



GUIDE FOR

HIGH VOLTAGE SHORE CONNECTION

NOVEMBER 2011

**American Bureau of Shipping
Incorporated by Act of Legislature of
the State of New York 1862**

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Foreword

It is envisaged that the effect of increasingly stricter air emissions legislation implemented through mainly local air quality controls will see an increasing number of vessels installing high voltage shore connection (HVSC) in the near future.

Shore power supply facilities have adopted high voltage rather than low voltage by necessity in order to keep the physical size of related electrical equipment such as shore connection cables manageable. Inevitably high voltage would otherwise introduce new risks to ship's crew and the shipboard installations if necessary safety features were not built into the HVSC system or safe operating procedures were not put in place. Accordingly, the requirements of this Guide have been developed with the primary focus on the safety of operating crews as well as for the security of the shipboard equipment.

It should be noted that the requirements in this Guide have been developed in consideration of the joint effort by IEC, ISO and IEEE to establish an international standard for Cold Ironing – High Voltage Connection Systems which at the time of the issuance of this Guide is under development.

The applicable edition of the *Rules for Building and Classing Steel Vessels* is to be used in association with the subject Guide.

This Guide becomes effective on the first day of the month of publication.

Users are advised to check periodically on the ABS website www.eagle.org to verify that this version of this Guide is the most current.

We welcome your feedback. Comments or suggestions can be sent electronically by email to rsd@eagle.org.



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1 Application

Requirements in this Guide apply to vessels equipped with a high voltage shore connection system (HVCS) designed to power the vessel with the shore power alone, enabling the shipboard generators to be shut down while in port. The installation of a HVSC is optional, however if installed it is to be designed, installed and surveyed in accordance with this Guide, and when found satisfactory, a classification notation as specified in Section 3 will be granted.

2 Objectives

The objective of this Guide is to provide requirements for the design, installation and survey of high voltage shore connection installations. The requirements in this Guide address:

- i)* The safety of shipboard and, where applicable, shoreside personnel during the deployment and retrieval of the cable and when making the HV connection.
- ii)* The safety of shipboard personnel during the period in which the vessel is operating using the established HV shoreside connection.
- iii)* The safety of the shipboard personnel should the HV connection malfunction.
- iv)* The safety of shipboard personnel and shoreside staff as applicable at the time the HV connection between the vessel and the shoreside supply is disconnected.
- v)* Requirements for the safe storage of the HV equipment and associated connections when the vessel is on voyage or in ports where no HV connection is established.

These objectives are to be achieved by means of the system design, the construction of the HV equipment and operating safety procedures.

3 Classification Notation

A vessel with a high voltage shore connection installation which is found to be in compliance with the requirements in this Guide will be assigned the classification notation **HVSC**.

4 Plans and Data to be Submitted

The following plans and data are to be submitted:

- i)* One-line diagram showing shipboard elements of the HVSC
- ii)* Descriptions of Electrical System Grounding philosophy (See Section 5 and 7.3.3)
- iii)* Descriptions of instrumentation, monitoring and alarms
- iv)* Short-circuit current calculations for each shore facility
- v)* Protection device coordination study for each shore facility
- vi)* Load analysis
- vii)* Capacity rating of HVSC installation, including maximum design short-circuit level
- viii)* Details of shore connection switchboard, including outline view, internal arrangement, dimensions, IP rating, circuit breaker rating, socket rating and schematics
- ix)* Details of transformer including kVA rating, impedance information and construction details

- x) Cable specifications
- xi) Details of portions of the ship's main switchboard that are associated with the HVSC interface
- xii) Descriptions of the automatic synchronization system for the temporary generator parallel running of ship's generator and the shore power, if fitted
- xiii) Descriptions of safety interlocks (See 7.11)
- xiv) Details of the cable management system, if installed
- xv) Equipment locations, including the routing of HV cables
- xvi) Operation manual as required by Section 11

5 Definitions

High Voltage Shore Connection (HVSC) Installation: Those onboard systems that are designed to accept high voltage shore power, typically involving incoming power receptacles, shore connection switchgear, step-down transformer or isolation transformer, fixed power cables, incoming switchgear at the main switchboard and associated instrumentation. HVSC is often referred to as *Cold Ironing* or *Alternative Marine Power*.

