: ship coupler consists of various contacts for power, pilots and *fibre optic* (3.11) (where applicable)

3.26
ship inlet
part of the *ship coupler* (3.25) incorporated in, or fixed to, the ship

Note 1 to entry: See Figure 5.

3.27
system earthing, system grounding, US
functional earthing and protective earthing of an electric system

[SOURCE: IEV 195-01-14]

3.28
tension load
force that acts to stretch or pull a material apart along its axis

4 General requirements

4.1 System description

A typical *HVOC* system described in this specification consists of hardware components as shown in Figure 1.

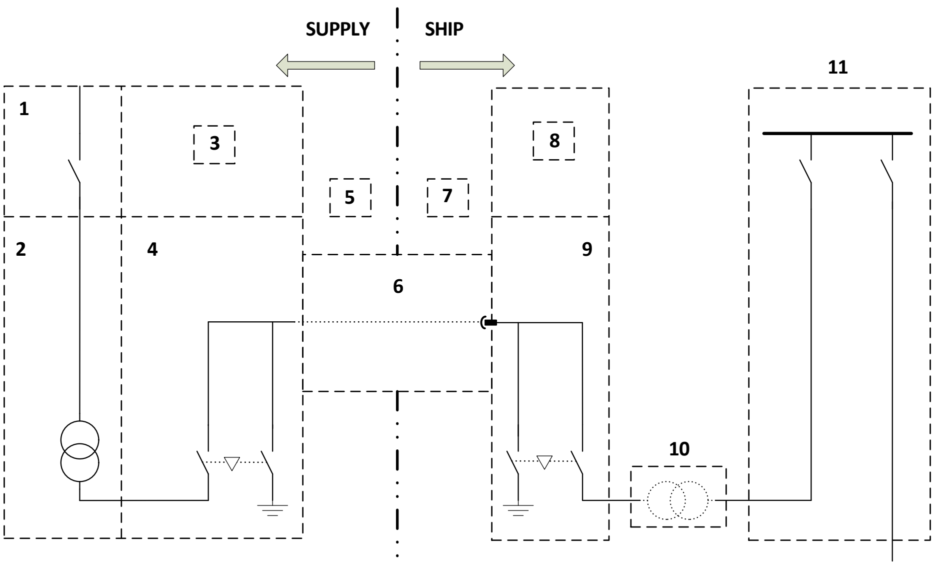

Figure 1 — Block diagram of a typical described HVOC system arrangement

1	Supply grid-interfacing switchgear	7	Ship control system
2	Supply transformer	8	Ship protection relaying
3	Supply protection relaying	9	Ship utility connection switchboard
4	Supply switchboard (circuit-breaker and earth switch)	10	Ship transformer (where applicable)
5	Supply control system	11	Ship receiving switchboard
6	Supply-to-ship connection and interface equipment		

A device shown in the typical HVOC system block diagram may be omitted if its operational and protective functions are provided by other devices (shown in Figure 1) and proven by documentation and testing.

Likewise, a device which is not shown in the typical HVOC system block diagram may be in included if it does not detrimentally impact the operational and protective functions of other devices (shown in Figure 1) and this is proven by documentation and testing. Cable lengths for the supply of an HVOC system can be variable depending on the arrangement.

The general system diagram is shown in Figure 2.

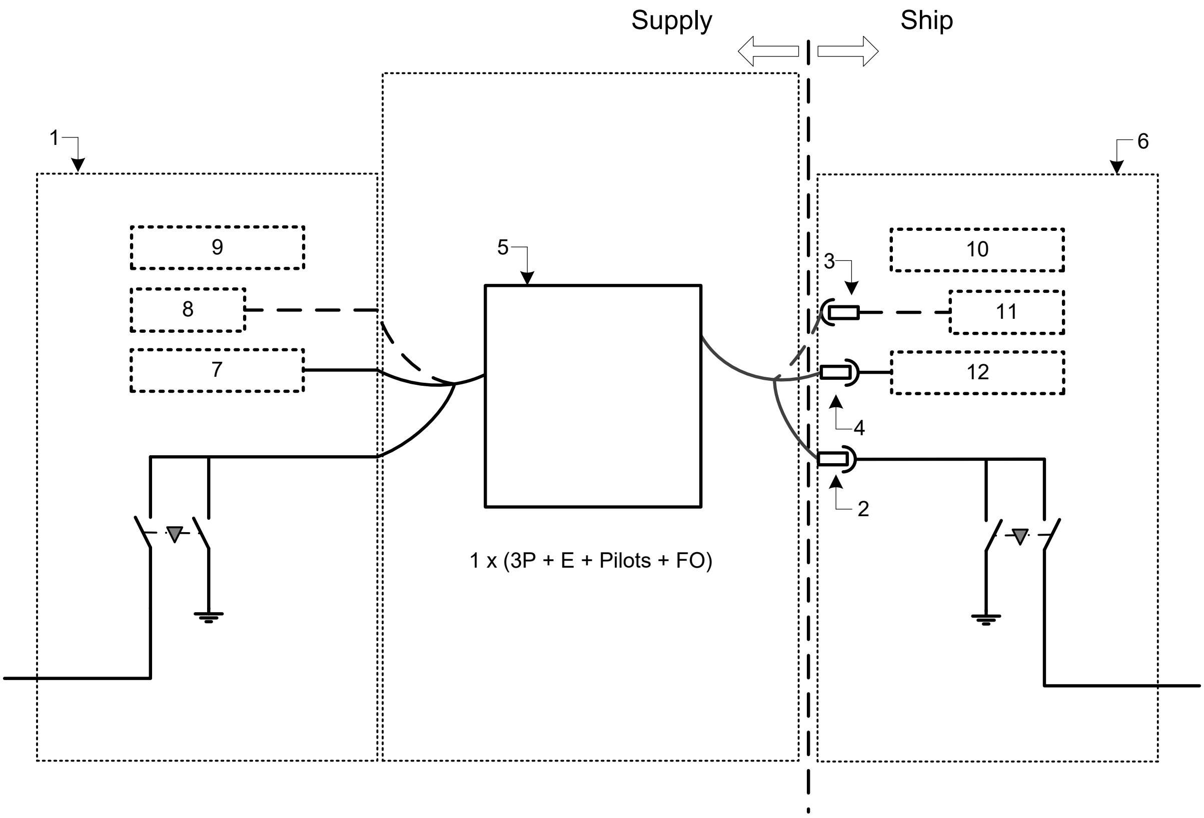

Figure 2 — General system drawing

1	Supply system	6	Ship HVOC connection switchboard
2	Power contacts	7	Supply interlocks with pilot wire
3	Fibre optic contacts (where applicable) for communication, control and monitoring, integrated in the ship coupler (this specification does not specify requirements for fibre optic communication)	8	Supply control system
		9	Supply protection relaying
		10	Ship protection relaying
4	Pilot contacts integrated in the ship coupler	11	Ship control system
5	Cable management system	12	Ship interlocks with pilot wire

4.2 Distribution system

4.2.1 General

Typical distribution system requirements used on shore and offshore are given in NEK IEC 61936-1. Typical ship distribution systems requirements are given in NEK IEC 60092-201 (general) and NEK IEC 60092-503 (high voltage).

NOTE 1 IEEE Std 45.1 ™ and IEEE Std 45.3™ provide additional information on typical ship distribution systems.

NOTE 2 Once published, NEK TR 412 Earthing in maritime electrical systems will provide practical examples of earthing of maritime distributions system.

4.2.2 Equipotential bonding

An *equipotential bonding* (3.9) between the ship's hull and offshore earthing system shall be provided, (see 6.2.4), and established by the earthing contacts of the *ship connector* (3.24) and *ship inlet* (3.26).

In order to ensure the integrity of the bonding in the offshore connection, two alternative procedures are allowed:

a) Continuous monitoring of the bonding. Verification of the equipotential bonding shall be a part of the *safety circuit* (3.22). Loss of equipotential bonding shall result in the shutdown of the HVOC system, and the ship shall go into ship power restoration mode (see 8.6).

b) Periodic testing and maintenance of the bonding connections. Where continuous monitoring of the equipotential bonding is not in place, periodic testing and maintenance of the bonding connections shall be performed and documented (see clause 11).

Earthing conductors in ship/offshore connectors shall be used as equipotential bonding conductor. Metallic hull and saltwater conductivity shall not be used as the only means for equipotential bonding.

A single *earth fault* (3.6) shall not create a step or touch voltage exceeding 30 V at any location in the offshore-to-ship power system.

NOTE The use of equipotential bonding as protection against electric shock is defined in NEK IEC 61140.

4.3 Compatibility assessment before connection

Compatibility assessment shall be performed to verify the possibility to connect the ship to an offshore supply facility. Compatibility assessment shall be performed prior to the first arrival at the facility.

