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HIGH VOLTAGE INSTALLATIONS ON BOARD SHIPS SPECIAL EDITION

Chris Spencer: Director of Loss Prevention
Telephone: +44 20 3320 8807
E-mail: chris.spencer@ctcplc.com

IN THIS ISSUE

This special edition *Standard Safety* highlights the dangers of high voltage electrical systems on ships. These are increasingly being used and present real dangers and hazards to personnel who are not trained or aware of the dangers. Those personnel using high voltage systems on ships should be trained in the additional safety procedures required before using or maintaining high voltage systems. The dangers of high voltage systems should not be underestimated, and untrained personnel could be at great risk.

The demand for electrical power has increased on many ships, especially those with diesel-electric propulsion where the supply current becomes too high. The supply current becomes far too high and it is not efficient or practical to use the common shipboard voltage supply of 440V. Higher voltage is needed to reduce the current. Modern ships, particularly container, passenger and specialist offshore ships are built now with high voltage generating plant; however, the engineer officers will normally only have been trained on low voltage systems. Also not every ship has an electrician and the engineers often have to do the electrician's work when things go wrong. The club's surveyors have often seen that many engineer officers do not fully understand the dangers associated with high voltage systems.

For example, when generating electrical power at 6.6kV, this will produce a current of 220 amps as opposed to 3,300 amps if the voltage is 440V. The short-circuit currents would also be much lower at only 9,000 amps for the 6.6kV instead of 90,000 amps for the 440V supply. This potential fault current is considerably lower for high voltage supplies and is easily handled by the equipment.

^ High voltage installation on special power station ship

WHAT IS CLASSED AS HIGH VOLTAGE?

In marine practice, voltages below 1,000Vac (1kV) are considered low voltage, and high voltage is any voltage above 1kV. Typical marine high voltage system voltages are 3.3kV, 6.6kV and 11kV.

HIGH VOLTAGE EQUIPMENT

A typical high voltage installation will incorporate only high voltage rated equipment on the following:

- generating sets
- high voltage switchboards with associated switchgear, protection devices and instrumentation
- high voltage cables
- high voltage/low voltage step-down transformers to service low voltage consumers
- high voltage/high voltage (typically 6.6kV/2.9kV) step-down transformers supplying propulsion converters and motors
- high voltage motors for propulsion, thrusters, air conditioning and compressors

^ Step-down transformer

THE MAJOR DIFFERENCES BETWEEN HIGH VOLTAGE SUPPLY AND LOW VOLTAGE SUPPLY ON BOARD SHIPS ARE:

- high voltage systems are more extensive with complex networks and connections
- isolated equipment MUST BE earthed down
- access to high voltage areas should be strictly limited and controlled
- isolation procedures are more involved
- switching strategies should be formulated and recorded
- specific high voltage test probes and instruments must be used
- diagnostic insulation resistance testing is necessary
- high voltage systems are usually earthed neutral and use current limiting resistors
- special high voltage circuit breakers have to be installed

^ Example of approved 'Potential Indicator' (or earthing rod)

^ High voltage test equipment

DANGERS WORKING WITH HIGH VOLTAGE EQUIPMENT

A high voltage electrical shock is a significant danger to any person carrying out electrical work. Any simultaneous contact with a part of the body and a live conductor will probably result in a fatal electric shock. There is also a risk of severe burn injuries from arcing if conductors are accidentally short-circuited.

A high voltage electric shock will almost certainly lead to severe injury or a fatality.

Factors that could increase the risk of receiving an electric shock:

- high voltage work may be carried out close to a person that is not familiar with high voltage hazards. Therefore, the area must be secured from the surrounding non-electrical work and danger notices posted
- areas of earthed metal that can be easily touched increase the possibility of electric shock from a high voltage conductor
- high voltage insulation testing (flash testing) can be particularly hazardous when several parts of the equipment are energised for a period of time
- equipment using water as part of the high voltage plant can lead to an increased risk of injury
- using test instruments when taking high voltage measurements can increase the risk of injury if the protective earth conductor is not connected. This can result in the enclosure of the instrument becoming live at dangerous voltages
- high voltage equipment will store energy after disconnection. For example, on a 6.6kV switchboard, a fatal residual capacitive charge may still be present hours or even days later
- if, during maintenance, a high voltage circuit main earth (CME) is removed from the system, it must not be worked on as the high voltage cabling can recharge itself to a high voltage (3–5kV) from induced voltages from nearby live high voltage cabling

HIGH VOLTAGE SYSTEM SAFETY REQUIREMENTS

TRAINING

High voltage system training is now a part of the Standards of Training Certification and Watchkeeping convention (STCW) following the 2010 Manila amendments for senior engineering staff who have responsibility for operating and maintaining electrical power plants above 1,000 volts. However, existing officers will not have this training until their certificates are revalidated.