High Voltage (HV): For the purpose of this Guide, the system nominal voltage is considered to be in the range from 1 kV AC to 15 kV AC.

Electrical System Grounding Philosophy: The manner in which electrical system is grounded (e.g., ungrounded system, solid neutral grounding system, low impedance neutral grounding system, or high impedance neutral grounding system), including ground potential transformer method. Circuit protection strategy is built around the selected method of system grounding in terms of over voltage prevention, over current prevention or continued operability under single phase grounded condition.

Cable Management System: The cable management system is the ship's interface point with the shore power system. The cable management system is typically composed of flexible HV cables with the plug that extends to the shore power receptacle, cable reel, automatic tension control system with associated control gears, and instrumentation. Shore power is fed to the shore connection switchboard via the cable management system.

Shore Connection Switchboard: Where no cable management system is provided onboard, the shore connection switchboard is normally the ship's interface point with the shore power system. HV shore power is connected to this shore connection switchboard by means of an HV plug and socket arrangement. The shore connection switchboard is provided with a shore power connecting circuit breaker with circuit protection devices.

Onboard Receiving Switchboard: The receiving switchboard is normally a part of the ship's main switchboard to which the shore power is fed from the shore connection switchboard.

6 Alternative Arrangements

Alternative arrangements that differ from the specific requirements in this Guide and that provide an equivalent level of safety may be considered on their technical merits.

7 System Design

7.1 Shore Power Compatibility

Means to check shore power compatibility (e.g., correct voltage range, frequency and phase rotation) are to be provided at the location from which the HVSC circuit breakers are controlled (e.g., at the control station in the engine control room).

7.2 Capacity

HVSC installation is to be sufficiently rated to supply the following:

- i) Normal services required in port
- ii) Emergency services
- iii) Services needed to support the ship's operations in port

7.3 Grounding

7.3.1 Equipotential Bonding

Equipotential bonding between the ship and the shore is to be provided. An interlock is provided such that the HV shore connection cannot be established until the equipotential bonding has been established. The bonding cable may be integrated into the HV shore power cable. If the equipotential bonding cable is intended to carry the shipboard ground fault current, the cable size is to be sufficient to carry the design maximum ground fault current.

7.3.2 Equipotential Bonding Safety Interlock

An interlock arrangement is to be provided such that the loss of equipotential bonding is to result in the disconnection of the HV shore power. See 7.13.2i).

7.3.3 System Grounding Compatibility

Arrangements are to be provided so that when the shore connection is established, the resulting system grounding onboard is to be compatible with the vessel's original electrical system grounding philosophy (for instance, the shipboard ungrounded power distribution system is to remain ungrounded, or the shipboard high impedance grounding system is to remain high impedance grounded within the design grounding impedance values). Ground fault detection and protection is to remain available after the shore connection has been established. Examples are shown in Figures 1 through 4.

7.3.4 Voltage rating

The voltage rating of electrical equipment insulation materials is to be appropriate to the system grounding method, taking into consideration the fact that the insulation material will be subjected to $\sqrt{3}$ times higher voltage under single phase ground fault condition.