Assessment of compatibility shall be performed to determine:

a) compliance with the requirements of this specification and any deviations from the recommendations;

b) minimum and maximum prospective short-circuit current (see 4.7 and 4.8);

c) nominal ratings of the supply, ship-to-offshore connection and ship connection (see 5.1);

d) any de-rating for cable coiling or other factors (see 7.2.1);

e) acceptable voltage variations at ship switchboards between no-load and nominal rating (see 5.2);

f) steady-state and transient ship load demands when connected to a supply, supply response to step changes in load (see 5.2);

g) system study and calculations (see 4.8);

h) verification of ship equipment impulse withstand voltage;

i) compatibility of supply and ship control voltages, where applicable;

j) compatibility of communication method and means;

k) distribution system compatibility assessment (supply transformer neutral earthing);

l) functioning of ship earth fault protection, monitoring and alarms when connected to an supply (see 8.2.2);

m) sufficient cable length;

n) compatibility of safety circuits;

o) total harmonic distortion (THD) (see 5.2);

p) consideration of *hazardous areas* (3.12), where applicable (see 4.6.4);

q) when a supply system is connected, consideration shall be given to provide means to reduce current in-rush and/or inhibit the starting of large loads that would result in failure, overloading or activation of automatic load reduction measures;

r) consideration of electrochemical corrosion due to *equipotential bonding* (3.9);

s) utility interconnection requirements for load transfer parallel connection;

t) equipotential bond monitoring (see 4.6.4);

u) that design variations are verified and meet the same safety and functional requirements.

4.4 HVOC system design and operation

4.4.1 System design

The design and construction shall be integrated and coordinated among the parties responsible for offshore and ship HVOC systems. System integration of offshore and ship HVOC systems shall be managed by a single designated party and shall be performed in accordance with a defined procedure identifying the roles, responsibilities and requirements of all parties involved.

4.4.2 System operation

During the operation of HVOC systems, a *person in charge PIC(s)* (3.19) shall be identified and located onboard the ship and shall be responsible for both ship and offshore supply facility operations, assuming the facility is normally unmanned.

In the case of a normally manned facility, it may be deemed necessary to identify a PIC both onboard the ship and at the facility. System operation of supply and ship HVOC systems shall be in accordance with a defined procedure identifying the roles, responsibilities and requirements of all parties involved.

The PIC(s) shall be provided with sufficient information, instructions, tools and other resources for safety and efficiency of these activities.

An independent means of voice communication should be provided between the ship and the facility (e.g. two-way radios), if different PIC are responsible.

4.5 Personnel safety

Design of the high voltage equipment and operating safety procedures shall ensure the safety of personnel during the establishment of the connection of the ship's supply, during all normal operations, in the event of a failure, during disconnection and when not in use.

NOTE The use of the term "safe" is not intended to suggest or guarantee that absolute safety can be achieved in any situation and/or by compliance with the recommended practices set forth herein. The use of terms such as "safe", "*fail-safe*", "electrically safe work practices", "safe work condition", "safe work environment", "safe design", "safe distance", "safe work method", "safe work area", "safe use" describe practices, conditions, etc. in which safety risks are minimized but not eliminated absolutely, such that safety is not guaranteed.

4.6 Design requirements

4.6.1 General

Protection and safety systems shall be designed based on the *fail-safe* (3.10) principle, hard wired**,** or any alternative that meet the same level of safety and protection.

4.6.2 Protection against moisture and condensation

Effective means shall be provided to prevent accumulation of moisture and condensation, even if equipment is idle for appreciable periods.

4.6.3 Location and construction

HVOC equipment shall be installed in access-controlled spaces.

Equipment shall be suitable for the environment conditions in the space(s) where it is expected to operate. Ship equipment shall comply with the applicable requirements of NEK IEC 60092-101 and NEK IEC 60092-503.

Equipment location is important to the safety and efficiency of operation of the ship. When determining the location of the HVOC system, the full range of operations shall be considered.

Interoperability between offshore charging solutions and shore connection solutions, should be considered. Refer to NEK IEC 80005-series for utility operations shall be considered.

4.6.4 Electrical equipment in hazardous areas

HVOC equipment shall be located outside the hazardous areas of the ship and offshore facilities under normal operating conditions, except where it is shown to be necessarily located in these areas for safety reasons. HVOC equipment that may fall within one of the hazardous areas of the offshore supply facility under emergency conditions (inadvertent movement of ship from installation) shall be:

a) certified in accordance with NEK IEC 60079 (all parts) as suitable for the flammable gas or vapour and/or combustible dust encountered; or

b) automatically isolated and discharged before entering the potentially hazardous area.

Control equipment located within hazardous areas shall not present an ignition hazard.

4.7 Electrical requirements

The type and routine tests for all components of HVOC system shall be performed according to relevant standards.

To allow standardisation of the HVOC supply and link nominal voltage 11 kV AC (optionally 6,6 kV AC) at different locations, any equipment requiring conversion to nominal voltage shall be installed onboard.

The prospective short-circuit contribution level at the ship inlet shall be limited by the supply system to 16 kA RMS for 1 s / 40 kA peak.

The prospective short-circuit contribution level at the ship inlet, originating from the onboard sources such as running motors, generators, and batteries in operation, shall be limited to a short-circuit current of 16 kA RMS for 1 s / 40 kA peak.

Electrical system/equipment, including short-circuit protective device rating, shall be suitable for the prospective maximum short-circuit fault current. Equipment shall be rated for minimum short-circuit withstand current of 16 kA RMS for 1 s, and 40 kA peak.

4.8 System study and calculations

The connected electrical system shall be evaluated. The system study and calculations shall adress the followingdetermine the following:

a) the electrical load during connection;

b) the short-circuit current calculations (see NEK IEC 61363-1) shall be performed in order to take into account the prospective contribution of the offshore supply facility and the ship's installations. The following ratings shall be defined and used in these calculations:

    1) for supply installations, a maximum and minimum prospective short- circuit current for visiting ships;

    2) for ships, a maximum and minimum prospective short-circuit current for visited supply installations.

c) the calculations may take into account any arrangements that

    1) prevent parallel connection of high voltage supplies with ship sources of electrical power, and/or

    2) restrict the number of ship sources of electrical power operating during parallel connection to transfer load, and

    3) restrict load to be connected.

    NOTE Provisional load restrictions can be necessary during load transfer.

d) transient current for offshore and ship; this transient current calculation shall consider the offshore power system and the expected ship power system including the on-line electrical sources;

e) supply transformer neutral earthing resistor analysis (see 6.2.3);

f) transient overvoltage protection analysis (see 5.2);

g) fail-safe principle for cables/connectors operation (see 4.6.1).

These calculated values shall be used to select suitably rated offshore connection equipment and to allow the selection and setting of protective devices so that successful discriminatory fault clearance is achieved for the largest on-board load while connected.

The system study shall be made available to relevant parties.

For ships with low voltage main distribution the connection between low voltage-side of the ship transformer and main switchboard shall be evaluated, and overload protection shall be provided between the ship transformer and the receiving switchboard.

Documented alternative proposals that take into account measures to limit the parallel connection to short times may be considered where permitted by the relevant authorities. This provision does not apply if the electrical source is provided by a DC-bus. Documentation shall be made available to relevant ship and offshore supply facility personnel.

4.9 Emergency shutdown including emergency-stop facilities

4.9.1 General

Emergency shutdown (3.8) facilities shall be provided. When activated, they will instantaneously open circuit-breakers on offshore supply facility and on-board ship.

Fail-safe, hard-wired circuits shall be used for emergency shutdown. This does not preclude emergency shutdown activation commands from programmable electronic equipment, for example programmable protection relays.

The relay contacts of the *sa*fety circuit shall be designed in accordance with NEK IEC 60947-5-1 and for a rated insulation voltage of Ui = 300 V, AC 5 A, DC 1 A.

Minimum current value in the safety circuits shall be 50 mA.

NOTE For wireless solutions, see 4.6.1.

4.9.2 Earthing following emergency shutdown

To address the potential hazard to personnel of access to HVOC ship connection cables that have not been discharged, the high-voltage power connections shall be either:

a) automatically earthed so that they are safe to touch immediately following the isolation from ship and offshore electrical power supplies, or

b) arranged for manual earthing and routed and located such that personnel are prevented from access to live ship connection cables and live connection points by barriers and/or adequate distance(s) under normal operational conditions.

4.9.3 Safety barriers and/or adequate distance following emergency shutdown

Barriers and/or adequate distance(s) shall be satisfied with operational procedures established to:

— restrict un-authorized access to HVOC spaces,

— control personnel access to HVOC spaces and areas when the high voltage connection is live; locking arrangements may be considered, and

— arrange for the safe discharge of high voltage conductors.

4.9.4 Emergency shutdown functions in hazardous areas

Where connection equipment can move into a potentially hazardous area (where flammable gas, vapour and/or combustible dust can accumulate) associated with the offshore supply facility as a result of the ship inadvertently leaving the position (slipping/breaking of moorings, etc.), all electrical powered HVOC equipment that is not certified for use in hazardous areas shall be automatically isolated, and high voltage equipment then automatically discharged, so that it will not present an ignition hazard.

The emergency shutdown facilities shall be activated in the event of:

a) loss of *equipotential bonding* (3.9), via the equipotential bond monitoring devices (where utilized),

b) over *tension* (3.28) on the flexible cable (mechanical stress) (see 7.2.2),

c) remaining cable length is too low (see 7.2.3),

d) loss of any safety circuit,

e) activation of any manual emergency-stop,

f) activation of protection relays provided to detect faults on the ship connection cable or connectors, or

g) disengaging of power plugs from socket-outlets while high voltage connections are live before the necessary degree of protection is no longer achieved.

4.9.5 Emergency stop push buttons

Emergency-stop push buttons, activating emergency shutdown facilities, shall be provided at each of the following locations:

a) an attended onboard ship *control station* (3.5) during HVOC;

b) in the vicinity of the cable management system;

c) at active cable management system control locations; and

d) at the offshore supply facility and ship circuit-breaker locations.

Additional emergency push buttons may also be provided at other locations, where considered necessary.