This training includes:

- operational and safety requirements for high voltage systems
- maintenance and repair of high voltage switchgear
- taking appropriate action when dealing with faults in a high voltage system
- switching strategies for isolating components of a high voltage system
- using suitable apparatus for isolation and testing of high voltage equipment
- switching and isolation procedures on a marine high voltage system
- understanding safety documentation for high voltage systems
- testing of insulation resistance and polarisation index on high voltage equipment

RISK ASSESSMENT

The access to high voltage switchboards and equipment must be strictly controlled by using a risk assessment and a permit to work system. Isolation procedures must involve a safety key system and earthing down procedures.

Remember the acronym:

- **D**isconnect
- **I**solate
- **E**arth

To help identify high voltage system work precautions, a risk assessment must be completed by the Chief Engineer or Chief Electrical officer before work begins, and this should consider:

- how familiar are the personnel with the high voltage system and equipment?
- can the work be done with the equipment dead?
- is it necessary for someone to work on or near live high voltage equipment?
- what precautions have been taken to avoid danger and prevent injury?
- is the person(s) carrying out the work competent or adequately supervised?

PERMIT TO WORK SYSTEM FOR HIGH VOLTAGE SYSTEM WORK

The company safety management system (SMS) should include a permit to work system for electrical equipment under 1,000V. A similar high voltage permit should also be included in the SMS. Samples of electrical permits for low voltage and high voltage installations can be found in the Code of Safe Working Practices for Merchant Seaman (COSWP) 2010 edition, which can be found free of charge at: http://www.dft.gov.uk/mca/coswp2010.pdf.

LOW VOLTAGE SYSTEM PERMITS TO WORK ARE NOT APPROPRIATE FOR WORKING WITH HIGH VOLTAGE SYSTEMS.

ADDITIONAL PROCEDURES NEEDED FOR HIGH VOLTAGE SYSTEMS

These additional procedures are freely available from the MCA Code of Safe Working Practices for Merchant Seaman (COSWP) 2010 edition, which could be used as reference.

Sanction-for-test System

Following work on a high voltage system, it is often necessary to perform various tests. Testing should only be carried out after the circuit main earth (CME) has been removed.

A sanction-for-test declaration should be issued in an identical manner to a permit to work provided and it should not be issued on any apparatus where a permit to work or where another sanction-for-test is in force. **Note:** A sanction-for-test is NOT a permit to work.

An example of a sanction-for-test declaration is shown in the Code of Safe Working Practices (COSWP) 2010 edition Annex 16.2.1.

Limitation of access form

When carrying out high voltage maintenance, it may be dangerous to allow anyone to work adjacent to high voltage equipment, as workers may not be familiar with the risks involved when working on or nearby high voltage equipment. The limitation of access form states the type of work that is allowed near high voltage equipment and safety precautions. The form is issued and signed by the Chief Engineer or Chief Electrical officer, and countersigned by the person carrying out the work.

Earthing down

Earthing down is a very important concept to understand when working with high voltage systems. It is important to ensure that any stored electrical energy in equipment insulation after isolation is safely discharged to earth. The higher levels of insulation resistance required on high voltage cabling leads to higher values of insulation capacitance (C) and greater stored energy (W). This is demonstrated by the electrical formula:

Energy stored (W) Joules = (Capacitance x Voltage^2)/2

Earthing down ensures that isolated equipment remains safe.

Even if the system is isolated, you can still receive a fatal shock caused by the stored energy. The system must be earthed and proven dead before work commences.

There are two types of earthing down a high voltage switchboard:

Circuit earthing – an incoming or outgoing feeder cable is connected by a heavy earth connection from earth to all three conductors after the circuit breaker has been racked out. This is done at the circuit breaker using a special key. This key is then locked in the key safe. The circuit breaker cannot be racked in until the circuit earth has been removed.

Busbar earthing – when it is necessary to work on a section of the busbars, they must be completely isolated from all possible electrical sources. This will include generator incoming cables, section or bus-tie breakers, and transformers on that busbar section. The busbars are connected together and earthed down using portable leads, which give visible confirmation of the earthing arrangement.

High voltage safety checklists for the following can be found in the Code of Safe Working Practices for Merchant Seaman (COSWP) 2010 edition:

- working on high voltage equipment/installations
- switchgear operation
- withdrawn apparatus not being used
- locking off
- insulation testing
- supply failure
- entry to high voltage enclosures
- earthing
- working on high voltage cables
- working on transformers
- safety signs
- correct personal protective equipment

Personnel should not work on high voltage equipment unless it is dead, isolated and earthed at all high voltage disconnection points. The area should be secured, permits to work or sanction for test notices issued, access should be limited and only competent personnel should witness the testing to prove isolation.

Members should consider, before it becomes a mandatory STCW requirement, that appropriate engineers are trained in the dangers associated with high voltage equipment and plant. Safety Management Systems should also address the additional requirements of high voltage systems.

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Standard House, 12–13 Essex Street,
London, WC2R 3AA, England

Telephone: +44 20 3320 8888
Fax: +44 20 3320 8800
Emergency mobile: +44 7932 113573
E-mail: p&i.london@ctcplc.com

Please send any comments to the editor –
Chris Spencer

E-mail: chris.spencer@ctcplc.com
Telephone: +44 20 3320 8807
Website: www.standard-club.com