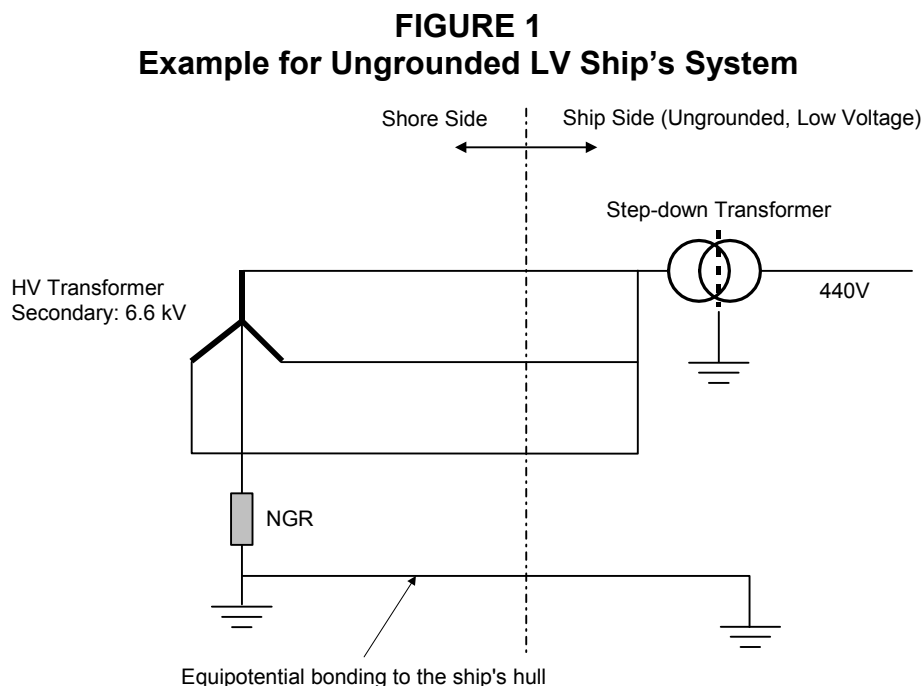


FIGURE 2
Example for Grounded HV Ship's System
(where NGR Value is Compatible with the Ship's Design Ground
Current Range, Otherwise 1:1 Isolation Transformer may be Required)

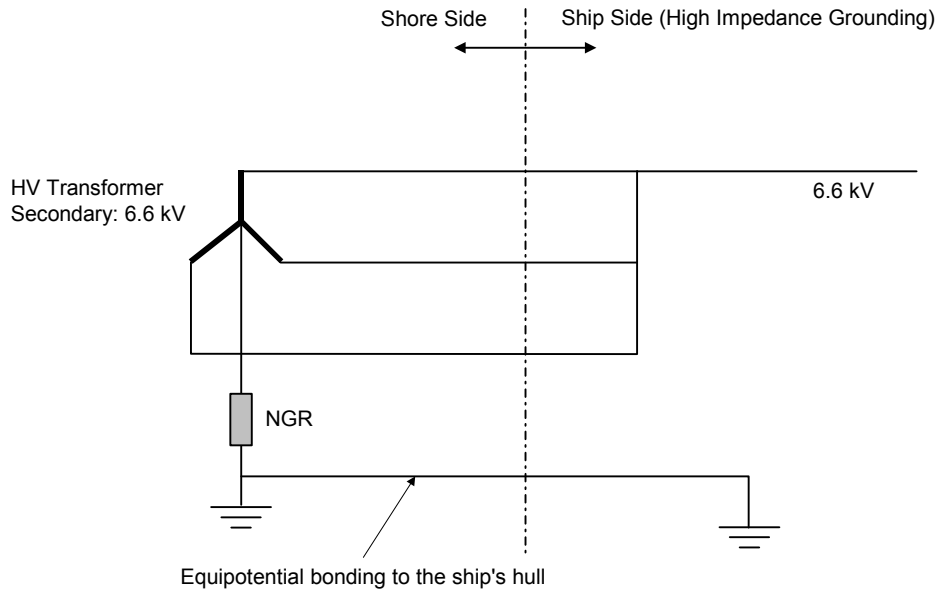


FIGURE 3
Example for Ungrounded Ship's System (e.g., Oil Carriers and Gas Carriers)

