A Guide to

Ship's Electro-Technology

Part 1

For Marine Engineers and Electrical Officers

Marine Insight©

A Guide to Ship's Electro-Technology: Part 1

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CONTENT

ELECTRICITY ON SHIPS

A ship is an independent floating structure having its own power plant for supplying electricity to its machinery and systems, which together assist in the propulsion of the ship from one port to another.

POWER GENERATION ON SHIPS: A ship is equivalent to a floating city that enjoys almost all privileges available to any operational set-up on land. Just like any conventional city, the ship also requires the basic amenities to sustain life on board, the chief among them being power or electricity. Electricity on ships is generated by an alternator or generator.

Shipboard power is generated when a prime mover and alternator works together. For this purpose, an alternating current generator is used on board. The generator works on the principle that as a magnetic field rotating around a conductor varies, a current is induced in the conductor.

The generator consists of a stationary set of conductors, wound in coils of iron core also known as the stator. A rotating magnet known as rotor turns inside this stator, producing a magnetic field, which cuts across the conductor and generates an induced EMF or electro-magnetic force as

the mechanical input causes the rotor to turn. The magnetic field is generated by induction (in a brushless alternator) and by a rotor winding energized by DC current through slip rings and brushes. Few points that are to be noted about power generated on board ships are:

-AC, 3-phase power is preferred over DC as it gives more power for the same size

- 3-phase is preferred over single phase as it draws more power and in the event of failure of one phase, other 2 can continue working

Power Distribution on Ships:

The ship's power distribution system consists of different components for distribution and safe operation of the system. The main components of this system are:

- Ship's generator - consists of prime mover and alternator
- Main switchboard - a metal enclosure taking power from the diesel generator and supplying it to different machinery systems
- Bus bars - acts as power carrier and allows transfer of load from one point to another
- Circuit breakers - act as a switch, and in unsafe conditions can be tripped to avoid breakdown and accidents
- Fuses - safety devices for machinery
- Transformers - to step up or step-down the voltage. When supply is to be given to the lighting system, a step down transformer is used in the distribution system

In a power distribution system, the voltage at which the ship' s electrical system works is usually 440v. However, there are some large installations wherein the voltage is as high as 6600v.

Power on ships is supplied through circuit breakers to large auxiliary machinery at high voltage. For smaller supply fuse and miniature circuit breakers are used.

The power distribution system, consisting of three wires, can be neutrally insulated or earthed. Insulated system is more preferred as compare to earthed system, as during an earth fault essential machinery such as steering gear can be lost.

Emergency Power Supply:

In case of failure of the ship's main power generation system, an emergency power system or a standby system is used. The emergency power supply ensures that the essential machinery systems continue to operate the ship.

Batteries or an emergency generator or even both can supply emergency power on ships.

Ratings of the emergency power supply should be such that it is able to support all essential systems such as:

- Steering gear system
- Emergency bilge and fire pumps
- Watertight doors
- Fire fighting system
- Ship's navigation lights and emergency lights
- Communication and alarm systems

HIGH VOLTAGE SYSTEMS ON SHIPS: As the ship's size and capacity increases, bigger machinery/ equipment are installed to ensure its operational efficiency; however high voltage is used only for few important machinery systems.

Usually a 3phase, 60Hz, 440 Volts supply is generated and distributed on board ships. As the ship size increases, there is a need to install more powerful engines and other machinery systems. This increase in size of equipment demands more electrical power and higher voltages.

Any voltage used on ship, if less than 1kV (1000 V) is called as LV (Low Voltage) system and any voltage above 1kV is termed as high voltage system.

Typical Marine HV systems usually operate at 3.3 kV or 6.6 kV. Passenger liners such as QE2 operate at 10kV.

Why High Voltage on Ships?

Let us assume that a ship generates 8MW of power at 440V, from 4 diesel generator sets of 2MW, 0.8 power factors each.
Each generator feeder cable and circuit breaker has to handle a full-load current of:

$I = 2 * 10^6 / (\sqrt{3} * 440 * 0.8)$

I = 3280.4 Amps (Approximately, 3300 Amps)

The protection devices such as circuit breaker should be rated at approximately 90kA for each feeder cable.

Let us now calculate the current if the generated voltage is 6600Volts.

Image Credit: Wilhelmsen

$$I = 2 * 10^6 / (\sqrt{3} * 6600 * 0.8)$$

I = 218.69 Amps (Approximately 220 Amps.)
Thus the protection devices can be rated as low as 9 k Amps.

Also, Power Loss = $I^2 * r$
Where, I - the current carried by the conductor, R - the resistance of the conductor.

The power loss varies square of the current carried by the conductor. If the supply voltage is 440V, then the current carried by the conductor is 0.002P, and if the voltage is raised to 6600V, then the current carried for the same power is **(1.515 *(10^-4)) * P.**

Thus it implies that the power loss is reduced by a greater extent if the voltage is stepped up. Also, it is always efficient to transmit power at a higher voltage. Conversely, reducing the resistance of the conductor can reduce the power loss.
$r = \rho * l/a$.

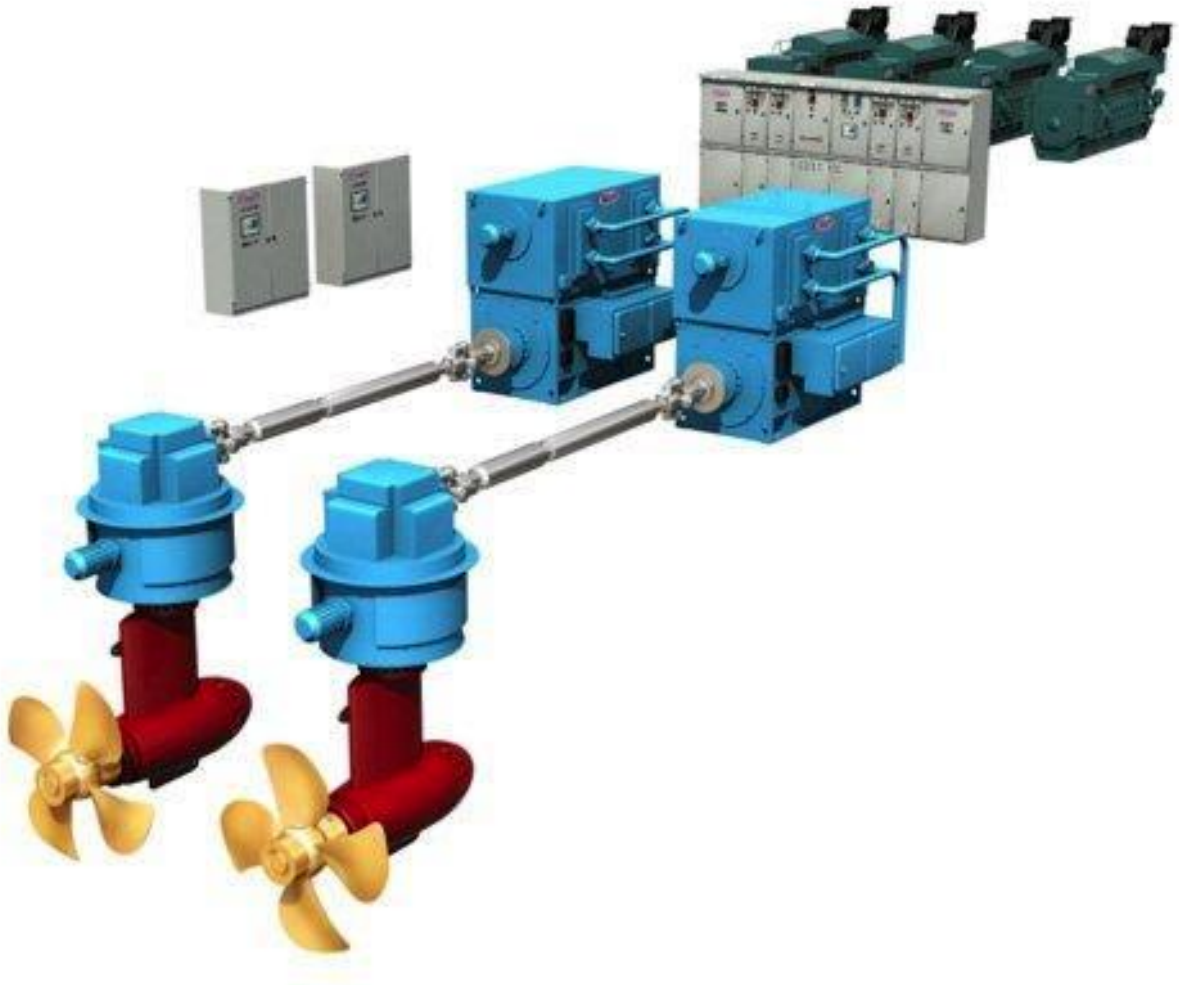
By increasing the cross-sectional area of the conductor (diameter), the resistance of the conductor and the power loss can be reduced.

But this involves huge increase in costs and size/ weight of cables, requiring additional supports. This method is therefore not used to reduce the power loss during transmission and utilization.

Also, it is not necessary to a have bigger size motor for high voltage systems. This means that the motor can be of a smaller size even if it's designed for 6600 Volts as compared to that of 440Volts.

Thus, most of the new ships are fitted with high voltage systems.

Electrical Propulsion System: The conventional propulsion system of ships is efficient but requires high operating costs and increases marine pollution. Among all prospective alternate power sources for ships, electrical propulsion system is one of the most promising alternatives in today's time.



Understanding the System

The electric propulsion system consists of a prime mover, which can be of two types:

- Diesel driven
- Turbine or steam driven

Both these systems produce less pollution as compared to conventional marine propulsion system, which involves burning of heavy oil.

The propeller shaft of the ship is connected to large motors, which can be D.C or A.C driven, also known as propulsion motors.

Ship's generator and prime mover assembly supplies power for the propulsion motor.

Arrangement and Operation

The generator can be direct or alternating current type with diesel or steam driven prime mover, depending on the requirements or demands of the owner/ship.

In the electrical propulsion system, the direction of the propeller rotation is governed either by the electrical control of the motor or by changing the electrical supply.

Normally variable speed electrical motor is used for fixed pitch propeller system and constant or variable motor can be used for variable pitch propeller or CPP.

Applications

Though electrical propulsion is normally used for smaller vessels, shipping companies are now adopting this system for big size cargo vessels as well.