The means of activation shall be visible and prominent, prevent inadvertent operation and require a manual action to reset.

Opening of safety circuit shall cause the automatic opening of ship and supply HVOC circuit breakers in a maximum time of 200 ms.

An alarm to indicate activation of the emergency shutdown shall be provided to advise relevant duty personnel when connected to HVOC supply.

For reliable operation of safety circuits, the pilot cable length and cross section shall be considered.

4.9.6 Emergency disconnection

Emergency disconnect buttons, activating emergency shutdown and disconnect facilities, shall be provided at each of the following locations:

a) an attended onboard ship control station on the bridge during HVOC;

b) in the vicinity of the connection point on the ship, at a safe distance from *tension loads* (3.28).

Additional emergency disconnect buttons may also be provided at other locations, where considered necessary. There shall be a system to monitor cable tension and cable pay-out, that activates limit-alarms.

The means of activation shall be visible and prominent, prevent inadvertent operation and require a manual action to reset. Means of activation for *emergency disconnect* (3.7) shall be visibility distinctive from the emergency stop push buttons.

Additionally, there should be a break point/weak link in the connection that shall automatically mechanically release cable and connector in extreme over-tension scenario. Personnel shall be protected from any hazards during a mechanically release.

The safety circuit will be opened and ship and offshore supply facility HVOC circuit breakers shall automatically open as a result of the emergency disconnection, in a maximum time of 200 ms.

Maximum time from activation of emergency disconnect until the cable and connector is offloaded from the ship, shall be 10 s.

For all emergency disconnection scenarios, after activation, the release should not require, external forces such as additional tension from weather conditions, manual intervention or vessel propulsion.

An alarm to indicate activation of the emergency disconnection shall be provided to advise relevant duty personnel when connected to HVOC supply.

5 Offshore supply system requirements

5.1 Voltage and frequency

To allow standardization of the high voltage supply and link nominal voltage at different locations, HVOC shall be provided with a nominal voltage of 11 kV AC (optionally 6,6 kV AC) galvanically separated from the offshore distribution system.

The operating frequencies (Hz) of the ship and supply electrical systems shall match; otherwise, a frequency convertor shall be utilized.

The phase sequence shall be L1-L2-L3 or A-B-C or R-S-T, anticlockwise. A phase sequence indicator shall indicate correct sequence prior to energizing or paralleling HVOC (see Figure 3).

Figure 4 illustrates the balanced three-phase voltages in the time domain.

If an observer looking at the phase sequence rotation diagram is fixed at its location, phasors shall rotate anticlockwise in relation to the fixed observer to produce a clockwise indication on the phase sequence indicator (see Figure 4).

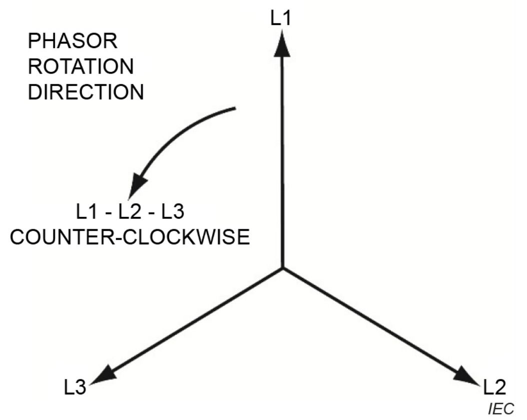

Figure 3 — Phase sequence rotation – Positive direction

L1-L1 = 0°   L1-L2 = -120°   L1-L3 = -240°

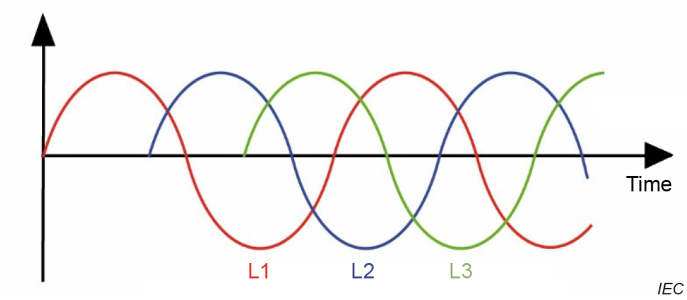

Figure 4 — Balanced three-phase variables in time domain

5.2 Quality of electrical supply

The supply system shall have a documented voltage supply quality specification. Electrical equipment of ships shall only be connected to offshore supplies that will be able to maintain the distribution system voltage, frequency and total harmonic distortion characteristics given below. For compliance, the compatibility assessment referred to in 4.3 shall include verification of the following:

a) voltage and frequency tolerances (continuous):

  1) the frequency shall not exceed the continuous tolerances ±5 % between no-load and nominal rating;

  2) for no-load conditions, the voltage at the ship connector shall not exceed a voltage increase of 6 % of nominal voltage;

  3) for rated load conditions, the voltage at the ship connector shall not exceed a voltage drop of −3,5 % of nominal voltage.

b) voltage and frequency transients:

  1) the response of the voltage and frequency at the offshore connection when subjected to an appropriate range of step changes in load shall be defined and documented for each HVOC supply installation;

  2) the maximum step change in load expected when connected to a HVOC supply shall be defined and documented for each ship. The part of the system subjected to the largest voltage dip or peak in the event of the maximum step load being connected or disconnected shall be identified;

  3) comparison of 1) and 2) shall be done to verify that the voltage transients limits of voltage +20 % and −15 % and the frequency transients limits of ±10 % will not be exceeded.

c) harmonic distortion: for no-load conditions, voltage harmonic distortion limits shall not exceed 3 % for single harmonics and 5 % for total harmonic distortion.

NOTE 1 IEC 61000-2-4 Class 2 implies that the total voltage harmonic distortion shall not exceed 8%.

NOTE 2 Additional recommendations are provided in IEEE Std 519™ and IEC 60092-101.

The above parameters shall be measured at the ship connector.

The HVOC supply shall include appropriate rated surge arrestors to protect against fast transient overvoltage surges (e.g. spikes caused by lightning strikes or switching surges).

Different voltage and frequency tolerances may be imposed by the authorities responsible for the supply system and these shall be considered as part of the compatibility assessment to verify the effect on the connected ship load is acceptable.

Where the possible loading conditions of a ship when connected to a HVOC supply would result in a quality of the supply different from that specified in NEK IEC 60092-101:1994/AMD1:1995, 2.8, due regard shall be given to the effect this may have on the performance of equipment.

6 Offshore supply facility installation

6.1 General

Offshore connection equipment and installations shall be in accordance with NEK IEC 61892, and where relevant, NEK IEC 61936-1.

NOTE 1 The grid operator and/or local authorities can have additional requirements.

The rating of the HVOC system shall be adequate for the required electrical load as calculated by 4.8.

The offshore supply facility electrical system shall ensure that each connected ship is galvanically isolated from other connected ships and consumers.

NOTE 2 Refer to upcoming technical document on galvanic corrosion prevention (Guidelines for preventing galvanic corrosion in utility connections) from TC18 joint working group 28.

The use of HVOC system shall not compromise the electrical protection selectivity of the largest on-board load (as per the definition in NEK IEC 60050-151:2001, 151-15-15) while connected.

Galvanic isolation may not be required where an HVOC supply is dedicated to supply only ships that have galvanic isolation on board. A risk assessment shall be performed.

6.2 System component requirements

6.2.1 Circuit-breaker, disconnector and earthing switch

The offshore connection switchgear and control gear shall be designed and tested in accordance with NEK IEC 62271-200 or ANSI/UL Metal-Clad Switchgear (IEEE Std C37.20.2TM). Switching devices and their combination shall be electrically or mechanically interlocked, to provide safe isolation before earthing and during operation.

NOTE 1 Switching devices and their combination for isolation and earthing can be part of different switchgear functional units (see NEK IEC 60050-441:2000, 441-13-04).

The rated making capacity of the circuit breaker and the earthing switch shall not be less than the prospective peak value of the short-circuit current (I_p) calculated in accordance with NEK IEC 61363-1.

The rated short-circuit breaking capacity of the circuit-breaker shall not be less than the maximum prospective symmetrical short-circuit current ($I_{AC(0,5\,T)}$) calculated in accordance with NEK IEC 61363-1.

NOTE 2 The short circuit contribution from the offshore side can be calculated using NEK IEC 60909.

A circuit-breaker equipped with *automatic protective operation* (3.1) shall be provided.

6.2.2 Supply transformer

In the event that adjustments are required to maintain the HVOC supply voltage within tolerances under load, then these adjustments shall be automatically controlled (see 5.2).

Transformers shall be of the separate winding type for primary and secondary side. The secondary side shall be star-configuration with neutral bushings (e.g., Dyn).

NOTE Dyn = Delta connected primary winding, star connected secondary winding, with provision to connect to the neutral point.

The temperature of supply transformer windings shall be monitored.

In the event of over-temperature, an alarm signal shall be transmitted to the ship using the data-communication link, if such data-communication link is installed (see 7.8). The alarm signal shall activate an alarm onboard to warn relevant duty personnel. An alarm signal shall also be transmitted locally to the offshore supply facility control station.

Short-circuit protection for each supply transformer shall be provided by circuit-breakers or fuses in the primary circuit and by a circuit breaker in the secondary. In addition, overload protection shall be provided for the primary and secondary circuit. Circuit breakers and transformers can be placed in different physical locations.