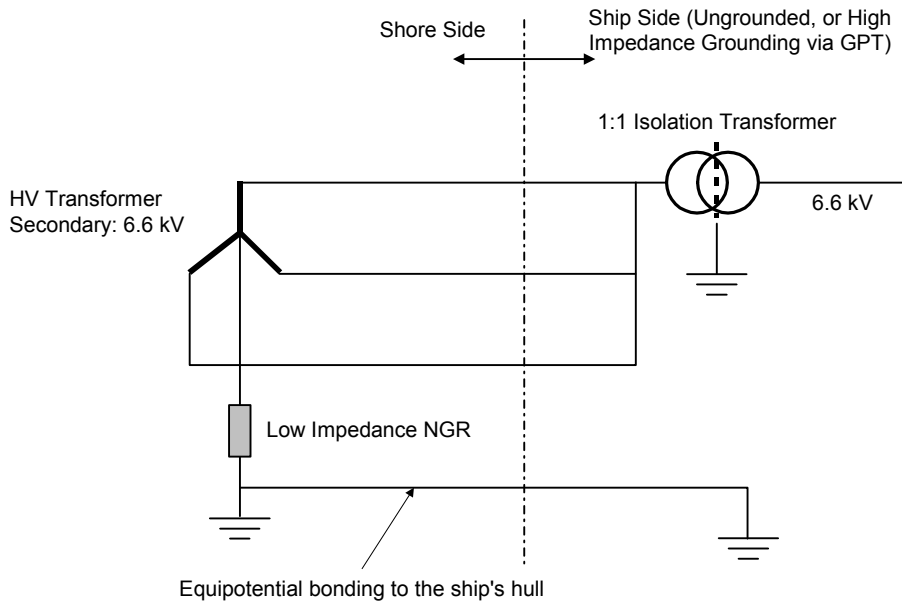
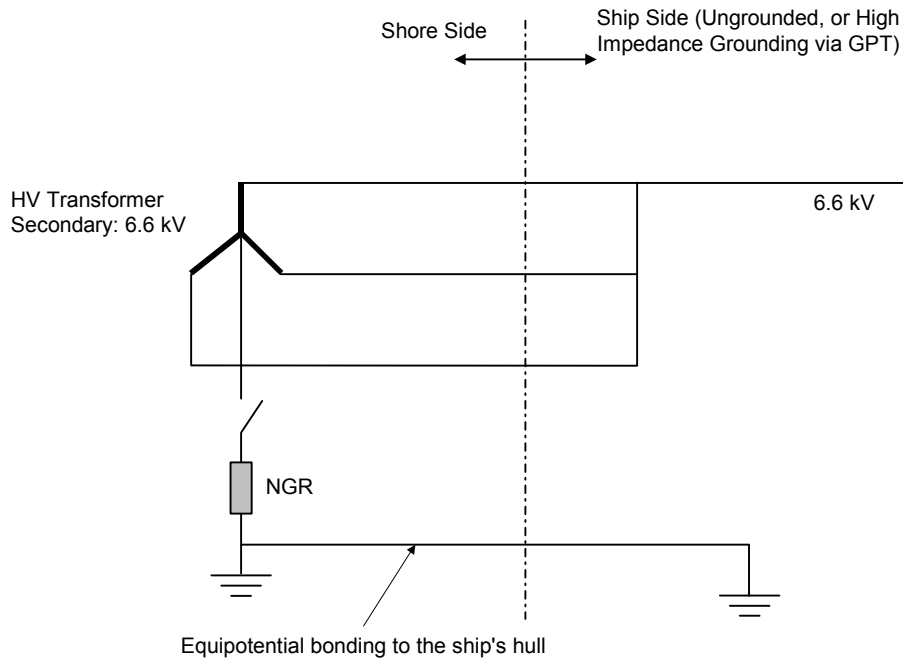


FIGURE 4
Example for Ungrounded Ship's System where Shoreside Option for Ungrounded Neutral is Available (e.g., Oil Carriers and Gas Carriers)



7.4 Circuit Protection

The HV shore connection switchboard is to be provided with a circuit breaker to protect fixed HV electrical cables installed from that point onward.

7.5 Short-circuit Level Compatibility

After a shore connection has been established, the prospective short-circuit current level at any point in the ship's power distribution system is not to exceed the short-circuit breaking and making capacities of circuit breakers installed onboard. Operational procedures are to be established for assessment of the shoreside impedance, which determines the prospective short-circuit current level after the shore connection has been established. Procedures are to be included in the operation manual.