Electrical propulsion is fitted in:

- Tugs and trawlers
- Dredgers
- Dynamic positioning vessels
- Cable laying ships
- Ice breakers
- Research ships
- Floating cranes
- Offshore Vessels

Advantages of electrical propulsion system are:

- A large amount of power is generated by the system and the excess power can be utilized by supplying it to cargo pumps, fire pumps and other important auxiliary machinery
- The space required for installation of electrical propulsion machinery is less and compact as compared to conventional systems
- There is no direct connection of

propeller shaft and prime mover and hence transmission of severe stresses such as torsional and vibration is reduced

- There is more flexibility in installation of machinery
- It provides improved maneuverability and high redundancy
- Increased payload through flexible location of machinery components
- Environmental benefits from lower fuel consumption and emissions
- High performance in tough ice conditions due to maximum torque at zero speed
- Reduces lifecycle cost by less fuel consumption and maintenance costs
- Better comfort due to reduced vibration and noise

Disadvantages of this system:

- The efficiency of electrical plant is less than that of conventional system
- The installation cost of electrical propulsion plant is much higher
- Improvised training for ship's crew is required as the system is completely different from mechanical system and involves major automation

From long-term perspective, electric propulsions systems are promising power sources for ships, considering their high efficiency and stringent marine environmental norms.

ELECTRICAL INSTRUMENTS

The ship consists of series of electrical wires and equipment, which are responsible for running its machinery systems. For periodic inspectional and up keeping of the electrical system onboard ships, a variety of electrical instruments are used.

MEGGER- CONSTRUCTION AND OPERATION: The most important routine maintenance for electrical machinery involves checking of insulation resistance, which is done by an instrument called “Megger” or “ohmmeter”.

Insulation Resistance:

Insulation resistance (I.R) is a critical parameter as it’s directly related to personal safety, safety of machinery and power reliability. The I.R value of an electric device changes with aging, mechanical and electrical stresses, temperature, contamination, atmosphere, humidity etc. It is therefore important for seafarers to check this parameter for avoiding fatal accidents due to electrical shock.

Megger or Ohmmeter:

Megger is a portable instrument used to measure insulation resistance of electrical machinery or system. It is battery operated or mechanically operated (hand crank dc generator) and gives direct reading in ohms. Megger is used to measure voltage ratings in the range of 100V to 5000V.

Construction:

A Megger consists of following parts:

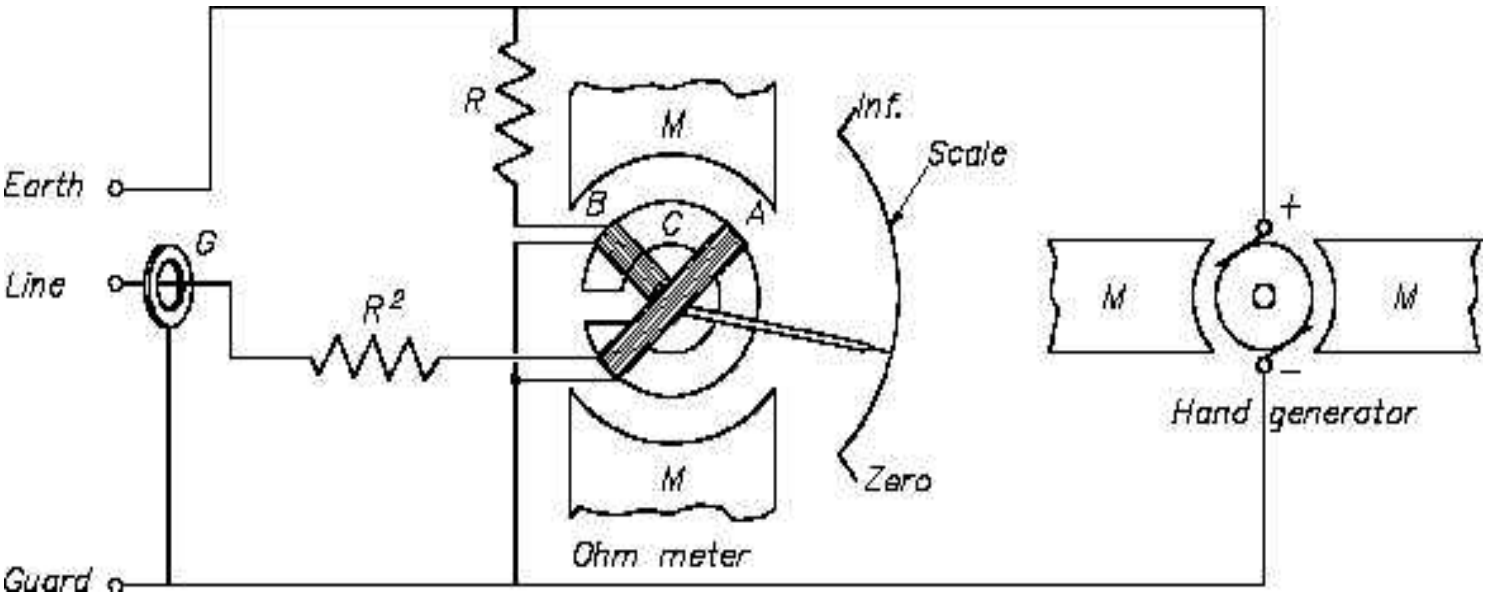
1) **Control and Deflecting coils**: They are normally mounted at right angle to each other and are connected parallel to the generator. The polarities are such that the torque produced by them is in the opposite direction.

2) **Permanent Magnet**: Permanent magnet with north and south poles are used for construction to produce magnetic effect for deflection of pointer.

3) **Pointer and scale**: A pointer is attached to the coils with its end floating on a scale ranging from "zero" to "infinity". The unit for this is "ohms".

4) **D.C generator or battery connection**: Hand operated D.C generator supplies testing voltage for manually operated Megger. In automatic type Megger, testing voltage is supplied by battery and electronic voltage charger

5) **Pressure coil and current coil**: They are provided for preventing damage to the instrument in case of low external source resistance.



Working

- The voltage for testing is supplied by a hand generator incorporated in the instrument or by battery or electronic voltage charger. It is usually 250V or 500V and smaller in size

- A test volt of 500V D.C is suitable for testing ship's equipment operating at 440V A.C. Test voltage of 1000V to 5000V is used for high voltage system onboard

- The current carrying coil (deflecting coil) is connected in series and carries the current taken by the circuit under test. The pressure coil (control coil) is connected across the circuit

- Current limiting resistor – CCR and PCR are connected in series with pressure and current coil to prevent damage in case of low resistance in external sources

- In hand generator, the armature is moving in the field of permanent magnet or vice versa, to generate a test voltage by electromagnetic induction effect

- With an increase of potential voltage across the external circuit, the deflection of the pointer increases and with an increase of current, the deflection of pointer decreases. Thus, the resultant torque on the movement is directly proportional to the potential difference and inversely proportional to the resistance

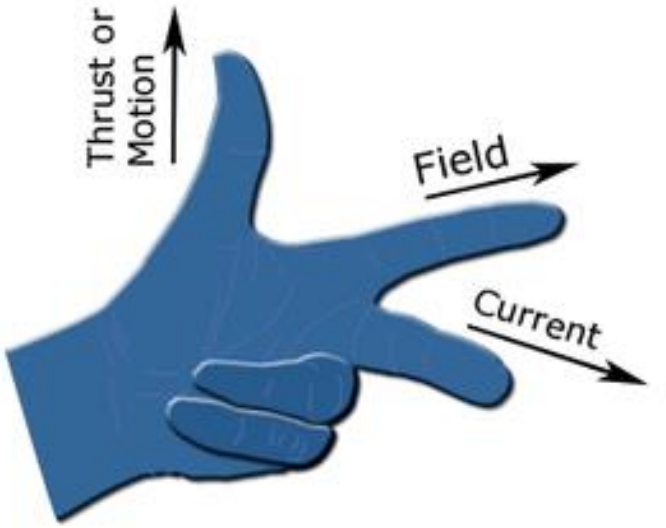
- When the external circuit is open, torque due to voltage coil will be maximum and the pointer will read "infinity". When there is short circuit, the pointer will read "0"

PERMANENT MAGNET MOVING COIL INSTRUMENT (PMMC): Variety of instruments are used onboard for measuring parameters of electrical machinery and systems. A permanent magnet moving coil (PMMC) is one such instrument which is popularly used onboard for several applications.

Principle of Operation:

When a current carrying conductor is placed in a magnetic field, it experiences a force and tends to move in the direction as per Fleming's left hand rule.

"If the first and the second finger and the thumb of the left hand are held so that they are at right angle to each other, then the thumb shows the direction of the force on the conductor, the first finger points towards the direction of the magnetic field and the second finger shows the direction of the current in the wire."



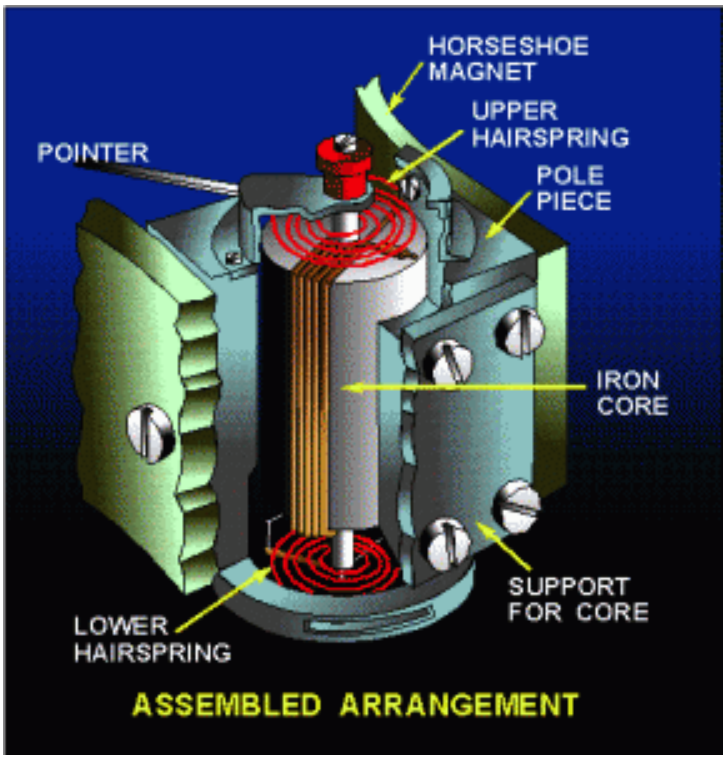


Image Credit: tpub

Construction:

A coil of thin wire is mounted on an aluminum frame (spindle) positioned between the poles of a U shaped permanent magnet made of magnetic alloys such as alnico.

The coil is pivoted on the jeweled bearing and is free to rotate. The current is fed to the coil through spiral springs, which are two in numbers. The coil current, which is to be measured, moves in a strong magnetic field produced by a permanent magnet and a pointer is attached to the spindle to show the measured value.

When a current flows through the coil, it generates a magnetic field that is proportional to the current when used as an ammeter. The deflecting torque is produced by the electromagnetic action of the current in the coil and the magnetic field.