6.2.3 Neutral earthing resistor

The neutral point of the HVOC supply transformer shall be earthed:

a) through a neutral earthing resistor, or

b) where frequency conversion of the supply is required, either through a neutral earthing resistor, or through an earthing transformer with a resistor on the primary or secondary side.

The neutral earthing resistor rating shall be minimum 25 A, 5 s.

The continuity of the neutral earthing resistor shall be continuously monitored. In the event of loss of continuity, the supply circuit breaker shall be tripped.

An earth fault shall not create a step or touch voltage exceeding 30 V at any location in the offshore-to-ship power system.

Supply transformer secondary side shall be earthed at the star point through a neutral earthing resistor.

Nominal voltage of 11 kV will require a 335-ohm resistor.

Nominal voltage of 6,6 kV will require a 200-ohm resistor.

6.2.4 Equipment earthing conductor bonding

A *system earthing* (3.27) conductor shall connect the neutral earthing resistor's earthing connection to a nearby system-earthing electrode. An additional system-bonding conductor shall connect the neutral earthing resistor's earthing connection to the earthing bus of the primary supply utility connection switchboard. Bonding shall be in accordance with 8.2.3 of NEK IEC 60204-11:2000.

Equipment-earthing conductors terminated at the offshore supply facility shall be connected to the ship and continued to the ship to create an equipotential bond between the facility and ship. This shall require bonding to the ship's switchgear earthing bus and/or bonding to the ship's hull.

6.3 Offshore-to-ship electrical protection system

The supply circuit breaker on the secondary side of the transformer shall open all insulated poles in the event of the following conditions:

a) over-current including short-circuit;

b) over-voltage/under-voltage;

c) reverse power;

d) earth fault;

e) unbalanced cable protection (refer to section 7.2.4).

To satisfy this requirement, at least the following protective devices, or equivalent protective measures, shall be provided:

f) synchro-check (25) or voltage sensing device (for dead bus verification);

g) under-voltage (27);

h) reverse power (32)

i) negative phase sequence over-current (46);

j) instantaneous over-current (50);

k) AC inverse time over-current (51);

l) earth fault over-current (51G or 51N);

m) over-voltage (59);

n) AC directional over-current (67);

NOTE Numbers in brackets refer to standard device designation numbers as per IEEE Std C37.2™.

Alarms shall be communicated to the ship as common alarm, using the data-communication link, if such data-communication link is installed.

The protection systems shall be provided with battery back-up adequate for at least 30 min. Upon failure of the battery charging or activation of the back-up system, an alarm shall be communicated to the ship (see 7.8).

6.4 High voltage interlocking

6.4.1 General

Operating personnel shall be protected from electrical hazard by an interlocking arrangement during connection and disconnection of high voltage connectors.

Operational procedures and interlockings to verify that non-fixed high voltage cables are discharged before disconnection shall be established.

6.4.2 Operating of the high voltage circuit breakers, disconnectors and earthing switches

Arrangements shall be provided so that the circuit breakers cannot be closed when any of the following conditions exist:

a) one of the earthing switches is closed (offshore-side/ship-side);

b) the (3.22) is not established (see 7.3.2);

c) emergency-stop facilities are activated;

d) ship or offshore supply facility control, alarm or safety system self-monitoring diagnostics detect an error that would affect safe connection;

e) the data-communication link between facility and ship is not operational, where applicable;

f) the permission from the ship is not activated (see 7.8);

g) the supply is not present;

h) *equipotential bonding* (3.9) is not established (via equipotential bond monitoring devices where utilized, or via manual override – see 4.2.2).

Arrangements shall be provided so that the disconnector cannot be closed, or the circuit breaker cannot be racked into the service position, when any of the following conditions exist:

i) one of the earthing switches is closed (offshore-side/ship-side);

j) the safety circuit is not established (see 7.3.2);

k) the communication link between facility and ship is not operational, where applicable;

l) equipotential bonding is not established (via equipotential bond monitoring devices where utilized, or via manual override – see 4.2.2).

Arrangements shall be provided so that the earthing switches can only be opened when all the conditions in 7.4 are fulfilled.

6.5 Offshore connection convertor equipment

6.5.1 General

Where provided, converting equipment (transformers, rotating frequency convertors and/or semiconductor convertors) for connecting HVOC supplies to a ship electrical distribution system shall be constructed in accordance with NEK IEC 60076 (all parts) for transformers, and NEK IEC 60146-1 (all parts) for semiconductor convertors, as applicable.

NOTE 1 Refer to IEEE Std 1662™ for additional recommendations on testing high voltage power electronics.

Rotating convertors shall be designed and tested in accordance with NEK IEC 60034 (all parts).

The effect of harmonic distortion and power factor shall be considered in the assignment of a required power rating.

Transformer winding and semiconductor or rotating convertor temperatures shall be monitored and an alarm shall be activated to warn relevant duty personnel if the temperature exceeds a predetermined safe value.

The use of frequency convertors shall not compromise the electrical protection selectivity of the largest on-board load (as per the definition in NEK IEC 60050-151:2001, 151-15-15) while connected.

Where additional selectivity (e.g. with transformer) is required and cannot be achieved, other measures may be agreed between ship and offshore supply facility giving due regard to a) to g) of 4.3.

NOTE 2 Other measures can include, among other things, switching of protection setting, other protection schemes other than over-current and short circuit.

6.5.2 Degree of protection

The protection for electrical equipment shall be in accordance with NEK IEC 61936-1, as applicable.

6.5.3 Cooling

Where forced or closed-circuit cooling is used, whether by air or with liquid, an alarm shall be initiated when the cooling medium exceeds a predetermined temperature and/or flow limits.

Semiconductor frequency convertor equipment shall be so arranged that it cannot remain loaded unless effective cooling is maintained. Alternatively, the load may be automatically reduced to a level compatible with the cooling available.

Liquid-cooled frequency convertor equipment shall be provided with leakage alarms. A suitable means shall be provided to contain any liquid which may leak from the cooling system so that it does not cause an electrical failure of the equipment.

Where liquid-cooled heat exchangers are used in transformer cooling circuits, there shall be detection of leakage, and the cooling system shall be arranged so that the entry of cooling liquid into the transformer is prevented.

Where the semiconductors and other current carrying parts of semiconductor convertors are in direct contact with the cooling liquid, the liquid shall be monitored for satisfactory conductivity, and an alarm shall be initiated if the conductivity is outside the manufacturer's limits.

The alarms shall be activated to warn relevant duty personnel.

6.5.4 Protection

In the event of overload, an alarm signal shall be activated to warn relevant duty personnel. The alarm shall be activated at a lower overload level than that of the circuit-breaker protection.

Alarms from the offshore protection equipment shall be transmitted to the ship using the data communication link, if such data communication link is installed (see 7.8).

7 Ship-to-offshore connection and interface equipment

7.1 General

Ship-to-supply connection and interface equipment includes standardized HVOC systems, cables, earthing and communications between ship and offshore supply facility.

One cable shall be used for HVOC systems.

A ship connection cable installation shall be arranged to provide adequate movement compensation, cable guidance and anchoring/positioning of the cable during normal planned ship-to-supply connection and operating conditions.

The ship-side of the ship connection cable shall be fitted with a ship connector.

The suitability of connectors with regard to peak short-circuit withstand capability shall be verified during the compatibility assessment (see 4.3).

7.2 Cable management system

7.2.1 General

The cable management system shall:

a) be capable of moving the ship connection cable, enabling the cable to reach between the ship connector and the ship inlet;

b) be capable of maintaining an optimum length of cable and prevents the tension limits from being exceeded;

c) address the risk of submersion through the equipment's design;

d) maintain the bending radius of cables above the minimum bending radius recommended by the manufacturer during deployment, in steady-state operation and when stowed;

e) be capable of supporting the cables over the entire range of operational range, for example ship draughts and tidal ranges, waves and wind conditions; and

f) be capable of retrieving and stowing the cables once operations are complete.

Where the cable management system employs *cable reel(s)* (3.4), the HVOC system rated power shall be based on the operating condition with the maximum number of wraps of cable stowed on the reel that is encountered during normal operations. Where applicable, the cable sizing shall include appropriate de-rating factors.

The cable reel shall be fitted at the offshore supply facility (see Figure 2). Figure 6 shows the safety circuits.

The control power voltages shall be less than 120 V DC or 50 V AC if *basic protection* (3.2) is provided, or less than 60 V DC or 25 V AC if basic protection is not provided. This is defined by the safety extra low voltage *(3.21)* type source as per NEK IEC 60364-4-41. Requirements for basic protection, see NEK IEC 60364-4-41 411.2.