7.6 Overvoltage Protection

Where a step-down transformer is installed onboard, the ship's low voltage system is to be protected against accidental overvoltage. This may be achieved by:

- i) Direct earthing of the lower voltage system while the shore power is connected
- ii) Earthed screen between the primary and the secondary windings of the transformer

7.7 Protective Device Coordination

The feeder circuit breaker on the main switchboard serving the shore connection is to be coordinated with the generator circuit breakers such that a short-circuit fault in the shore connection circuit will not result in a blackout condition.

7.8 Protection of Transformer

Transformer, where provided, is to be protected against short-circuit and overload protection in accordance with 4-8-2/9.19 of the *ABS Rules for Building and Classing Steel Vessels (Steel Vessel Rules)*. The overload protection device must have time-current protection characteristics consistent with the transformer's thermal damage characteristics.

7.9 Load Transfer

7.9.1 Temporary Parallel Running

Where the shipboard generator is intended to run in parallel with the shore power for a short period of time for the purpose of connecting to the shore power or back to ship power without going through a blackout period, the following requirements are to be complied with:

- i)* Means are to be provided to verify that the incoming voltage is within the range for which the shipboard generator can be adjusted with its automatic voltage regulator (AVR)
- ii)* Means are to be provided for automatic synchronization
- iii)* Load transfer is to be automatic
- iv)* The duration of the temporary parallel running is to be as short a period as practicable allowing for the safe transfer of the load. In determining the rate of the gradual load transfer, due regard is to be paid to the governor characteristics of shipboard generator in order not to cause excessive voltage drop and frequency dip.

7.9.2 Load Transfer via Blackout

Where load transfer is executed via blackout (i.e., without temporary generator parallel running), safety interlock arrangements are to be provided so that the circuit breaker for the shore power at the shore connection switchboard cannot be closed while the HV switchboard is live with running shipboard generator(s).

7.10 Failure Recovery Strategy

In the event of a shore power failure, the shipboard power is automatically restored to an extent that the safe operations of the ship can be maintained. Detailed procedures for the failure recovery are to be included in the operation manual.

7.11 Safety Interlocks

An interlock, which prevents plugging and unplugging of the HV plug and socket outlet arrangements while they are energized, is to be provided.

7.11.1 Handling of HV Plug

While the HV shore connection circuit breakers are in the open position, the conductors of the HV supply cables are to be automatically kept earthed by means of an earthing switch. A set of pilot contactors embedded in the HV plug and socket-outlet may be used for this purpose. The earthing switch control is to be designed based on a fail-to-safe concept such that the failure of the control system will not result in the closure of the earthing switch onto the live HV lines.

7.11.2 HV Shore Connection Circuit Breakers

Arrangements are to be provided to prevent the closing of the shore connection circuit breaker when any of the following conditions exist:

- i)* Equipotential bonding is not established
- ii)* The pilot contact circuit is not established
- iii)* Emergency shutdown facilities are activated
- iv)* An error within the HV connection system that could pose an unacceptable risk to the safe supply of shoreside power to the vessel. These errors may occur within the alarm system, whether on board the ship or at the shoreside control position, or within any relevant safety systems including those which monitor system performance.
- v)* The HV supply is not present

7.11.3 Closing of Shoreside HVSC Circuit Breaker

Arrangements are to be provided such that the shoreside HVSC circuit breaker may be closed after the ship side sends a "permission to close" signal to the shore. Such arrangements may be based on an interlock or visual signal.

7.12 HVSC Circuit Breaker Control

HV shore connection circuit breakers are to be remotely operated away from the HVSC equipment. Operational procedures are to be established that state that the attempts to close HV shore connection circuit breakers are to be made only when it has been established that personnel are evacuated from the HV shore connection equipment compartments. The operation manual is to describe these established procedures.

7.13 HVSC Emergency Shutdown

7.13.1

In the event of an emergency, the HV system shall be provided with shutdown facilities that immediately open the shore connection circuit breaker. These emergency shutdown systems are to be automatically activated.