The controlling torque is provided by two phosphorous bronze flat-coiled helical springs. These springs serve as a flexible connection to the coil conductors.

The eddy current set up in the aluminum coil dampens the oscillation.

Applications:

The PMMC has a variety of uses onboard ship such as:

1) **Ammeter**:
When PMMC is used as an ammeter, except for a very small current range, the moving coil is connected across a suitable low resistance shunt, so that only small part of the main current flows through the coil.

The shunt consists of a number of thin plates made up of alloy metal, which is usually magnetic and has a low temperature coefficient of resistance, fixed between two massive blocks of copper. A resistor of same alloy is also placed in series with the coil to reduce errors due to temperature variation.

2) **Voltmeter**:
When PMMC is used as a voltmeter, the coil is connected in series with high resistance. Rest of the function is same as above. The same moving coil can be used as an ammeter or voltmeter with an interchange of above arrangement

3) **Galvanometer**:
Galvanometer is used to measure small value of current along with its direction and strength. It is mainly used onboard to detect and compare different circuits in a system.

5) **Ohm Meter**:
The ohmmeter is used to measure resistance of the electric circuit by applying a voltage to a resistance with the help of battery. A galvanometer is used to determine the flow of current through the resistance. The galvanometer scale is marked in ohms and as the resistance varies, since the voltage is fixed, the current through the meter will also vary.

Advantages:

- The PMMC consumes less power and has great accuracy
- It has uniformly divided scale and can cover arc of 270 degree
- The PMMC has a high torque to weight ratio
- It can be modified as ammeter or voltmeter with suitable resistance
- It has efficient damping characteristics and is not affected by stray magnetic field
- It produces no losses due to hysteresis

Disadvantage:

- The moving coil instrument can only be used on D.C supply as the reversal of current produces reversal of torque on the coil
- It is very delicate and sometimes uses AC circuit with a rectifier
- It is costly as compared to moving coil iron instruments
- It may show error due to loss of magnetism of permanent magnet

THERMOCOUPLES: Thermocouple is a device widely used as a pyrometer on board ships for continuous measurement of temperature for machinery systems such as main engine, auxiliary engine, gas turbines etc.

It is absolutely important to choose the correct thermocouple material for different temperature range operations, depending upon the machinery and thermocouple location where the parameter has to be measured.

Construction of Thermocouple:

A thermocouple consists of two dissimilar homogeneous materials connected together. The materials used depend upon the application and usage. Normally, following materials are used for different temperature ranges:

Copper – Constantan (copper nickel alloy) for range of –200 to +400 °C

Iron – Constantan for temperature range of −40 to +750 °C

Chrome – Alumel (alloy of nickel, manganese, aluminium and silicon) for temperature range of −200 to +1350 °C. These materials are connected together in a ceramic sheath covered again by a metal sheath and are fitted at desired locations such as exhaust manifold etc. One end of the thermocouple is placed in hot junction and other end is kept in a constant cold junction.

These materials are led to a temperature indicator through an amplifier and compensator lead. The amplifier and compensator lead (normally made up of copper and does not effect the circuit) helps in transmitting the output to a remote location.

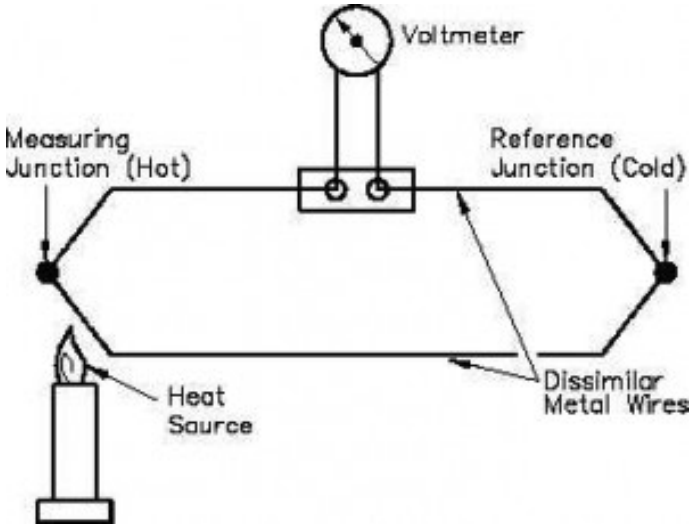
Principle & Working

Thermocouple works with the principle of "seebeck effect" which states that- *"Temperature between two dissimilar metals in a circuit converts into electric current"*

When two dissimilar metal wires, suppose iron and constantan, are coupled together and exposed to difference in

temperatures at both the ends, EMF is generated and the current flows from hot to cold side.

The magnitude of the current depends on the temperature difference between the junctions. If one junction is kept at constant temperature, then the value of temperature for the other junction can be easily determined.



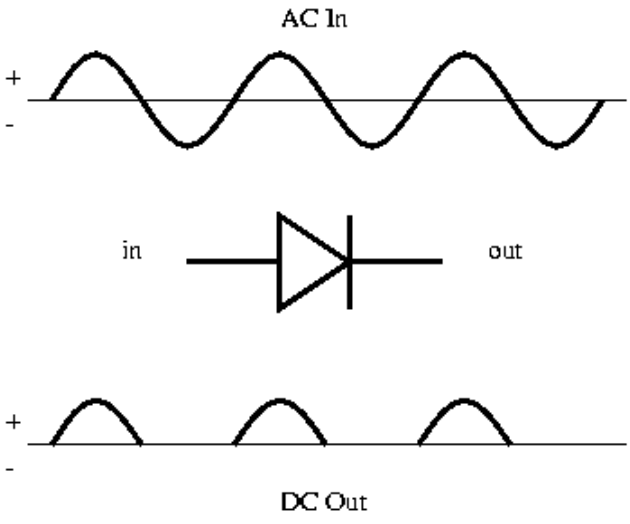
Advantages of Thermocouple

- Can be used for remote temperature sensing
- Can be used for continuous temperature sensing
- Temperature difference can be measured with high accuracy
- They are inexpensive and easily interchangeable

RECTIFIER AND RECTIFIER CIRCUITS: Since most of the ships generate A.C current from its alternator, it becomes essential to use a device, along with the transformer, that can convert this A.C current into D.C current for using equipment or circuit running on direct current. Rectifier is a circuit, which utilizes one or more semiconductor diodes to convert an alternating current into a pulsating direct current.

All electrical and electronic equipment or circuits on board ships play a vital role in the operation of ship's machinery systems. Equipment onboard vessels utilize alternating current, direct current or both depending upon the nature of operation.

Some of the important circuits and setups are run through D.C current. Hence it is important to convert the generated A.C current in to D.C current and this process of conversion is known as rectification. Rectifiers are used for this purpose.



Half Wave Rectifier

Types of Rectifiers

Half wave rectifier:

Half wave rectifier consists of a single diode connected in series with the load resistor. During the positive half cycle of input voltage, the diode is forward biased and conducts for all voltages greater than its barrier potential.

During negative half of the cycle, the diode is reverse biased hence it does not conduct.

Full wave rectifier:

Full wave rectifier circuit allows unidirectional current to flow to the load during the entire input cycle. There are two types of single full wave rectifier:

- Two diodes connected back-to-back using a center-tapped transformer.

- Full wave bridge rectifier using four diodes connected in the form of bridge.

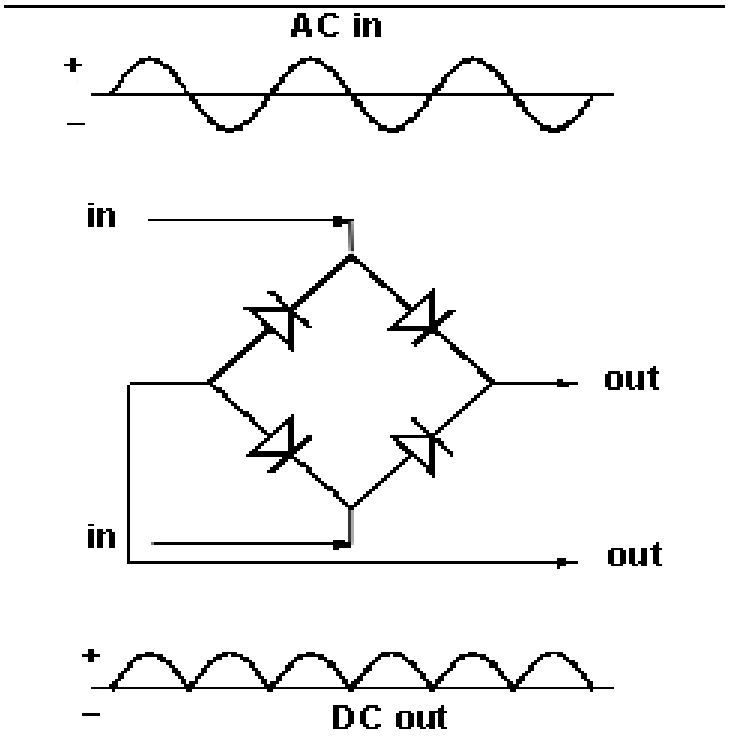
Bridge rectifier:

A single-phase bridge rectifier is used with four diodes connected in bridge with a non-center tapped transformer.

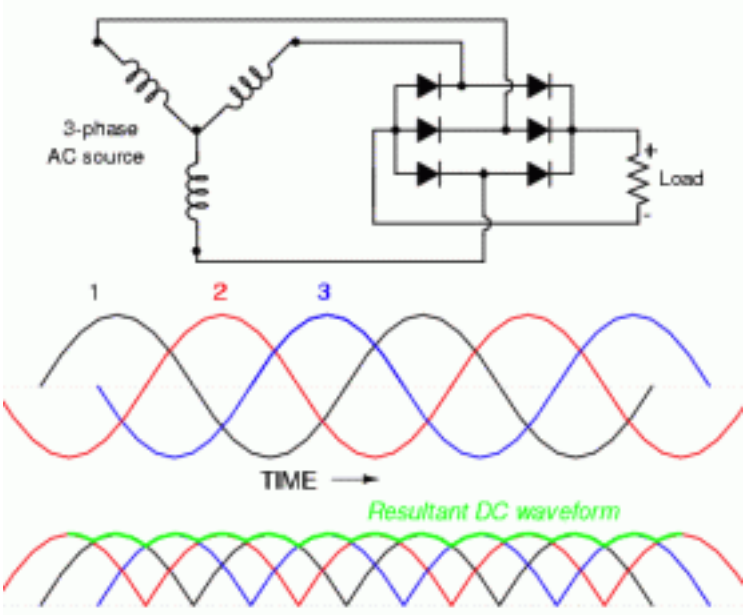
Full wave rectifier has an advantage of converting both polarities of input A.C waveforms into D.C and therefore it is more efficient.