D	Ship coupler
E	Ship connector
F	Ship inlet

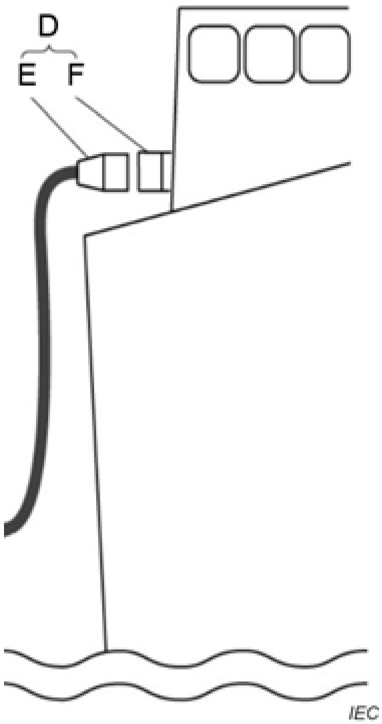

Figure 5 — HVOC accessories

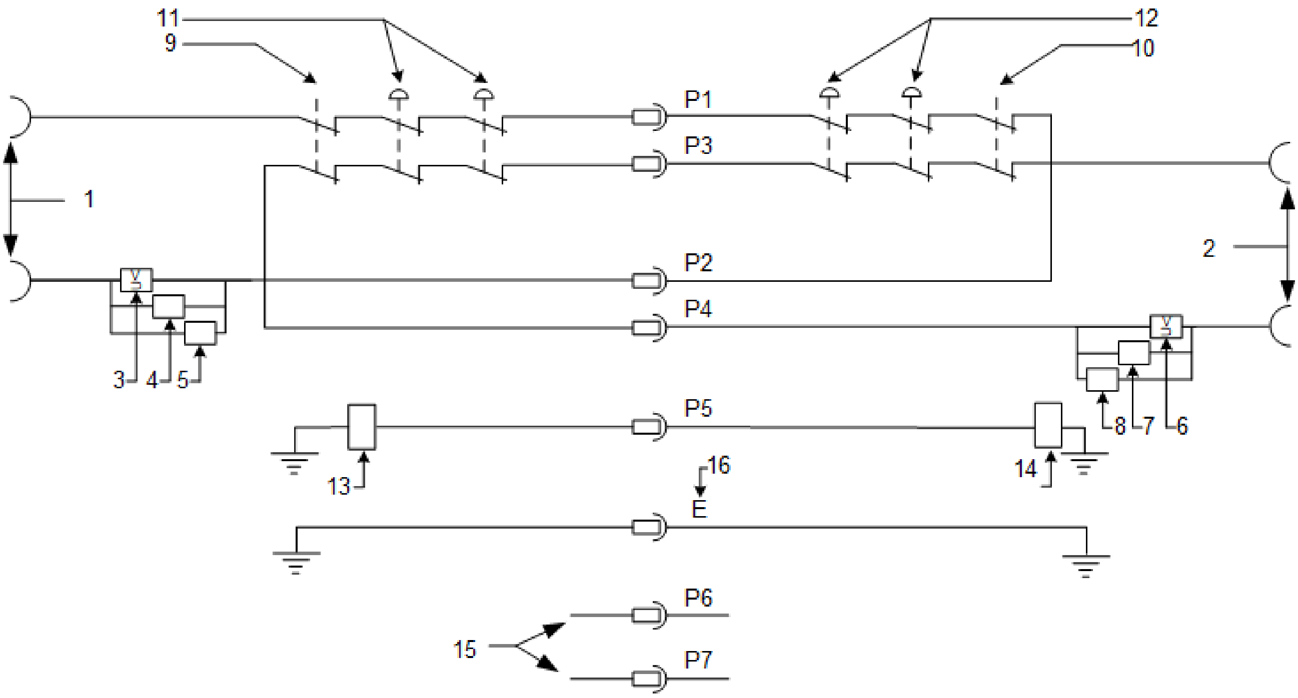

Figure 6 — Safety circuits

1	Supply control power pilot loop	2	Ship control power pilot loop
3	Supply safety circuit control power pilot loop under-voltage coil	6	Ship safety circuit control power pilot loop under-voltage coil
4	Supply safety circuit coil	7	Ship safety circuit coil
5	Supply earthing switch permission	8	Ship earthing switch permission
9	Supply control emergency shutdown ESD and emergency disconnection EDC	10	Ship control ESD and EDC
11	Supply manual ESD and EDC	12	Ship manual ESD and EDC
13	Supply equipotential bond monitoring device (where utilized)	14	Ship equipotential bond monitoring termination device (where utilized)
15	Spare contacts/pilots	16	E denotes earth connection (PE)

NOTE Safety circuit control power pilot loop under-voltage coil (both supply and ship) may be directly connected to the safety circuit or through a *safety relay* (3.23) (or equivalent).

7.2.2 Monitoring of cable mechanical tension

The cable management system shall not permit the cable tension to exceed the permitted design value.

A means to detect maximum cable tension shall be provided, or where an active cable management system that limits cable tension is provided, means to detect the shortage of available cable length shall be provided with threshold limits provided in two stages:

Stage 1: alarm;

Stage 2: activation of emergency shutdown facilities (see 4.9).

7.2.3 Monitoring of the cable length

The cable management system shall enable the cables to follow the ships' movements over the entire range of the ships' draughts, tidal ranges and weather conditions, and the maximum range of allowable motion .

Where the cable length may vary, the remaining cable length shall be monitored, and threshold limits are to be arranged in two stages:

1) alarm;

2) activation of emergency shutdown facilities (see 4.9).

Consideration may be given to equivalent alternative measures (automatic break-away release, connectors with shear bolts and pilot lines, connection with ship/offshore emergency shutdown system, etc.).

7.2.4 Connectors protection

The ship and offshore high voltage circuit-breakers shall be arranged to open all insulated poles in the event of a damaging current unbalance between multiple phase conductors (separate, parallel power cables and connectors).

Protective devices to satisfy this requirement shall be installed on the offshore supply facility to isolate the connection in the event of damaging unbalance detection.

7.2.5 Equipotential bond monitoring (where utilized)

The equipotential bond monitoring device, where utilized, shall be installed either on the *offshore supply facility* (3.17) or onboard where the *cable management system* (3.3) is installed. Equipotential bond monitoring termination devices, where utilized, shall be installed on the other side.

Equipotential bond termination device shall meet the following requirements:

a) Characteristic: Zener Diode

b) Zener voltage: 5,6 V ± 0,03 V DC at 100 mA

c) Forward voltage: 0,5 V ± 0,1 V DC at 100 mA

d) Maximum impedance: 20 mOhms at 100 mA

e) Operating temperature: −40 °C to +60 °C

f) Current range: 2 mA to 25 A

g) Frequency range: 0 kHz to 20 kHz, −3 db

NOTE Other methods of monitoring the equipotential bond are acceptable (see 4.2.2).

7.2.6 Slip ring units

Slip ring units shall be tested in accordance with NEK IEC 62271-200 (excluding non-applicable tests) for:

a) high voltage tests,

b) impulse-voltage withstand tests,

c) insulation resistance measurements,

d) heat run test with nominal currents,

e) short-circuit withstand tests,

f) arc test, if accessible under energized conditions, and

g) ingress protection tests (IP rating).

Other testing standards may be considered.

7.3 Connectors

7.3.1 General

Contact assignment of ship connector and ship inlet shall be in accordance with Figure 7. Connectors shall be agreed between the individual parties. Extra elements, including *fibre optics* (3.11), may optionally be added based on agreement with stakeholders.

Handling of connectors shall be possible only when the associated earthing switch is closed.

Connections shall be made in areas where personnel will be protected in the event of an arc flash as a result of an internal fault in the connectors by barrier and access control measures. These measures shall be supported by access control procedures.

Each connector shall be fitted with *pilot contacts* (3.20) for continuity verification of the safety circuit.

Contact sequence shall be in the following order:

a) connection:

  1) earth contact;

  2) power contacts;

  3) pilot contacts.

b) disconnection:

  1) pilot contacts;

  2) power contacts;

  3) earth contact.

Support arrangements are required so that the weight of connected cable is not borne by any plug or ship connector termination or connection.

Contact assignment of ship connector and ship inlet shall be in accordance with Figure 7. Connectors shall be agreed between the individual parties. Extra elements, including fibre optics, may optionally be added based on agreement with stakeholders.

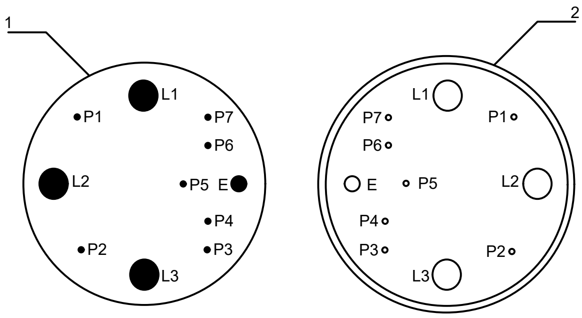

Figure 7 — Three-phase ship connector and ship inlet contact assignment

1	Ship connector face	P2	Pilot contact 2
E	Earth	P3	Pilot contact 3
L1	Phase A (R)	P4	Pilot contact 4
L2	Phase B (S)	P5	Pilot contact 5
L3	Phase C (T)	P6	Pilot contact 6
2	Ship inlet face	P7	Pilot contact 7
P1	Pilot contact 1		

The short-circuit withstand current is 16 kA RMS for 1 s and a maximum peak short-circuit current of 40 kA.

Each ship connector and ship inlet shall be fitted with seven pilot contacts.

7.3.2 Pilot contacts

Pilot contact (3.20) connections shall open before the necessary degree of protection is no longer achieved during the removal of the ship connector. Pilot contacts are part of the safety circuit (see 4.9 and Figure 6).

7.3.3 Earth contact

The current-carrying capacity of the earth contact shall be at least equal to the rated current of the earth conductor(s) in the ship connection cable (see A.2.5.1).

7.4 Interlocking of earthing switches

The earthing switches shall remain closed until:

a) all connections are made and the pilot contact circuit (see 7.3.2) is closed,

b) no emergency-stop switch is activated,

c) no emergency disconnect switch is activated,

d) the communication link between offshore and ship is operational,

e) ship or offshore control, alarm or safety system self-monitoring properties detects that no failure would affect the safety of connections, and

f) the permission from ship and offshore is activated.