7.13.2

Any of the following conditions are to cause emergency shutdown of the shore power supply:

- i)* Loss of equipotential bonding
- ii)* High tension level of HV flexible shore connection cable, or low remaining cable length of cable management system
- iii)* Shore connection safety circuits fail
- iv)* The emergency stop button is used (see 7.13.3)
- v)* Any attempts to disengage the HV plug while live (this may be achieved by the pilot contactors embedded in the plug and socket such that the pilot contactors disengage before the phase contactors can disengage)

7.13.3

Emergency stop buttons that initiate emergency shutdown systems are to be provided:

- i)* At the remote location from which the HVSC circuit breakers are controlled (see 7.12)
- ii)* At the shipboard control center for management of the cable and connection and at additional control locations, as applicable and deemed necessary
- iii)* At the shore connection switchboard

Emergency stop buttons are to be clearly marked so that their method of operation is visible, legible and easily followed. Positioning of the emergency stop buttons and attendant operational instructions should be such as to prevent accidental or inadvertent operation. Once activated, the emergency stop button should require manual action to reset.

Activation of the emergency stop button is to result in a clearly visible visual warning and easily recognizable audible alarm.

7.13.4

Following the emergency shutdown, the ship's electrical power is to be automatically restored. See 7.10.

7.14 Harmonics

Where power converter equipment is provided within the shore connection system in order to obtain desired voltage and/or frequency, the total voltage harmonic distortion of the converter is not to exceed 5 percent at any operating load.

7.15 Monitoring and Alarms

The following monitoring and alarms are to be provided at the location from which the HVSC circuit breakers are controlled, and at other strategic locations that are normally manned if deemed necessary:

- i) Overtension alarm on HV flexible shore connection cables, or cable management system over-deployment (low remaining cable length) alarm, prior to the emergency shutdown [see 7.13.2ii]
- ii) The loss of shore power
- iii) Emergency shutdown
- iv) Manual emergency-stop
- v) Safety device activation alarms (e.g., overcurrent, earth fault)

8 Equipment Design

8.1 General

Electrical equipment is to be constructed of durable, flame-retardant, moisture-resistant material, which are not subject to deterioration in the marine environment and at the temperatures to which it is likely to be exposed. The determination of equipment protection class (IP rating) is to be in accordance with 4-8-3/Table-2 of the *Steel Vessel Rules*.

8.2 Protection Against Moisture and Condensation

Means are to be provided to prevent accumulation of moisture and condensation.

8.3 Air Clearance

Phase-to-phase air clearances and phase-to-earth air clearances between non-insulated parts are to be not less than the minimum, as specified in Table-1.

TABLE-1
Air Clearance

<i>Nominal Voltage kV</i>	<i>Minimum Air Clearance mm (in.)</i>
3 - 3.3	55 (2.2)
6 - 6.6	90 (3.6)
10 - 11	120 (4.8)

Where intermediate values of nominal voltages are accepted, the next highest air clearance is to be observed.

8.4 Creepage Distance

Creepage distances between live parts and between live parts and earthed metal parts are to be adequate for the nominal voltage of the system, due regard being paid to the comparative tracking index of insulating materials under moist conditions according to the IEC Publication 60112 and to the transient overvoltage developed by switching and fault conditions.

8.5 Shore Connection Switchboard

8.5.1 Construction

The HV shore connection switchboard is to be designed, manufactured and tested in accordance with a recognized standard such as IEC 62271-200.

8.5.2 Circuit Breaker

- i)* Shore connection HV circuit breaker is to be equipped with low voltage protection (LVP)
- ii)* The rated short-circuit making capacity of the circuit breaker is not to be less than the prospective peak value of the short-circuit current
- iii)* The rated short-circuit breaking capacity of the circuit breaker is not to be less than the maximum prospective symmetrical short-circuit current
- iv)* HV shore connection circuit breaker is to be remotely operated

8.6 Onboard Receiving Switchboard

8.6.1 Construction

The HV shore connection switchboard is to be designed, manufactured and tested in accordance with a recognized standard such as IEC 62271-200.