A three-phase rectifier circuit consists of six diodes, which are in pair of three, connected in series (anode to cathode).

It is commonly used in three phase circuits.



Full Wave Rectifier



Bridge Rectifier

Applications onboard

Some of the uses of rectifiers on board ships are:

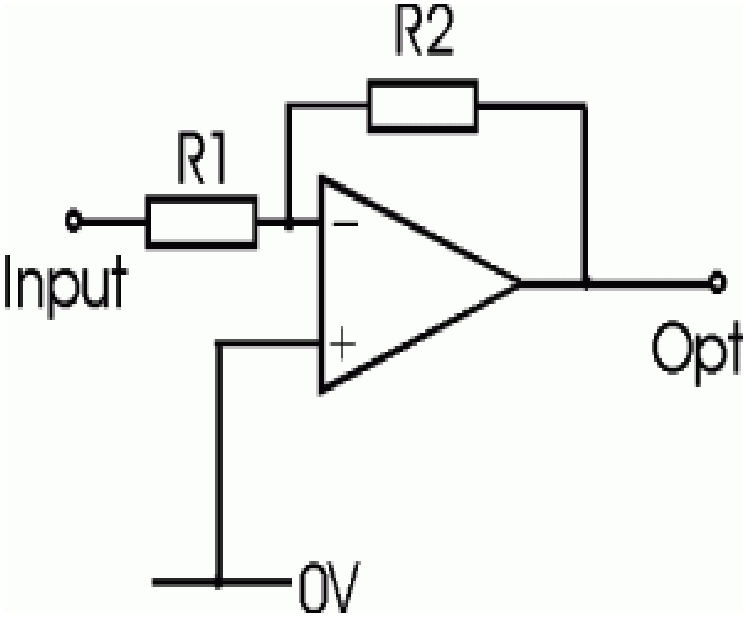
- Used in marine electronic devices and circuits
- Used for onboard battery charging from the ship supply
- Used in detection of radio signals
- Used in electroplating process
- Used in ship construction for electrolyte refining of metals
- Used in operation of D.C motor
- Used in field excitation of three-phase alternator

AMPLIFIER AND AMPLIFIER CIRCUITS: An Amplifier or an operational amplifier (op-amp) circuit is commonly used in the automation, control and other electronic circuits of marine applications. The applied input signal is normally a voltage or a current signal. The purpose of an amplifier is to produce an output signal larger than that of the input signal.

Purpose of Amplifier:

As the name suggest, the purpose of an amplifier or an op amp is to amplify or increase the input signal to produce an output signal, which is much larger than that of the input, with a similar waveform as that of the input.

The main change in the output signal will be the increase in the power level. This additional power is supplied by a D.C voltage, which is externally provided. The output signal is controlled by the input signal in an amplifier.



Operation of Amplifier Circuit

The input of the amplifier consists of differential input voltage V+ input and V- input and this difference in the voltage is amplified to produce a larger output.

The op-amp equation can be given by:

V o/p = [(V+)- (V-)] x A o/l

Where **A o/l** - is open loop gain of the amplifier.

In an op-amp the magnitude of **A o/l** is very large which gives a larger output even when the input differential is small.

Other important properties

- It has a high output gain
- It has high input and low output impedance
- Bandwidth is in very high range

Applications of Amplifier Circuit

An amplifier circuit is popularly used in marine electrical/ electronic circuits and applications such as:

- It is used to amplify audio signal (loudspeaker, VHF)
- It is used as voltage and current regulator
- It is used as analog to digital converter and vice-versa
- It is used as a servo amplifier in motors
- The output signal from amplifier is supplied to a relay in a circuit

ELECTRICAL SAFETY

Electrical equipment systems on ships are extremely hazardous and seafarers must take special care while handling them. Personal safety is of utmost importance while dealing with electrical systems on ships.

ELECTRICAL SHOCK: When we talk about accidents on a ship, an electrical shock is the worst of all kinds. Electrical wires and connections are present everywhere on a ship and it is important to prevent yourself and others from getting a major electrical shock.

Steps to Minimize the Risk of an Electrical Shock

- Start with the first round of the day; check all electrical motors, wiring, and switches, for abnormal sounds, variation in temperatures and loose connections
- Ensure that all electrical connections are inside the panel box so that no one can touch them accidently
- In accommodation area multiple socket plugs shouldn't be used
- Turn off the breaker before starting any work on an electrical system
- Use ply cards and notice board as much as possible to inform others about the ongoing work to avoid accidental "starts"
- Double check electrical tools such as portable drills for any loose wires before attempting any job
- Always wear protective clothing, rubber gloves, rubber kneepads and safety shoes to avoid risk of shock

- Use electrically insulated handle tools for working or checking electrical systems
- Before working, remove jewelry, wrist bands and other conductive items
- When working or removing multiple wires, tape off all but the one wire you are working on
- Try as much as possible not to work on live system and even if you do so, be a professional and work carefully, taking all necessary safety precautions and with utmost concentration
- During working in group or pair, organize a tool box meeting and discuss the procedure, risk and hazards of the job in hand
- If you don't know about the system, ask for assistance. Don't work without knowing the system
- Always think first about your personal safety and safety of fellow seafarers while carrying out any electrical work on board ships

MAIN AND EMERGENCY SWITCHBOARD SAFETY: It is very important to isolate any type of fault in an electrical system supplied from the main switchboard (MSB), or else, it will affect all the other systems connected to the same. If such isolation is not provided then short circuit in even a smaller system can cause blackout of the whole ship.

The main switchboard is an intermediate installation in the ship's power distribution circuit, connecting the power generators and power consumers. The power generators on ships are auxiliary engines with alternators and the different engine room machineries such as motors, blowers etc. are the consumers.

Variety of safety devices are used on board ships and installed on the main switchboard (MSB) and electrical distribution panels. This ensures safe and efficient running of machinery systems and safety of the seafarers from electric shocks.

The Important safety devices fitted on main switchboard are:

Circuit breakers: A circuit breaker is an auto shutdown device, which activates during an abnormality in the electrical circuit. Especially during overloading or short circuit, the circuit breaker opens the supplied circuit from MSB and protects the same. Different circuit breakers are strategically installed at various locations on the ship.

Fuses: Fuses are mainly used for short circuit protection and comes in various ratings. If the current passing through the circuit exceeds the safe value, the fuse material melts and isolates the MSB from the default system. Normally, fuses are used with 1.5 times of full load current.

Over current relay: OCR is used mainly on the local panel and MSB for protection from high current. It is installed where a low power signal is a controller. Normally relays are set equivalent to full load current with time delay.

Dead front panel: It is also a safety device provided on the main switchboard individual panels, wherein you cannot open the panel until the power of that panel is completely switched off.

Maintenance and operational safety plays an important role for the overall safety of the main switchboard.

ELECTRICAL FIRE SAFETY: The root cause of any electrical fire is the insulation of the circuit or wire. If the insulation is weak or damaged, it may lead to spark, electrical shock or fire in the system causing major accidents and causality. The best way to avoid electrical fire is to maintain the insulation of electrical wires and equipment.

The insulation of the electric cable is generally made up of rubber or plastic. The amount of smoke generated by the plastic in case of fire is dependent on factors such as nature of plastic, type of additive used, flame of fire and ventilation arrangements. In general, most plastics produce a very dense smoke when heated.

Some plastic burns very clearly when subjected to heat and flame, producing very less smoke. If insulation used is of urethane foam, a very dense smoke is produced and visibility in the room is lost. Some plastics contain Poly Vinyl Chloride (PVC), which produces pungent, and irritating odor.

Rubber when used for insulation produces a dense, black, oily smoke and has some toxic qualities. The most common gases produced during combustion of rubber are hydrogen sulphide and sulphur di-oxide. Both these gases are dangerous for health and can be fatal in certain cases.

Ways to Reduce these Hazards

The following steps should to taken as preventive measures:

- Cables having E.P.R (Ethylene Propylene Rubber) insulation with necessary sheathing of Poly Chloro Prene or Chloro Sulphonated Polyethylene (PCP or CSP) may be used to protect the insulation against fire

- G.I armor may be used to protect insulation from fire but needs to be earthed

- By using cables having high oxygen index number, the number allotted to material depending on minimum percentage of oxygen required to sustain combustion

- If the material used is having oxygen index number 27, it means that minimum percentage of oxygen required to burn the material is 27 % which is well above the normal atmospheric oxygen percentage of 21 %. Thus, the insulation material will not catch fire

Important Precautions for Installation of Electric Cables

1) The cables and wirings external to the equipment must have flame retardant properties and should be installed in such a manner that it should not interfere with the original flame retarding properties.

2) Cables and wirings for emergency equipment, lightings, communication and signal should be kept away from spaces such as galley, laundries, machinery space of category A & other high risk areas

3) Special precautions are to be taken for cable installation in hazardous area as it might lead to explosion in case of electrical fault.

4) Terminations and joints are to be made in such a manner that they should retain their original fire resisting properties.

5) Avoid cable for damage and chaffing during installation.

6) Fireproof glands to be used in case of cables passing through the bulkhead to prevent fire from one compartment to other.

GENERATOR SAFETY: Generators onboard ships are the power suppliers for the entire vessel and are the primary sources of power to all running machinery systems, including the propulsion plant. For this reason, safe and efficient running of the ship's generator has to be given highest consideration. Two important safety measures of generators are: Preferential trips and Air Circuit Breaker (ACB).

Preferential trip is a kind of electrical arrangement, which is designed to disconnect the non-essential circuit i.e. non-essential load from the main bus bar in case of partial failure or overload of the main supply.