Interlocking shall be hardwired.

7.5 Ship connection cable

Cables shall be at least of a flame-retardant type in accordance with NEK IEC 60332-1-2. The outer sheath shall be oil-resistant and resistant to sea air, seawater, solar radiation (UV) and shall be non-hygroscopic. The temperature class shall be at least 90 °C. The insulation shall be in accordance with Annex A. Correction factor for ambient air temperatures above 45 °C shall be taken into account according to NEK IEC 60092-201:1994, Table 7. The maximum operating temperature shall not exceed its specification, taking into account any heating effects (e.g. as a result of cable coiling).

Due consideration should be given to requirements for smoke emission, acid gas evolution and halogen content for cables installed or stored in accommodation spaces and passenger areas.

Guidance for ship connection cable electrical ratings and specification is given in Annex A.

7.6 Control and monitoring cable

Control and monitoring cables shall be at least of a flame-retardant type in accordance with IEC 60332-1-2. The environmental requirements for the sheath shall be the same as described for the ship connection cable in 7.5.

The control and monitoring cables, if integrated with the power cable assembly, shall be able to withstand internal and external short-circuits.

For details and further guidance, see Annex A.

7.7 Storage

Where equipment is not designed for outdoor storage, arrangements shall be provided for stowage when not in use, such that:

a) ship-board equipment is stored in dry spaces;

b) offshore supply facility equipment shall comply with national standards;

c) removable equipment shall be stowed, stored and removed without damage;

d) equipment does not present a hazard; and

e) connectors shall maintain their IP ratings.

Temporary coverings not designed for the purpose, canvas, plastic or similar, are not considered to satisfy this requirement.

7.8 Data communication

The data-communication link between ship and offshore supply facility arrangements shall be used for communicating the following information:

a) supply transformer high-temperature alarm (see 6.2.2);

b) supply circuit-breaker protection activation (see 6.3);

c) permission to operate high voltage circuit-breakers for ship-to-offshore connection (see 6.4 and 8.5.5);

d) if ship or offshore control, alarm or safety system self-monitoring properties detect an error that would affect safety of connection (see 6.4.2 and 4.9);

e) indication of emergency-stop activation (see 4.9);

f) where provided, offshore control functions in accordance with clause 9;

g) indication of emergency disconnection of the supply (see 4.9); and

h) failure of the battery's charging or activation of the back-up system (see 6.3).

The communication protocol for communication link between ship and facility shall be in accordance with NEK IEC/IEEE 80005-2.

If a data-communication link is installed, data communication shall be performed utilizing fibre optic systems, hard wired communication, or wireless communication links. Emergency shutdown functions shall be performed with pilot conductors (see Annex A).

8 Ship requirements

8.1 General

The instrumentation described shall be at all locations where load transfer and synchronization are performed.

On ships without high voltage power generation systems, additional efforts may be required so that the ship's person in charge (PIC) is aware of high voltage safe operating practices and of the operation of the ship's HVOC system in accordance with NEK IEC 60092-509.

The onboard HVOC system shall not interfere with the normal operation of the ship at any time.

The bending radius of cables shall be maintained above the minimum bending radius recommended by the manufacturer.

8.2 Ship electrical distribution system protection

8.2.1 Short-circuit protection

The maximum prospective short-circuit current for which the HVOC supply or the ship's electrical system/ equipment is rated shall not be exceeded at any point in the installation by connecting to offshore supplies. This shall be addressed as part of the compatibility assessment (see 4.3).

Where connection to more than one high voltage supply is possible, measures shall be taken to prevent supplies from being connected in parallel if the maximum prospective short-circuit current is exceeded at any point in the installation.

Where device settings are required to be changed when connected to an supply, means shall be provided to change settings to predetermined values. The protection settings in use shall be clearly indicated at the control station.

8.2.2 Earth fault protection, monitoring and alarm

Earth fault protection, monitoring and alarm devices shall be of a type designed to operate effectively when connected to an HVOC supply with distribution system earthing in accordance with 6.2.3. 6.2.3 requires distribution system earthing that may differ from that of the ship's.

Where device settings are required to be changed when connected to an supply, means shall be provided to change settings to predetermined values. The protection settings in use shall be clearly indicated at the control station.

8.3 Utility connection switchboard

8.3.1 General

A utility connection switchboard shall be provided at a suitable location, as close as possible to the *ship inlet* (3.26).

The utility connection switchboard shall be in accordance with NEK IEC 62271-200, service continuity LSC1.

The switchboard shall include a circuit-breaker to protect the ship's electrical equipment downstream. In no case shall the protection at the utility connection switchboard be omitted.

8.3.2 Circuit-breaker, disconnector and earthing switch

In order to have the installation isolated before it is earthed, the circuit-breaker, disconnector and earthing switch shall be interlocked in accordance with NEK IEC 62271-200.

The rated making capacity of the circuit breaker and the earthing switch shall not be less than the prospective peak value of the short-circuit current (I_P) calculated in accordance with NEK IEC 61363-1.

The rated short-circuit breaking capacity of the circuit-breaker shall not be less than the maximum prospective symmetrical short-circuit current ($IAC(0,5T)$) calculated in accordance with NEK IEC 61363-1.

A circuit-breaker equipped with *automatic protective operation* (3.1) shall be provided.

NOTE 1 Switching devices and their combination for isolation and earthing can be part of different switchgear functional units (see IEC 60050-441:2000, 441-13-04).

NOTE 2 Circuit breakers can typically handle significantly more operations than other earthing switches commonly used. A circuit breaker for earthing is typically located in a separate switchboard cubicle.

NOTE 3 The short circuit contribution from the supply can be calculated using NEK IEC 60909.

8.3.3 Instrumentation and protection

The utility connection switchboard shall be equipped with:

a) voltmeter: all three phases;

b) short-circuit devices: tripping and alarm;

c) over-current devices: tripping and alarm;

d) earth fault indicator: alarm; and

e) unbalanced protection for systems with more than one ship inlet.

The protection and safety system shall be continuously powered. A standby power supply for the protection and safety system with automatic change-over shall be provided with a capacity for at least 30 min, in accordance with NEK IEC 60092-504, 9.7.2.6. Upon failure of the battery's charging or activation of the back-up system, an alarm shall be activated to warn relevant duty personnel.

Alarms and indications shall be provided at an appropriate location for safety and effective operation.

8.4 Ship transformer

Transformers, if any, shall be of the separate winding type for primary and secondary side.

If the transformer supplies low voltage systems, an earthed shield winding shall be provided between high voltage and low voltage windings.

A ship transformer may not be required if the ship's network is designed for the supply voltage and the neutral point treatment is in line with the ship's systems.

When necessary, means shall be provided to reduce transformer current in-rush and/or inhibit the starting of large motors, or the connection of other large loads, when a supply system is connected (see 4.8 and 5.2).

8.5 Ship main switchboard

8.5.1 General

A panel shall be provided as an onboard receiving switchboard.

Synchronizing devices shall be provided.

NOTE An onboard receiving switchboard connection point is normally a part of the main switchboard (see Figure 1).

8.5.2 Circuit-breaker and earthing switch

The rated making capacity of the circuit breaker and the earthing switch shall not be less than the prospective peak value of the short-circuit current (I_P) calculated in accordance with NEK IEC 61363-1.

The rated short-circuit breaking capacity of the circuit-breaker shall not be less than the maximum prospective symmetrical short-circuit current ($I_{AC(0,5T)}$) calculated in accordance with NEK IEC 61363-1.

A circuit-breaker equipped with *automatic protective operation* (3.1) shall be provided.

An earthing switch shall be installed if the main switchboard rated voltage exceeds 1 000 V AC.

8.5.3 Instrumentation

The instrumentation shall be:

a) two voltmeters or dual voltmeter,

b) two frequency meters or dual frequency meter,

c) one ammeter with an ammeter switch to enable the current in each phase to be read, or an ammeter in each phase,

d) phase sequence indicator, and

e) one synchronizing device.

One voltmeter and one frequency meter shall be connected to the switchboard's busbars; the other voltmeter and frequency meter shall enable the voltage and frequency of the offshore connection to be measured.

8.5.4 Protection

Tripping and alarm criteria for the circuit-breaker shall be the following:

a) short-circuit: tripping with alarm;

b) over-current in two steps:

 1) alarm, and

   2) tripping with alarm;

c) earth fault:

   1) tripping with alarm if required by the type of isolation system used;

d) over-/under-voltage in two steps:

   1) alarm, and

   2) tripping with alarm;

e) over-/under-frequency in two steps:

   1) alarm, and

   2) tripping with alarm;

f) reverse power: tripping with alarm, and

g) phase sequence protection with alarm and interlock.

To satisfy this requirement, at least the following protective devices, or equivalent protective measures, shall be provided:

a) synchro-check (25);

b) under-voltage (27);

c) reverse power (32);

d) phase sequence voltage (47);

e) overload (49);

f) instantaneous over-current (50);

g) over-current (51);

h) earth fault (51G) or (59N);

i) over-voltage (59);

j) frequency (81) (under and over).

NOTE 1 The phase sequence protection protects the ship's system against wrong phase connection.

NOTE 2 Numbers in brackets refer to standard device designation numbers as per IEEE Std C37.2.

Tripping of unessential consumers and restoration of ship power should be considered where these measures could prevent complete power loss.