8.6.2 Instrumentation

The receiving switchboard is to be equipped with:

- i)* Voltmeter(s), all three phases, for the shore power and the shipboard power
- ii)* Phase rotation indicator for the shore power
- iii)* Frequency meter(s) for the shore power and the shipboard power
- iv)* Ammeter for the shore power, all three phases
- v)* Synchronizing device, see 7.9.1
- vi)* Short-circuit protection
- vii)* Overcurrent protection
- viii)* Earth-fault detection

8.6.3 Circuit Breaker

- i)* The rated short-circuit making capacity of the circuit breaker is not to be less than the prospective peak value of the short-circuit current
- ii)* The rated short-circuit breaking capacity of the circuit breaker is not to be less than the maximum prospective symmetrical short-circuit current
- iii)* HV shore connection circuit breaker is to be remotely operated

8.7 Cable Management System

The cable management system is to allow extending cable and retracting cable without causing undue stress to the cable. The slip ring, where provided, is to be tested in accordance with 12.3.

8.8 Shore Connection Plugs and Receptacle

- i)* Interlock between the plug and the shore connection circuit breaker is to be provided such that the plug can be disengaged only after the shore connection circuit breaker has been opened. This may be achieved by the construction of a plug and socket. An example is shown in Figure 5.
- ii)* Plugs and sockets are to be protected from dust, moisture and condensation while not in use. The minimum protection rating of plugs and sockets is to be IP66. An example of the socket is shown in Figure 5.

8.9 Transformer

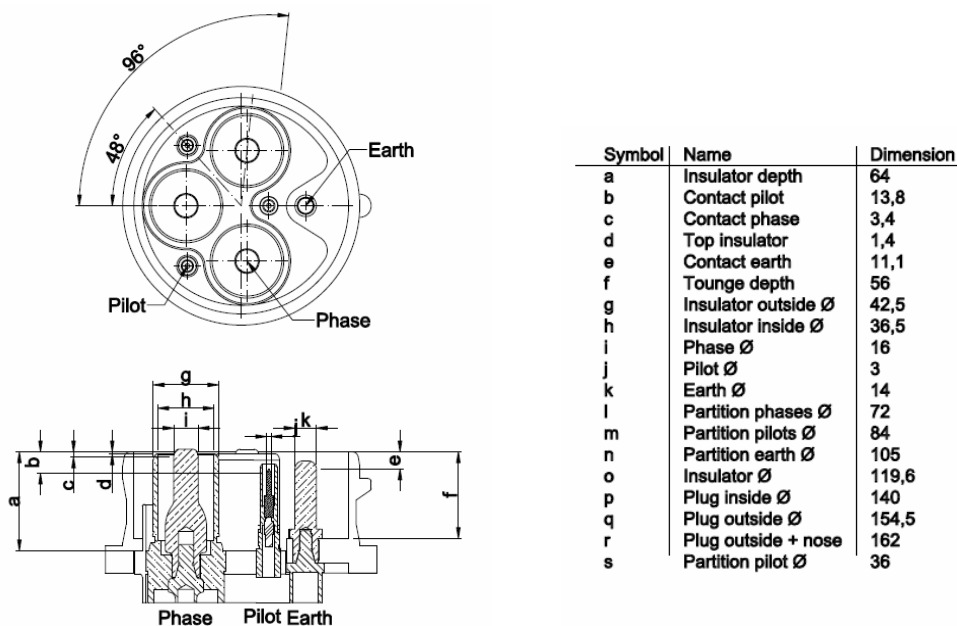
Where provided, the transformer is to be in compliance with the requirements of 4-8-5/3.7.5 of the *Steel Vessel Rules*.

In determining the continuous rating of the transformer, the level of harmonics current is to be taken into consideration.

8.10 HV Cables

Shipboard fixed HV cables are to be in compliance with IEC 600092-353, 600092-354 or other relevant standards acceptable to ABS. Non-fixed HV cables are to be constructed and tested to recognized standard acceptable to ABS.

FIGURE 5
Example of Plug and Socket, interlock by Pilot Contactor
 (The pilot contactor disengages before the phase conductors disengage)



Note: Image courtesy of CAVOTEC.