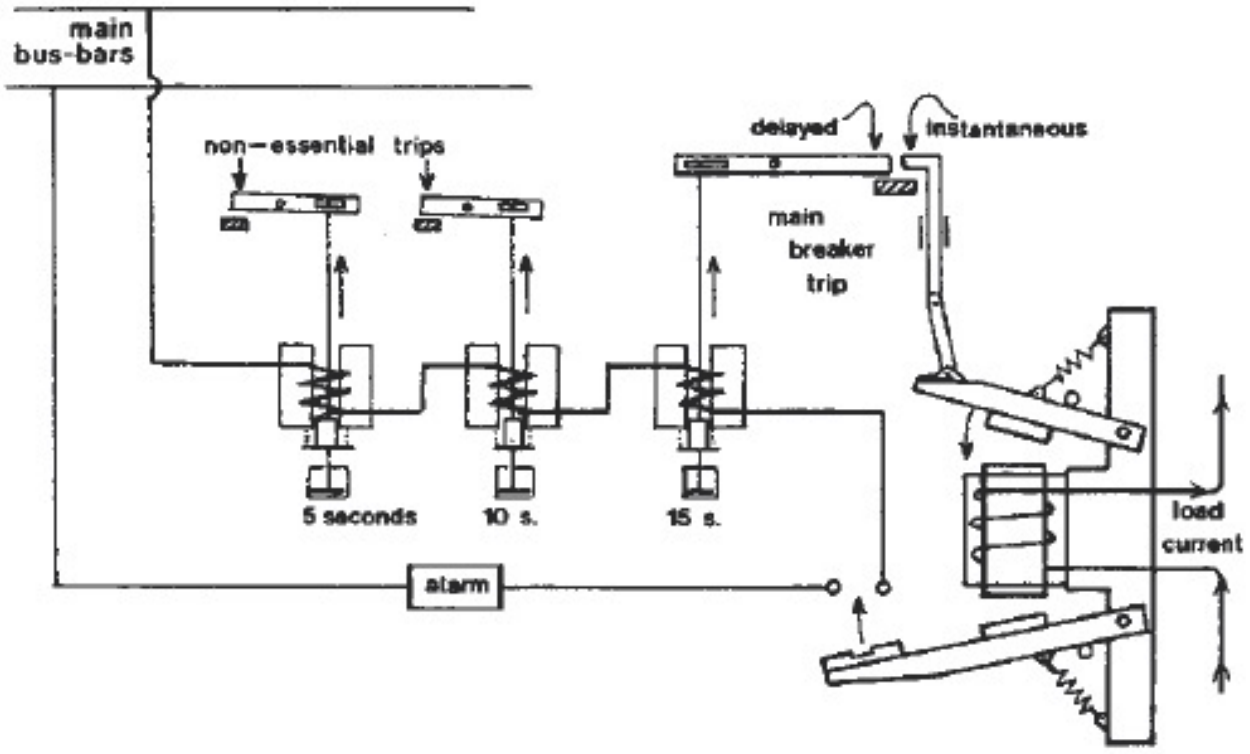
The non-essential circuits or loads on ships are air conditioning, exhaust and ventilation fans, and galley equipment, which can be disconnected momentarily and can be connected again after faultfinding. The main advantage of preferential trip is that it helps in preventing the operation of main circuit breaker trip and loss of power on essential services, thus blocking blackout and overloading of generators.

Construction and Working

The preferential trip circuit consists of an electromagnetic coil and a dashpot arrangement to provide some delay to disconnect the non-essential circuits. Along with this, there is also an alarm system provided, which functions as soon as an overload is detected and the trips start operating.

There are some mechanical linkages, which instantaneously operate and complete the circuit for preferential trips.

The dashpot arrangement consists of a



piston, with a small orifice, placed inside a small cylinder assembly. This piston moves up against the fluid silicon and the orifice in the piston governs the time delay.

Working of Preferential Trip

The current passes through the electromagnetic coil and the linkages are kept from contacting using a spring arrangement.

As soon as the current value increases the limit, the electromagnetic coil pulls the linkage up against the spring force and operates the instantaneous circuit and the alarm system. The lower linkage completes the circuit for the preferential trip.

The current passes through the coil in the preferential trip circuit, which pulls the piston in the dashpot arrangement. The movement of this piston is governed by the diameter of the orifice and the time delay made by the same.

The preferential trip operates at 5, 10 and 15 seconds and the load is removed accordingly. If the overload still persists, then an audible and visual alarm is sounded.

The preferential trip is one of those important electrical circuits, which help in removing the excessive load from the main bus bar, thus preventing situation like blackout especially when the ship is sailing in restricted or congested waters.

Air Circuit Breaker (ACB)

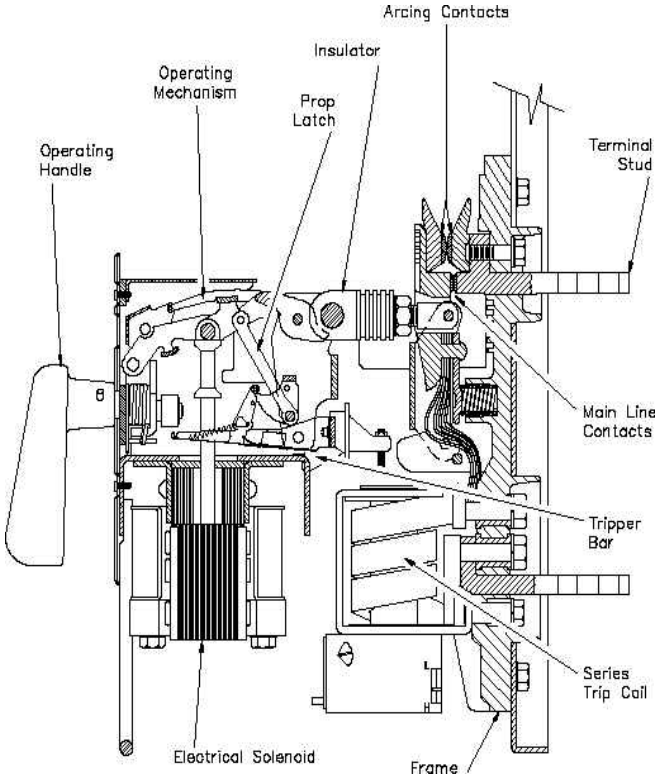
Air circuit breaker is designed to overcome the defects and safeguard the machine before it breakdowns.

The main function of air circuit breaker is to:

- Open and close a 3 phase circuit, manually or automatically

- Open the circuit automatically when a fault occurs. Faults can be of various types – under or over voltage, under or over frequency, short circuit, reverse power, earth fault etc.

The main feature of ACB is that it dampens or quenches the arcing during overloading.



Air Circuit Breaker (ACB) Construction & Working

ACB has two sets of contacts i.e. main and auxiliary contacts. Each set of contact consists of a fixed contact and a moving contact.

The main contact normally carries most of the load current. All the contacts are made of cadmium-silver alloy, which has good resistance to damage by arcing.

When the ACB is closed, the powerful spring is energized and the ACB is then latched shut against spring pressure. The auxiliary contact makes first & breaks last i.e. when ACB is closed, the auxiliary contact closes first and then the main contact follows.

When the ACB is open, the main contact open firsts and then the auxiliary contact opens. Thus the auxiliary contacts are subjected to arcing during the opening of ACB and can easily be replaced.

The main contact closing pressure is kept high so that the rise in the temperature in the contacts while carrying current remains within limits.

Closing coil operating on D.C voltage from a rectifier is provided to close the circuit breaker by operating a push button.

How Arc Quenching is achieved?

Quenching of arc is achieved by:

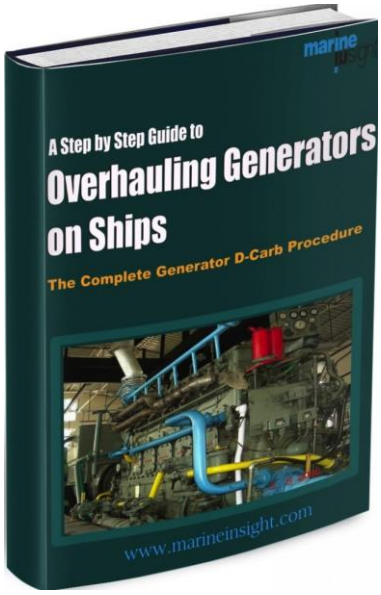
1) Using arcing contacts made of resistance alloy and silver tips for the main contacts. Arcing contacts close earlier and open later than the main contacts.

2) When opening contacts have travelled at high speed to stretch the resultant arc, which is transferred to the arcing contact.

3) Cooling and splitting of the arc is done by arc chutes, which draw the arc through splitters by magnetic action and quickly cools and splits the arc until it snaps. The circuit breaker opens when the arc is quenched.

Know the complete Decarb Procedure of the Marine Generator in our eBook-

"A Step by Step Guide to Overhauling Generators on Ships"



BLACKOUT SITUATION: Blackout is one condition each and every mariner is familiar with and also afraid of. It is one situation everyone on the ship is terrified of as it brings the whole ship and its operations to a standstill.

Understanding Blackout Condition

Blackout condition is a scenario on a ship, wherein the main propulsion plant and associate machinery such as boiler, purifier and other auxiliaries stop operating due to failure of the power generation system of the ship – Generator and alternator.

With advance technologies and automation, preventive measures are provided to avoid such blackout situations by means of auto load sharing system and auto standby system, in which, the generator set that is running in parallel or standby comes on load automatically when the running diesel generator fails.

What to Do in Case of a Blackout?

In case of a blackout following precautions and actions should be taken:

- Never panic in such situation, be calm and composed. Emergency generator will restore the power in no time
- Inform officer on bridge briefly about the condition
- Call for manpower and inform the chief engineer
- If the main propulsion plant is running, bring the fuel lever to zero position
- Close the feed of the running purifier to avoid overflow and wastage of fuel
- If auxiliary boiler was running, shut the main steam stop valve to maintain the steam pressure
- Find out the problem and reason for blackout and rectify the same
- Before starting the generator set, start the pre- lubrication priming pump if the supply for the same is given from the emergency generator; if not, then use manual priming handle (provided in some generators)
- Start the generator and take it on load. Then immediately start the main engine lube oil pump and main engine jacket water pump
- Reset breakers and start all the other required machinery and systems. Reset breakers that are included in preferential tripping sequence. (Non-essential machinery)

Seafarers require both skills and patience to tackle a situation like blackout, especially when the vessel is sailing or maneuvering.

However, the best way to tackle such situations is to be calm and composed; and to know your engine room and machinery very well in advance.

ELECTRICAL MAINTENANCE

Scheduled and routine maintenance is the key to ensure smooth running of electrical machinery systems and to prevent hazardous accidents on board ships.

Earth Fault on Ships: Earth fault is considered very critical on board a ship. Some ships, which operate at 440V do not have any trip devices attached for a single earth fault. However, when the operating voltage exceeds 3000V, it is mandatory to have a protection system that isolates when ship machinery suffers an earth fault.