8.5.5 Operation of the circuit-breaker

Arrangements shall be provided so that the circuit-breakers cannot be closed when any of the following conditions exist:

a) one of the earthing switches is closed (supply or ship);

b) the safety circuit is not established (see 7.2.2);

c) emergency-stop facilities are activated;

d) emergency-connect facilities are activated;

e) ship or offshore supply facility control, alarm or safety system self-monitoring properties detect an error that would affect the safety of the connection;

f) the data-communication link between the facility and ship is not operational, where applicable;

g) the HVOC supply is not present;

h) *equipotential bonding* (3.9) is not established (via equipotential bond monitoring devices where utilized, or via manual override – see 4.2.2);

i) earth fault on ship distribution system is detected.

In the case of a normally manned facility, it may be deemed necessary to identify a PIC both onboard the ship and at the facility. System operation of offshore and ship HVOC systems shall be in accordance with a defined procedure identifying the roles, responsibilities and requirements of all parties involved.

An independent means of voice communication should be provided between the ship and the facility (e.g. two-way radios), if different PIC are responsible.

8.6 Ship power restoration

In case of both a failure of supply from the connected HVOC supply and a blackout of the ship, the utility connection switchboard circuit-breaker shall automatically open followed by

a) starting of the emergency source of electrical power to supply emergency services equivalent to SOLAS CH II- 1/D, Reg. 42 for passenger ships or 43 for cargo ships,

b) automatic connection of the transitional source of electrical power to emergency services, equivalent to SOLAS CH II- 1/D, Reg. 42 for passenger ships or 43 for cargo ships, and

c) starting and connecting to the main switchboard of the main source of electrical power and sequential restarting of essential services, in the shortest time practical. This shall be automatic in the event of emergency shutdown activation).

Failures include loss of high voltage power or disconnection (including activation of emergency shutdown or electrical system protective device activation).

It may be necessary to relax the requirements for automatic starting and connection of the ship's electrical power sources onboard existing ships constructed prior to the introduction of SOLAS CH II -1/D, Regs. 42 or 43. In such cases, alternative measures for the restoration of ship power acceptable to the relevant authorities should be provided.

An alarm shall be provided to advise relevant duty personnel. The alarm shall indicate the failure that caused the activation.

9 HVOC system control and monitoring of load transfer

9.1 General requirements

Ship equipment shall be protected and controlled by the ship's own protection and control systems.

If the supply from the facility fails for any reason, supply by the ship's own electrical power sources is permitted, in conjunction with automatically disconnecting the supply from the facility as a result of an opening of the safety circuit.

Load transfer shall be provided by suitable means, such as blackout or automatic synchronization.

9.2 Load transfer via automatic synchronization

9.2.1 General

HVOC supply and the ship's source(s) of electrical power temporarily in parallel shall be in accordance with the following:

a) load shall be automatically synchronized and transferred between the HVOC supply and the ship's source(s) of electrical power following their connection in parallel;

b) the load transfer shall be completed in the shortest time practical without causing machinery or equipment failure or operation of protective devices, and this time shall be used as the basis for defining the transfer time limit;

c) any system or function used for paralleling or controlling the offshore connection shall have no influence on the ship's electrical system, when there is no offshore connection.

The transfer time limit shall be defined and made available to the personnel responsible. Where the transfer time limit is adjustable to match the ability of an external source of electrical power to accept and shed load, the procedure for setting this limit shall be addressed in operating instructions.

Where operation of only designated or a restricted number of ship source(s) of electrical power is required to permit the safe transfer of load between an HVOC supply and ship source(s) of electrical power, the arrangements shall fulfil this requirement before and during parallel connection.

The instrumentation and protection requirements contained in 8.5.3 and 8.5.4 shall be met for parallel transfer.

9.2.2 Protection requirements

If the defined transfer time limit (see 9.2.1) for transferring of load between offshore supply facility and ship source(s) of electrical power is exceeded, one of the sources shall be disconnected automatically by the ship, and an alarm shall be provided to advise relevant duty personnel. Special care shall be taken not to exceed the maximum permissible load steps of the generator sets in accordance with NEK IEC 60092-301.

Where load reductions are required to transfer load, this shall not result in loss of essential services for the ship's safety.

10 Verification and testing

10.1 General

All HVOC system components shall have passed type tests and routine tests according to the relevant standards.

The HVOC system, including control equipment, shall be tested in accordance with a prescriptive test programme.

Tests shall be performed to demonstrate that the electrical system, control, monitoring and alarm systems have been correctly installed and are in good working order before being put into service. Tests shall be realistic and simulations avoided as far as is practicable.

If the equipment has not been used for a period of 30 months, the initial tests shall be repeated.

NOTE Such tests are intended to indicate the general condition of the installation. However, satisfactory test results do not in themselves necessarily ensure that the installation is satisfactory in all respects.

10.2 Initial tests of offshore supply facility installation

10.2.1 General

These tests shall verify that the *offshore supply facility* (3.17) installation complies with this specification to achieve a documented conformity record.

Tests shall be performed after completion of the installation.

10.2.2 Tests

The following tests shall be performed:

a) visual inspection;

b) power frequency test for high voltage switchgear assemblies and voltage test for cables in accordance with NEK IEC 62271-200 and NEK IEC 60502-2;

c) insulation resistance measurement;

d) measurement of the earthing resistor, including connection cables to star point and earthing bus;

e) offshore supply facility bonding connection resistance from earthing bus of supply switchboard terminal to connection point of facility (refer to 11.3);

f) function test including correct settings of the protection devices;

g) function test of the interlocking system;

h) function test of the control equipment;

i) phase-sequence test (see);

j) function test of the cable management system where applicable;

k) additional tests if required by national regulations.

10.3 Initial tests of ship installation

10.3.1 General

These tests shall verify that the ship installation complies with this specification. The target is to achieve a test certificate.

Tests shall be performed after completion of the installation.

These tests shall be conducted as witness tests together with the appropriate authorities.

10.3.2 Tests

The following tests shall be performed:

a) visual inspection;

b) power frequency test for high voltage switchgear assemblies and voltage test for cables in accordance with NEK IEC 62271-200 and NEK IEC 60502-2;

c) insulation resistance measurement;

d) ship bonding connection resistance (refer to 11.3);

e) function test including correct settings of the protection devices;

f) function test of the interlocking system;

g) function test of the control equipment;

h) phase-sequence test (see Figure 3);

i) function test of the cable management system, where applicable; and

j) integration tests to demonstrate that the ship installations such as the power management system, integrated alarm, monitoring and control system work properly together with the new installation.

10.4 Tests at the first call at a offshore supply facility

10.4.1 General

A compatibility assessment study in accordance with 4.3 shall be performed.

Upon completion of the tests in 10.2.2 and 10.3.2, the tests of 10.4.2 shall be conducted.

10.4.2 Tests

The following tests shall be performed as an integration test of the complete HVOC system:

a) visual inspection;

b) power frequency test for high voltage switchgear assemblies and voltage test for cables in accordance with NEK IEC 62271-200 and NEK IEC 60502-2;

c) insulation resistance measurement;

d) measurement of the earthing resistance;

e) function test of the protection devices;

f) function test of the interlocking system;

g) function test of the control equipment;

h) equipotential bond monitoring test, where utilized, or manual override test;

i) phase-sequence test (see Figure 4);

j) function test of the cable management system;

k) integration tests to demonstrate that the supply and ship installations work properly together.

The power frequency test for high voltage switchgear assemblies, voltage test for cables, insulation resistance measurement and measurement of the earthing resistance shall be performed only if one of the installations, either supply or ship, has been out of service or not in use for more than 18 months.

11 Periodic tests and maintenance

11.1 General

A record of annual maintenance, repair, equipment modifications and the test results shall be available for the offshore supply facility- and ship-side HVOC system.

11.2 Tests at repeated calls of a offshore supply facility

11.2.1 General

If the time between calls at the same offshore supply facility for the same ship does not exceed 12 months and if no modifications have been performed either on the supply or ship installation, or both, the verification in 11.2.2 shall be conducted.

If this time is exceeded, the tests in accordance with 10.4.2 shall be performed.

NOTE The time between connection calls means the same ship at the same offshore supply facility.

11.2.2 Verification

The following shall be performed or provided:

a) visual inspection;

b) (remote) confirmation that no earth fault is present;

c) (remote) statement of voltage and frequency;

d) an authorized switching and connection procedure or equivalent.

Procedures should include an approved method of securing against re-connection that is jointly controlled by the PIC(s).

11.3 Earthing bonding connections

Where equipotential bonding is not continuously monitored, the following procedures are required:

a) Physical connection points shall be inspected at a frequency not exceeding 18 months.

b) offshore supply facility bonding connection resistance shall be measured at a frequency not exceeding 18 months. Results shall not exceed 1 Ω.

c) Ship bonding connection resistance shall be measured at a frequency not exceeding 6 months. Results shall not exceed 1 Ω.

Measurement methods are site-specific and shall be documented.

12 Documentation

12.1 General

For the HVOC system and each control apparatus, the manufacturer shall deliver documentation concerning principles of operation, technical specifications, mounting instructions, required start-up or commissioning procedures, fault-finding procedures, maintenance and repair, as well as lists of necessary test facilities and replaceable parts.

12.2 System description

A complete system description, including circuit diagrams, specifying set points and operation instructions, shall be prepared by parties responsible for offshore supply facility and ship HVOC systems.

The parties responsible for offshore supply facility and ship HVOC systems shall provide a testing and verification programme for the whole installation that will demonstrate compliance with the specification.