9 Installations

9.1 Equipment Locations

- i) Access to HVSC equipment is to be subject to appropriate controls.
- ii) The shore connection switchboard is to be located in a compartment that is sheltered from the weather. HV shore cables are to enter this compartment through a temporary opening with weathertight arrangements
- iii) This compartment is not to have any opening(s) within a designated hazardous area
- iv) Ample space around the shore connection switchboard is to be available for the operating crew to freely perform connecting and disconnecting operations

9.2 Voltage Segregation

Higher voltage equipment is not to be combined with low voltage equipment in the same enclosure, unless segregation or other suitable measures are taken to provide safe access to lower voltage equipment.

9.3 HV Cable Installation

9.3.1 Runs of Cables

In accommodation spaces, high voltage cables are to be run in enclosed cable transit systems.

9.3.2 Segregation

High voltage cables are not to be installed on the same cable tray for the cables operating at the nominal system voltage of 1 kV or less.

9.3.3 Installation Arrangements

High voltage cables are to be installed on cable trays or equivalent when they are provided with a continuous metallic sheath or armor which is effectively bonded to earth; otherwise, they are to be installed for their entire length in metallic casings effectively bonded to earth.

9.3.4 Marking

High voltage cables are to be readily identifiable by suitable marking.

9.4 Storage

Appropriate arrangements are to be provided for storage of removable HVSC equipment when not in use. Such storage should take into account issues such as, but not restricted to, temperature, humidity, moisture, condensation, dirt, and dust, and should protect against the likelihood of physical damage to the cable, plugs, sockets, and associated equipment.

10 Maintenance Plan

A maintenance plan is to be developed to establish periodic tests and maintenance procedures for the HVSC system. The maintenance plan is to be included in the Operation Manual.

11 Operation Manual

A manual depicting operational procedures for the HV shore connection system is to be readily available for the operating crew. The manual is to include, but not limited to, the following:

- i)* Operating crews' qualification requirements
- ii)* Shore power compatibility assessment procedures, including acceptable voltage tolerance, frequency and correct phase rotation, the shoreside source impedance for the assessment of prospective short circuit current, and the shoreside neutral grounding method for the assessment of ship's system grounding compatibility (see 7.3.3)
- iii)* Operational procedures to establish actions to be taken when the shore power is found not compatible with the shipboard system.
- iv)* Step-by-step instructions to establish shore connection and disconnection, including equipotential bonding and load transfer
- v)* Procedures for sending to the shore "permission to close" shoreside HVSC circuit breaker (see 7.11.3)
- vi)* Emergency shutdown procedures (see 7.13)
- vii)* Failure recovery procedures (see 7.10)
- viii)* Storage requirements for HVSC equipment (see 9.4)
- ix)* HVSC system maintenance plan (see Section 10)

The operation manual is to be readily available for operators at the operating stations

12 Tests

12.1 HV Switchboard

12.1.1 Type Test

HV switchboards are to be subjected to an AC withstand voltage test in accordance with Table-2 or other relevant national or international standards. A test is to be carried out at the manufacturer's test facility in the presence of the Surveyor.

12.1.2 Onboard Test

After installation onboard, the HV switchboard is to be subjected to an insulation resistance test in accordance with Table-2 in the presence of the Surveyor.

**TABLE 2
AC Withstand Test**

System Nominal Voltage	11 KV rms	6.6 KV rms
AC withstand test voltage	32 KV rms	20 KV rms
Insulation resistance test	DC1 KV	DC 1 KV

Note: The dielectric test is to be performed for 1 minute.

12.2 HV Transformer

A transformer is to be tested in accordance with 4-8-5/3.7.5 (e) of the *Steel Vessel Rules*. A transformer rated 100 kVA and above is to be tested in the presence of Surveyor.

12.3 HV Cable Reel Slip Ring

12.3.1 Type Test

A slip ring is to be subjected to an AC withstand voltage test in accordance with Table-2 or other relevant national or international standards. The test is to be carried out at the manufacturer's test facility in the presence of the Surveyor.

12.3.2 Onboard Test

After installation onboard, the HV switchboard is to be subjected to an insulation resistance test in accordance with Table-2.

12.4 Cable Test After Installation

A voltage withstand test is to be carried out in accordance with 4-8-5/3.13.3 of the *Steel Vessel Rules* in the presence of the Surveyor.