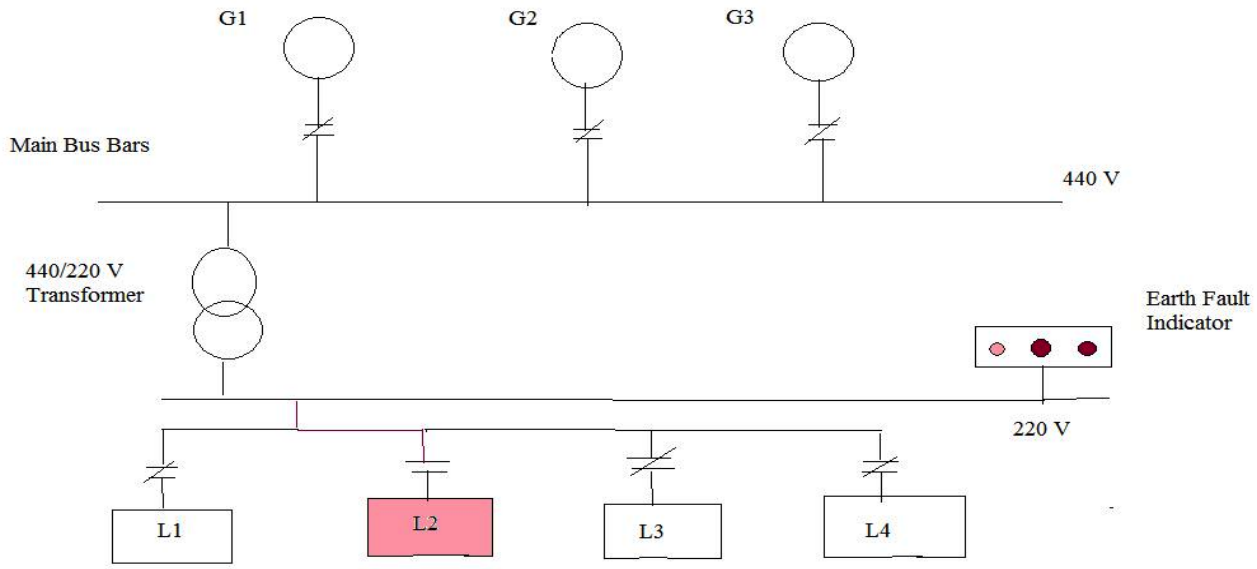
The seriousness of the action to be taken on an Earth Fault depends on the part of the electrical system it affects. Conventional ships which operate on 3 Phase, 440V, have earth fault indicators installed on all three phases.

Any earth fault on a 440V system is considered to be a serious trouble and immediate action is required to identify the faulty circuit. Earth fault on 220V or any low voltage lighting circuit can be considered as important but need not require immediate attention. However, attention should be paid at the next earliest opportunity.

Finding Earth Fault on 440V circuit

Whenever there is an earth fault alarm, immediately inform the electrical officer (if he is on board). First action is to check the trueness of the alarm. Usually there will be a test button which when pressed, resets the alarm and rechecks the condition of the earth fault.

If the ship is having IAS (Integrated Automation System), check on the computer in the list of events, after which the alarm has activated. If IAS facility is not available, there is only one option left i.e. isolating each and every machinery system in the 440 V circuit.



When this is done, check for which machinery the earth fault indication returns back to normal.

Isolation of all machinery, which operates on 440V is not always possible. Certain critical equipment like steering gear and lubricating oil pumps cannot be isolated when the ship is underway. However changeover can be done from running machinery to the standby one and the earth fault can be found.

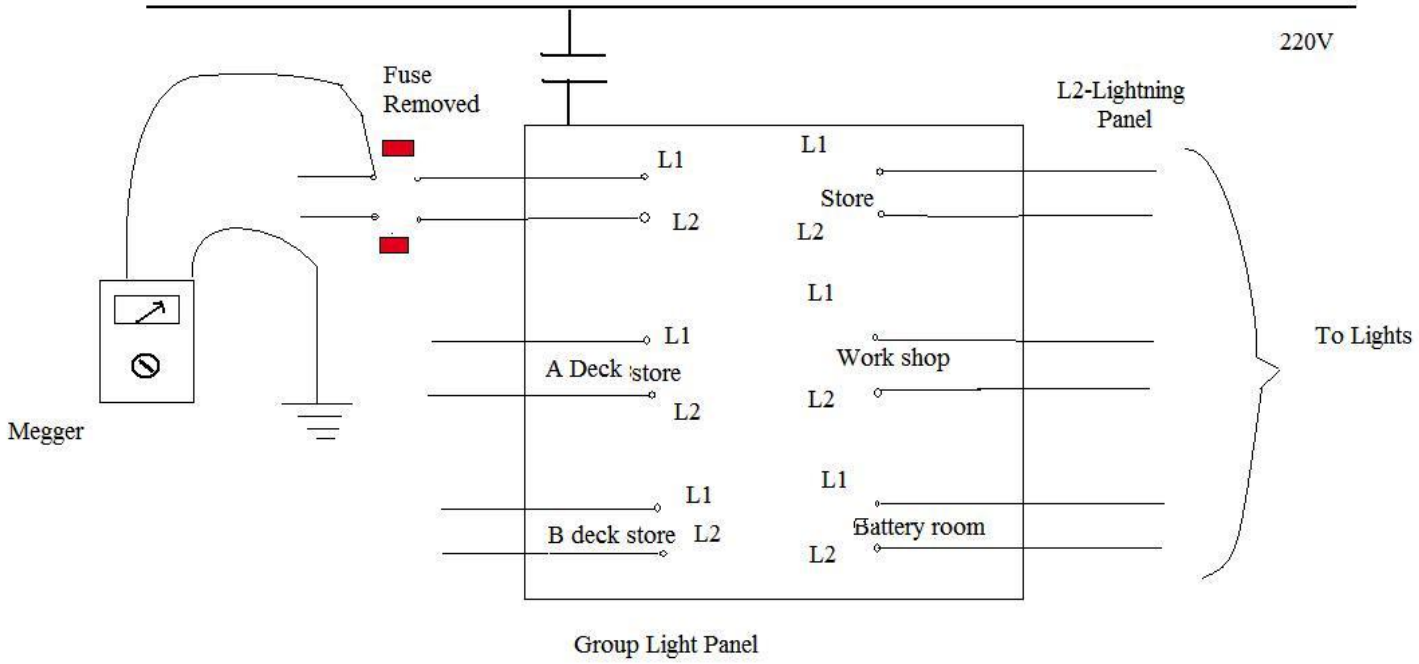
Finding Earth Fault on 220V Circuit

Finding an earth fault on a 220V circuit is comparatively difficult than a 440V circuit. The main reason being the lighting circuits found all round the vessel. However, any earth fault alarm with respect to a 220V circuit is usually treated as important but not an emergency.

When a 220V earth fault alarm sounds, as said earlier, pressing the test button checks the trueness of the alarm and then investigation can be started on each and every 220V circuit.

Example: Earth Fault Alarm Sounds on a 220V Panel

- Check the trueness of the alarm
- Isolate the complete group start panel for a lighting division one by one
- Check the Earth Fault indicator for status (still faulty or normal)
- If faulty, then put on the breaker which is put off earlier and isolate other group start panel for lighting circuit
- Once the group start panel is identified, then individual lighting switches are turned off one by one and checked for the alarm condition
- When any switch is turned off and the condition becomes normal, the lighting circuit is marked and then inspection is done on the particular light for abnormalities.



Ingress of moisture is most common reason for an earth fault.

Alternate Idea: Instead of turning off breakers one by one for the lighting circuit, turn off the lighting circuit of a particular doubted area. This method helps when there are two or more earth faults in 220V lighting circuit.

Turning off all the breakers of a particular area and then switching on the breaker one by one will eliminate multiple earth faults.

When turning off lighting switches one by one, it is difficult to identify multiple earth faults.

Once the particular faulty circuit is spotted, then further break them into individual parts and check them for earth faults. For this, usually a megger against earth is used.

By removing the fuse of the two-phase lines, each line can be tested and the fault pinned down.

Electrical Relay Maintenance on Ships: A relay is an important electromechanical safety device in ship's electrical circuit and is normally used to open the faulty circuit from the main supply when any kind of electrical fault occurs.

A relay is fitted in the Main and Emergency switchboards of the ship as a protective device.

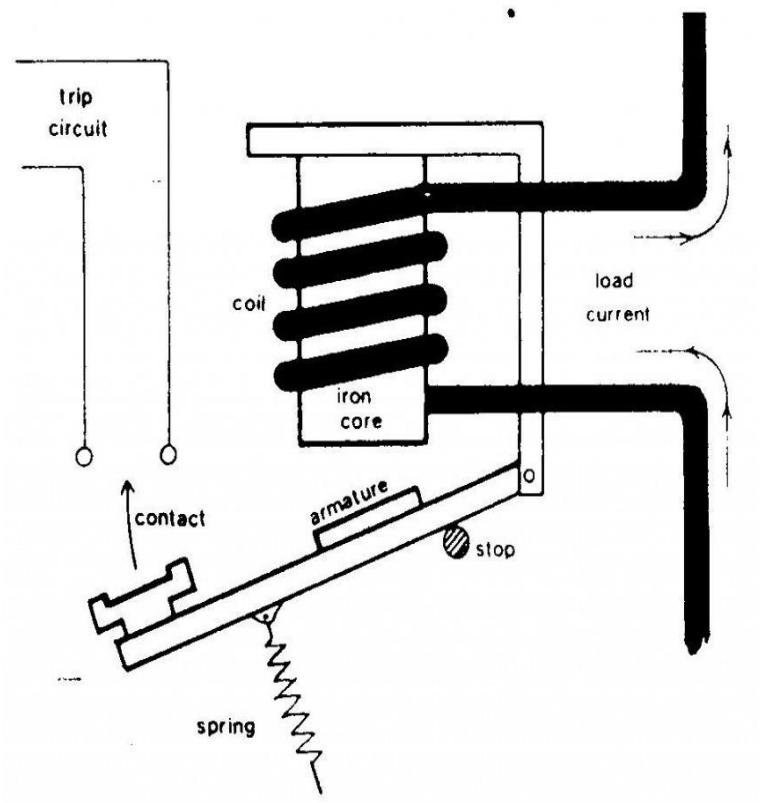
Relay has to be kept operational and healthy at all times, else at the time of fault if the relay does not operate properly, the whole system may suffer loss of power or damage. The most common application of relays is for overload and short circuit protection.

A ship engineer or electrical officer has to make sure that the relay is efficiently in operation and the maintenance is carried out on the same as per schedule. If during inspection, the relay is found out to be defective it must be replaced immediately with a spare one.

A simple electromagnetic relay will get activated when the magnetic effect of the iron core is sufficiently increased by the excess or high current in the coil, which will attract the iron armature held against the spring force to trip the circuit.

A brief maintenance procedure for relay is given as follows-

- Checks to be carried out on relay contacts for damage due to arcing
- Polish the contact with emery paper to remove rust and deposits
- Check the closing linkage for free movement
- Check the continuity of the contacts with multimeter
- There are arc chutes provided to quench the arcing. Check for burnout of the same
- Check the tension of the spring
- Open circuit and short circuit tests to be performed on the coil by multimeter
- Check the continuity of the trip circuit by multimeter
- Check tightness of the supply terminals



Electrical Motor Overhauling on Ships: Like any other mechanical machinery, electrical motors also have their own running hours, after which, the complete overhauling of the motor is to be done to ensure efficient working and performance.