Annex A
(informative)

Ship connection cable

A.1 Rated voltage

The standard rated voltages $U_0/U \quad (U_m)$ of the cables considered are as follows:

$U_0/U \quad (U_m) = 6/10(12)$ kV RMS

where

U_0 is the rated voltage between phase conductor and earth or metallic screen for which the cable is designed;

U is the rated frequency voltage between phase conductors for which the cable is designed;

U_m is the maximum value of the highest system voltage that may be sustained under normal operating conditions at any time and at any point in the system. It excludes transient voltage conditions and rapid disconnection of loads.

A.2 General design

A.2.1 General

The cables should be constituted as follows: power cores with copper conductors, conductor screen, insulation, insulation screen. The power cores should be laid up with earth cores with copper conductor and semi conducting layer. Additional elements, when required, such as pilot, *fibre optic* (3.11), metallic shields and cable tensile-strengthening should be designed in a manner suitable for the application.

NOTE NEK IEC 60092-350:2008, 4.6, provides further information regarding the use of inner coverings. NEK IEC 60092-350:2008, 4.7, provides further information regarding the use of inner sheathing.

Where an alternative to the recommendations of Annex A is proposed, it is possible that the installation will not be suitable for connection to a compliant offshore supply facility or ship. Application of an alternative should be documented and made available to personnel in charge of the compatibility assessment.

A.2.2 Conductors

All conductors should be flexible (class 5 of NEK IEC 60228 or Table 11 of IEEE Std 1580-2010™). The conductors should be plain or metal-coated copper conductors.

A.2.3 Insulation of power cores

The insulating compounds should be extruded cross-linked solid dielectric designated as EPR, HF EPR, HEPR or HF HEPR in NEK IEC 60092-360 or equivalent of EPR, HF EPR, HEPR or HF HEPR in IEEE Std 1580™.

Electrical and non-electrical characteristics of the insulation system should be as specified in NEK IEC 60092-360 or IEEE Std 1580™ for the type of insulating compound used.

Insulation thickness should be in accordance with NEK IEC 60092-354, or IEEE Std 1580™ for the standard rated voltages.

Other insulating compounds may be used if agreed by stakeholders to be more suitable for use in offshore applications.

A.2.4 Screening

Screening of individual power cores should consist of a conductor screen and an insulation screen.

The conductor screen should be non-metallic and should consist of an extruded semi-conducting compound or a combination of an extruded semi-conducting compound and a semi-conducting tape. The conductor screen should be firmly bonded to the insulation.

The insulation screen should consist of a non-metallic semi-conducting layer and, if necessary to fulfil the cable test requirements within Annex A , in combination with a metallic layer.

The metallic layer, where required, should be applied over the individual cores and should comply with the requirements of 5.5 of NEK IEC 60092-354:2014, or IEEE Std 1580™.

National authorities having jurisdiction may require a metallic component in the insulation screen

A.2.5 Earth conductors

A.2.5.1 General

Earth conductors should be flexible copper conductors in accordance with class 5 of NEK IEC 60228 or Table 11 of IEEE Std 1580™-2010 forming together at least 50 % of the power core cross-section. A smaller earth conductor may be used if proven sufficient by calculation, but not less than 16 mm2 (see 6.2.3).

A.2.5.2 Conductor screen of earth conductors (optional)

The conductor screen, when used, should be non-metallic and should consist of an extruded semi-conducting compound, in accordance with IEC 60092-354 or IEEE Std 1580.

A.2.6 Pilot element with rated voltage U0/U (Um) = 150/250 (300) V

A.2.6.1 Conductors

Pilot conductors should be flexible, plain or metal-coated copper conductors in accordance with class 5 of NEK IEC 60228 or Table 11 of IEEE Std 1580™-2010, with a minimum nominal cross-sectional area of 1,5 mm2.

A.2.6.2 Insulation

The insulation of pilot conductors should be extruded cross-linked solid dielectric of one of the types indicated in A.2.3.

Electrical and non-electrical characteristics of the insulation system should be as specified in NEK IEC 60092-360 or IEEE Std 1580 for the relevant type of insulating compound used.

Thickness of insulation should be in accordance with NEK IEC 60092-376 or IEEE Std 1580™ for the relevant insulation type.

Other insulating compounds may be used if agreed by stakeholders to be more suitable for use in offshore applications.

A wrapped covering with tapes or an extruded covering is permitted over the cores. Screening is optional.

A.2.7 Optical fibres

Optical fibres shall consist of a minimum number of six 62,5/125 gradient fibres. Optical fibres should be in accordance with NEK IEC 60793-2-10, product specification A1b.

There should be no breakage of the optical fibres after conclusion of the mechanical bending test (see A.3) of the cable.

A.2.8 Cabling

The three power cores, the earth core(s), the pilot element and, if present, the optical fibres should be laid up.

A.2.9 Separator tape

If separator tape is used, it should be wrapped around the assembled cores and should consist of a suitable, non-hygroscopic material.

A.2.10 Outer sheath

The outer sheathing material should have a high level of mechanical properties as per NEK IEC 60092-360 or IEEE Std 1580™. Thermoplastic polyurethane (TPU) in accordance with NEK EN 50363-10-2 is also an acceptable material.

Other outer sheathing materials may be used if agreed by stakeholders to be more suitable for use in offshore applications.

For all sheath materials, the minimum tensile strength should be 12,5 N/mm2. Minimum elongation at break should be 300 %. The minimum thickness at any point of the extruded outer sheath should be 6 mm for high voltage cables and 2,5 mm for separate neutral cable.

A.2.11 Markings

A.2.11.1 Indication of origin

Cable sheaths should be permanently marked repeatedly throughout their length with an indication of origin with the manufacturer's name and/or registered trademark, rated voltage (U0/U), construction (number of cores and cross-sectional area of power conductors, earth conductors, pilots and fibre type of fibre optics) and the relevant standard.

EXAMPLE "Manufacturer's name or trademark" 3×185/95 + 3×1.5 + 6× 62.5/125 6/10 kV NEK IEC/IEEE Std 80005-1

A.2.11.2 Continuity

Continuity should be in accordance with NEK IEC 60092-354 (NEK IEC 60092-353, for neutral cable) or IEEE Std 1580™.

A.2.11.3 Durability

Durability should be in accordance with NEK IEC 60092-354 (NEK IEC 60092-353, for neutral cable) or IEEE Std 1580™.

A.2.11.4 Legibility

Legibility should be in accordance with NEK IEC 60092-354 (NEK IEC 60092-353, for neutral cable) or IEEE Std 1580™.

A.3 Tests on complete cables

For these tests, reference is made to the relevant clauses of NEK IEC 60092-350 or IEEE Std 1580™.

For test methods for insulation and sheaths, reference should be made to the appropriate part of NEK IEC 60811 (all parts).

Routine tests, special tests and type tests should be conducted in accordance with NEK IEC 60092-354 or IEEE Std 1580™ with the following additions or modifications:

a) Bending test (see Figure A.1):

   1) The test should consist of 5 000 cycles of operation.

   2) After 2 500 cycles, the cable should be rotated 180 degrees.

b) The diameter of the bending reels should be 10 D with a tolerance of ±5 %; where:

   1) D is the actual external diameter of the cable sample, in millimetres;

   2) tensile force should be 15 N/mm2 of power cores;

   3) maximum percentage of broken wires for each conductor and metallic screen, if required, should not exceed 20 %;

   4) maximum percentage of broken optical fibres, if present, to be 0 %.

   On completion of this test, the sample should be subjected to a partial discharge measurement. The magnitude of discharges at 1,73 U_0 should not be higher than 10 pC.

c) Sunlight-resistance test on outer sheath (duration of test 720 h):

   1) The test should be performed in accordance with ISO 4892-2:2013, Table 3, test method A, cycle no. 1.

   2) Maximum permissible change: tensile strength ±40 %, and elongation at break ±40 %.

d) Abrasion test on outer sheath:

   1) The test should be performed in accordance with ISO 4649:2010, test method A.

   2) Relative volume loss,$\Delta V_{rel}: max \quad 300 \quad mm^3$

e) Flame propagation test:The test should be performed in accordance with NEK IEC 60332-1-2 and should at least satisfy the recommended requirements of Annex A of this specification.

f) Behaviour of completed cable at low temperatures: The test should be performed in accordance with NEK IEC 60092-350:2008, 8.9.1, 8.9.2, and Annex E, or IEEE Std 1580™. The test should be conducted at −40 °C ± 2 °C.

g) Resistance between earth conductor and semi-conductive layer:The resistance between earth conductor and semi-conductive layer should be maximum 500 ohms before and after bending test.

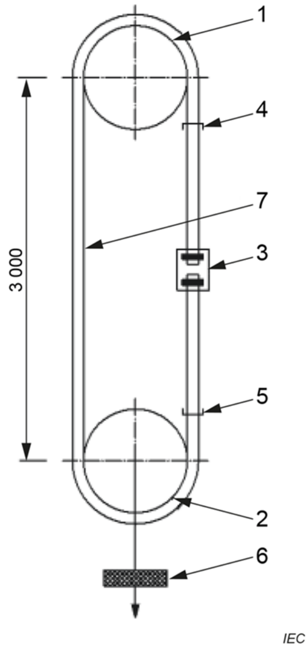

Figure A.1 — Bending test arrangement

1	Upper bending reel	5	Lower point of return
2	Lower bending reel	6	Tensioning device
3	Clamp	7	Specimen movement
4	Upper point of return		