Most of the motors in the ship's engine room are continuous running motors connected to a pump or compressor or some other machinery

In motor construction, the air gap between the stator and the rotor is very less. If there is a little deviation in the shaft rotation, the rotor will slowly start touching the stator (In this condition, you can feel much more vibrations in the motor), which can lead to short circuit and burning of windings.

The scheduled maintenance of motor should be carried out in such a way that the motor does not reach this stage. Thus, proper overhauling of the motor is of great importance.

Also, if any other parameters such as voltage, current or insulation resistance is abnormal or the motor came in contact with water (due to flooding or water leakage), the overhauling of motor is to be performed.

Before overhauling the motor, rotor running hours should be calculated, along with the lifetime of the bearing (running hours). The bearing must be renewed if required.

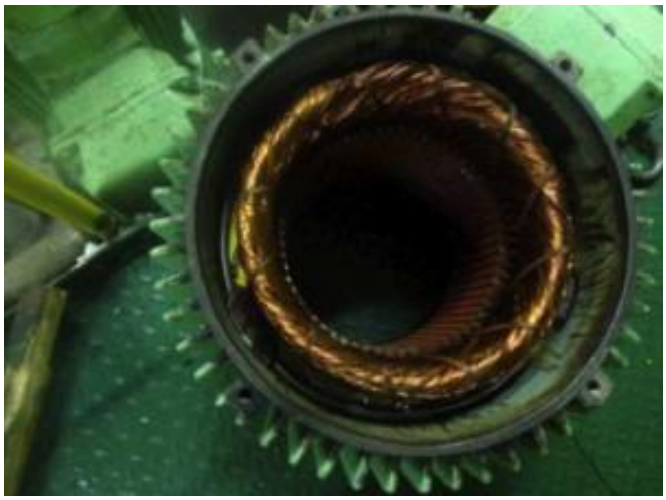
In the motor, bearings are most susceptible to damages from friction during transmission.

How To Do Motor Overhauling?

Insulation test:
Checking the insulation of the stator winding is very important before and after the overhaul procedure. Multimeter is used for this purpose, with its one probe connected to the winding and other to the earth with switch selected in the resistance knob.

Dismantling

Note: Before dismantling any part of the motor or motor connection, marking of both motor housing and connection wires is very important. This will ensure that the boxing back procedure is smooth and there is no mismatch of parts. Also check the direction of the motor rotation before stopping the motor for overhauling.



Before overhauling the motor, pre-planning of removing and fixing back the motor safely in place must be discussed and implemented (depends on place where it's fixed and also on the size of the motor) otherwise the load side (for e.g. Pump connected to motor) will be damaged by the motor shaft.

The motor can be connected to the load as vertically coupled load and horizontally coupled load.

Horizontally coupled having two types:

- Hinge mounted (Must be done very carefully)
- Base mounted

Dismantling can be done in two ways:

a. **In place** (On board ship, it is mostly applicable for very big vertically coupled motor to load)
   - Removing the motor from the place by chain block
   - Remove the coupling and key
   - Keep the motor in place and fix the nuts
   - Open the motor from top (cooling fan side)
   - Take out the rotor by chain block, take out the stator winding separately

b. Out place

- Take out the motor from the place and keep it in a horizontal position
- Open the motor from any one side
- If it's a small motor take out the rotor
- If it's a huge motor keep the rotor inside and open the bearings using a good bearing puller

After any one of the above two processes are completed, perform the following procedure:

Removal of Bearing Housing Cover:

While removing the bearing housing cover, note that some motors will be having inner bearing cover tightened with nut bolts. Remove it carefully.

In other constructions the bearing housing cover is locked with bearing by a circle clip. Whenever removing the housing cover on both sides (Driving End & Non Driving End) make sure proper care is taken while handling.

Removal of Bearing or Coupling:

- Use a suitable puller (depends on the size of the bearing or coupling);

mostly use the 3 arm puller as it has a good pulling strength

- First use the puller by barely applying any pressure and try to take out the bearing or coupling
- If it's not coming out even after enough load, use a pipe and extend the tightening spanner and try to remove the bearing
- If the bearing is still stuck at the original position, heat the bearing or coupling up to 100 deg. C while it's locked with the puller and apply little pressure
- If the bearing or coupling is not coming out with the above tricks, the last method is to apply the load on puller through hydraulic jack along with heating
- After opening the stator cover, thoroughly inspect the inside condition of the stator. If there is little damage in rotor, repair it
- If the insulation of the motor is less, clean the windings by an evaporative type cleaner and give sometime to let it dry. Apply insulation coating and heat the winding around 40 deg. C to 50 deg. C by means of powerful halogen lamps
- Clean both side bearing housing covers, cooling fan, body of the motor and protection cover of the motor with electro clean or suitable chemical

Insertion of bearings:

Clean the shaft on both ends and heat the new bearing up to 70 deg. C to avoid tight insertion of the bearing in the shaft. Do this for both sides.

Wait for 20 minutes, let the bearing cool down, and after that insert the bearing housing cover from one side.

Assembling the motor:

Before boxing up the motor, do the insulation test again to compare with previous values. If the values are on higher side, start boxing back, otherwise heat up the winding for some more time with halogen light.

- Box up to be done as per the markings
- Take up the rotor with one side cover (If bearing locking nut were there in one of the sides, prefer that to be the first to assemble) and push it inside the stator
- Lock with one side nut bolts, slowly insert the other side cover, do the hammering slowly by wooden hammer, insert and lock with nut and bolts, and the rotor will now apply load on the bearing
- Gently tighten the bolts using opposite tightening method. Insert the cooling fan and protection cover, and once again verify the tightness of the bolts
- Fix in place the motor as per the marking and give the connections accordingly
- Try out and check the Amperage. Compare with rated amperage and before overhaul amperage

Note: Check the direction of rotation after overhauling. If it indicates opposite direction, it means the connection done is wrong.

Starter Panel Maintenance on Ships: Dozens of motors are used on board ships for a variety of purposes in both deck and engine departments. Each of these motors has its dedicated starter panel, which is used for the switching purpose i.e. On and Off operations. Like any other machinery system, these motor starter panels also need regular maintenance to ensure smooth motor operation.

What is Starter Panel Routines?

Motor starter panel routines include inspection and maintenance of motor's starter panel.

- Starter panel routines mean inspection and cleaning of contactor's (the switch inside the starter panel box controlling the on and off of the motors) contacts
- Checking of connections in the starter panel
- Cleaning of the complete starter panel
- Checks in the terminal box on the motor for loose connections
- Visual inspection of overall starter panel

Why Starter Panel Routines and Maintenance are Important?

Every time we switch on the motor, the contacts in the panel get energized as electricity flows through the contacts (high current flows during starting).

At the time of on/off of the switch, a spark is generated in the contacts for a fraction of seconds. In case of poor contacts, this spark will damage the same, leading to pitting/scoring marks in the contacts along with carbon deposits on the contact surface.

Safety Measures to be Followed While Starting Motor Starter Panel Routines:

1. Switch off the main power supply from the circuit breaker

2. Take out the main fuses in the starter panel, and if required control fuses as well

3. Put the lock out tag

4. Inform the engineer who is in charge of that particular machinery

How to Carry Out Motor Starter Panel Maintenance?

- Open the motor starter panel and the contactors. This would need special 'T' type key, which is found with the electrical officer. The panel can be opened when the breaker is switched off

- Take out the moving contacts and the arc huts. Keep a very fine emery paper, good evaporative type contact cleaner, and a clean cloth for cleaning and maintenance purpose

- Mark the moving contacts from where it was removed; clean the fixed and moving contacts, and the arc huts

- Fix the contacts as per the markings and check for any lose connections inside the panel

- By visual inspection we can identify the contact's condition. Take out the contact, clean it by a smooth cloth or a very fine emery paper and measure the contact's width by a vernier caliper at 3 different places. Note down the values

- Simultaneously take a same type of new contact, measures and note down the width values measured in 3 different places. Now compare the values to find out the actual contacts condition

- If difference between the values is bigger, replace the contact with a new one (same type)

- Also make sure that the measured value of a single contact must be same on both sides in both moving and fixed type contacts, otherwise there is a high possibility of sparks generation

Important Points

If cleaning of deposited carbon is not carried out at regular intervals, it can lead to two main issues:

- A poor contact – which will increase the spark amount and frequency

- Increase of fire hazard – The deposited carbon will act as fuel for fire

Checking for Loose Connections

Inside the motor starter panels, check should me carried out for loose connections to avoid short circuit, spark or accidents.

How to Check for Loose Connections?

- Tighten the loose screws using a Screw driver, if found any
- Using your hand, try to pull out the wires slowly. If any wire comes out completely or more than it should, take it out and reconnect
- Check the insulation of the connected wires, as because of aging and sparks there is a possibility of damage to the wires

Cleaning of the Starter Panel

- The motor starter panel should always be maintained clean to reduce fire hazards
- Clean the whole starter panel by a wet cloth and use brushes where hands cannot reach
- A vacuum cleaner can be used to remove dust

Checking the terminal box of the motor

Motor is a dynamic machine, and thus there will always be vibrations. This leads to loose connections in the terminal box of the motor.

- Open the terminal box of the motor by loosening the nuts
- Check the tightness of the connection by shaking the wires and use the correct size spanner to tighten the connections
- If there are any loose connections, it will lead to sparks in the terminal box causing fire in the motor
- Short circuit is also possible because of a loose connection

After the maintenance is done on the motor starter panel:

- Remove the lock out tag
- Insert the main and control fuses in the starter panel
- Switch on the main power supply from the circuit breaker
- Inform the engineer who is in charge of that particular machinery
- Start the machine and check the starter panel if there is any abnormal sound

Busbar Maintenance on Ships: A busbar is a copper plate/bar, which is used, in ship's main and emergency switchboards to conduct electricity from generators or from one electrical terminal to another. Technically, there are no electrical wire connections inside the main and emergency switchboards on ships for connecting power supply from generators to these switchboards. All high voltage and high current systems are connected by bus bars.

The busbar's copper plates/ bars are connected together with the help of nut bolts, which transmit electricity as required. During normal ship operations, the busbar connections are subjected to ship's harsh environment along with the vibrations generated by the ship and ship machinery such as main engine, auxiliary engines, compressors etc.

These vibrations cause loosening of nut bolts in the busbar, which can lead to short circuit or any other type of accident. Loose connections inside the switchboard can also lead to sparks that can cause fire.

Moreover, the busbars are meant to carry high voltage and current, which tend to heat up the lines due to energy flow in the system. For this reason, inspection and maintenance of busbar at regular inspection of time are required for smooth operation.

Safety

If any maintenance is planned for busbars, highest standards of safety are required as even the tiniest mistake can lead to electrocution and even death of the crew. The busbar maintenance is therefore performed when the complete busbar panel or switchboard is turned "OFF".

When the bus bar maintenance should be done?

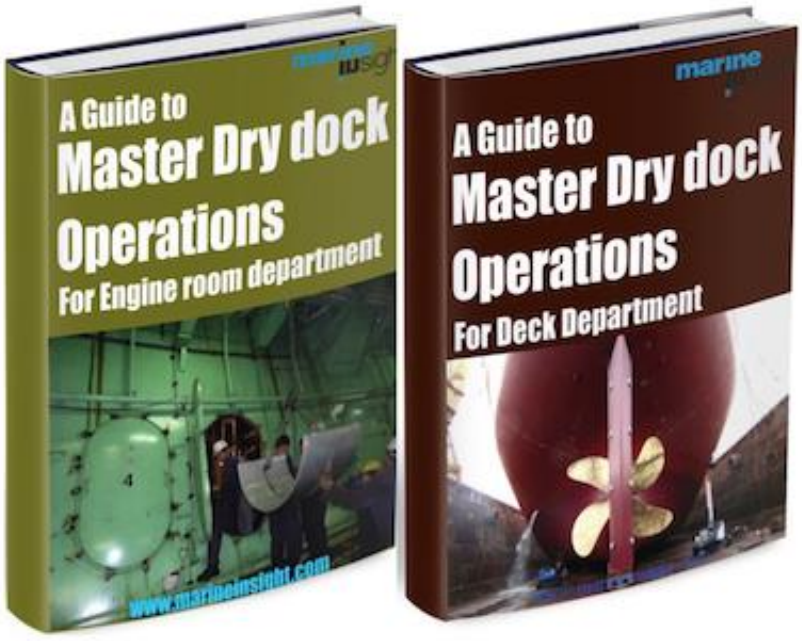
- Busbbar maintenance can be done when the ship is in black out condition, i.e. ship's generators are not running and no power is supplied to main or emergency switchboards

- If the main switchboard busbars are to be inspected or to be work on, keep emergency generator running. Keep in mind that there will be some portion of the main switchboard, which will be fed by emergency switchboard. Hence know the complete system properly and keep away from those areas

- The best time to do busbar maintenance is when the ship is in the dry dock

Know the Complete Dry Docking Procedure of a cargo ship in our eBook-

" A Guide to Master Dry Dock Operations- Engine and Deck Departments"



Safety before doing busbar maintenance:

- Put the "lockout" tag in all generators and in the emergency generator
- Keep all the generator system including load dependent start stop system in manual mode
- Ensure to wear rubber gloves even when the board is not in "Live" condition
- Wear all required personal protective equipment (PPEs) when working on switchboard
- If the ship is in complete black out situation, ensure that before cleaning the main and emergency switchboard, the area is well lit by sufficient lights. In dry dock, same can be arranged from shore workshop

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How Busbar Inspection and maintenance is carried out?

Any maintenance on busbars should only be performed when the ship in Dry dock or black out condition.

- Open the door for main and emergency switchboards where inspection is to be performed
- Carryout visual inspection of copper plate and nut bolts. Mark any missing or burn out areas
- By hand or using a metal or plastic stick (where access for hand is not possible), tap the bus plates gently so as to make out for any loose connection. Ensure to wear electrical gloves even when busbar is not live
- The busbars are mechanically supported inside the switchboard by means of insulators, which may be of rubber or ceramic materials (bad conductors). Check for any damages in the insulator part
- By using an adjustable spanner or particular size spanner, tighten the nuts in the busbar connection for main and emergency switch boards
- Check the tightness of the wire connections, which is connected to the circuit breakers
- Clean the bus bar and switchboard area with the help of vacuum cleaner
- If u find any loose connection or spark, black-out the particular and adjacent busbar before tightening the nut
- If u find any metal piece or nut bolts missing or inside the panel, ensure to remove it as the same can cause short circuit or fire
- Inform the Chief Engineer and the in-charge of that particular machinery regarding the same
- Reset the main power and check if there is any abnormal sound in main switch board and emergency switch board
- Monitor the temperature of the busbar area with laser temperature gun
- Keep the emergency switchboard in the auto mode

The ship's electrical officer is required to inspect the busbar periodically for record keeping and also as stated by the preventive maintenance system. This is done to avoid any type of accident from electrical faults on ships.

When doing such inspection the following highest safety measures are to be taken with all required PPEs as the Busbar is "LIVE".

- Check the load in the running generator by means of KW meter provided in the main switchboard
- Open the bus bar access door provided at the backside of MSB or ESB

Once the inspection and maintenance is completed:

- Close the bus bar access doors
- Remove the lock out tag
- Restore the main power supply by the generator

Alternator Maintenance on Ships: An alternator is an electro-mechanical device comprising of stator, rotor winding and an external exciter for supplying excitation voltage. Alternator generates electricity when coupled with a prime mover.

Alternator on a ship is exposed to harsh weather and sea conditions, due to which, its capacity and efficiency tends to reduce. It is very important to have proper maintenance on the alternator part of the generator as per planned maintenance or as and when required.

Maintenance on Alternators:

Before starting any maintenance work on the alternator, all safety precaution should be taken and the alternator should be shut and locked down. Also, post notice and ply cards on relevant places and alternator heater to be isolated.

- Clean the alternator ventilation passage and air filter
- Check the Insulation resistance of stator and rotor winding
- Air gap between stator and rotor to be checked and maintained between 1.5 to 2 mm
- Slip rings to be checked for even wear down to be renewed if required
-

- Carbon brushes to be cleaned and checked for free movement
- The brush contacting pressure to be checked by spring balance
- Automatic Voltage Regulator to be checked and cleaned off oil and dust
- The lube oil level of pedestal bearing to be maintained and renewed as per planned maintenance
- A vacuum cleaner can be used to remove dust accumulated in the inner parts of alternator
- All the connection in the terminal box to be tightened properly
- The terminal box cover gasket to be checked for proper oil and water tightness.
- Cable gland to be checked for integrity
- Forced Ventilation around alternator must be maintained all the time
- Check heater for proper operation
- The foundation bolts of the alternator to be checked for tightness

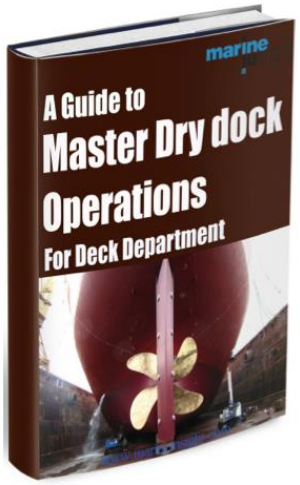
After maintenance is performed, a no load test should be carried out and general condition such as noise, temperature, voltage generated etc. of the alternator should be observed and noted.

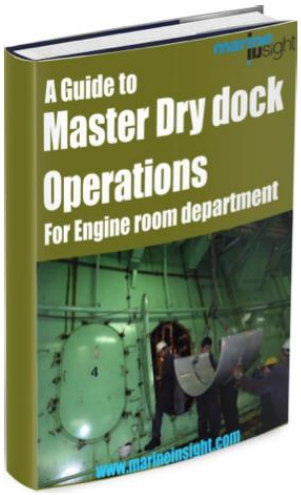
Electrical systems form an integral part of ship's operational machineries. Just like all other mechanical systems, electrical systems must also be checked at regular intervals of time.

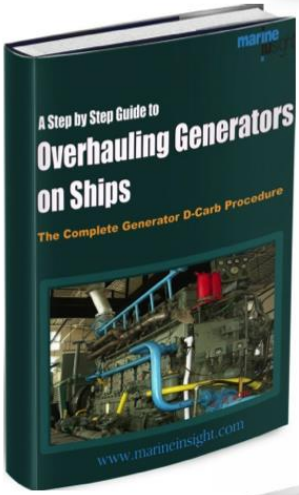
Marine engineers and electrical officers on ships must know their machinery systems and all electrical equipment attached to them extremely well.

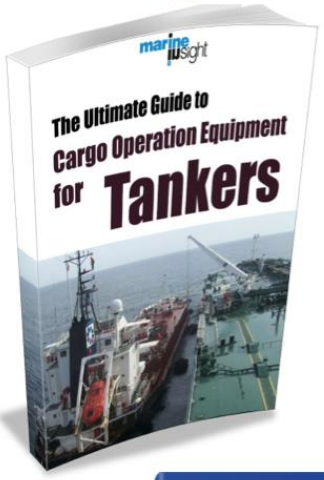
Periodic maintenance is the key to efficient and smooth running of all electrical systems on ships.

If you have any query or suggestion, please mail us at info@marineinsight.com









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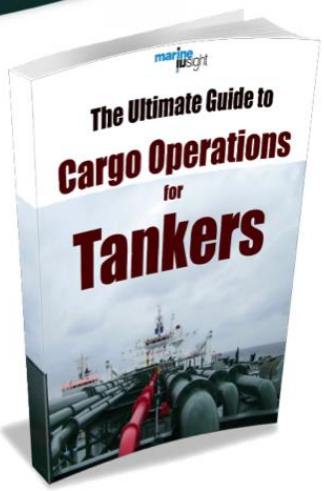

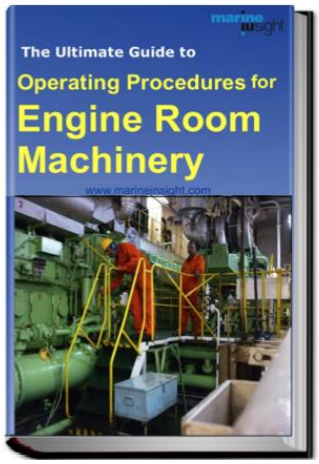

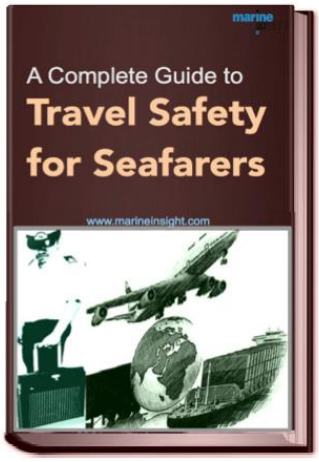

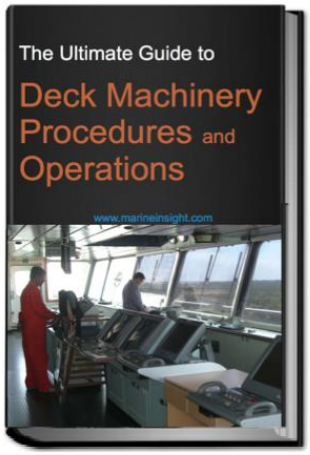

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