A safe trip all the time
– with reliable power supply

The failure of navigation and drives fail may raise considerable problems concerning the operation of the ship. But this is not the only reason why safe electric power supply on modern ships plays a major role. Power supply systems of different safety relevance and different voltages require a differentiated distribution and supply concept including the respective monitoring devices in order to prevent unexpected operational interruptions and possible hazards in a comprehensive way.

Power supply systems

In contrast to onshore power supplies in buildings, power supplies on ships pose special requirements that stem inevitably from the operating location "Sea".

- A ship is an autonomous system that does not require an external supply over a long period of time
- Climatic conditions range from tropical to arctic
- Specific demands on high sea through list, shocks (for example through ice)
- Chemically aggressive influence of sea-water
- Change of location/position (different supply systems ashore).

Electrical supply systems onboard ships and offshore facilities are classified into primary and secondary systems: While primary systems are directly connected to the generator, the secondary systems have no direct connection. For example they are insulated from the generator by a transformer or by a motor-generator. Electrical installations shall be designed so that:

- The operation of the equipment required for safety will be ensured under various emergency conditions
- The safety of passengers, crew and the ship from electrical hazards will be ensured
- The requirements of the various regulations and standards are adhered to.

Standards and regulations

There are many standards and regulations that govern the construction and operation of sea-going ships, which significantly influence the design of the electrical equipment.

These are for example

• Standard IEC 60092-xxx	Electrical installations in ships
• Standard IEC 61892-xxx	Mobile and fixed offshore units – electrical installation
• Lloyd`s Register of Shipping	Rules & Regulations for ...
• Det norske veritas	Rules for classification of ...
• International Maritime Organisation (IMO)	International Convention for the Safety of Life at Sea (SOLAS)

Earthed power supply systems (TN systems)

When talking about unearthed systems on ships, this term refers to systems where a live conductor or the neutral is connected to the protective conductor (TN systems). These systems are used, for example, on passenger ships for cabin lighting, on cruise ships in the field of entertainment or sometimes for lifts. But also in offshore facilities this type of distribution system is used for sub-distribution boards or for circuits resp. loads which are less important and used occassionally.

Standards for ships and offshore facilities often require continuous monitoring of fault currents and an acoustic alarm in case of a fault for earthed systems. Such as for example in IEC 61892-7:2007-11 „Mobile and fixed offshore units – Electrical installations Part 7: Hazardous areas, in IEC 60092-502:1999-02 „Electrical installations in ships – Part 502: Tankers special features or in Det norske veritas – Oil carriers Pt. 5. Ch. 3 Sec 8 A200:2012

To accomplish this, residual current monitors (RCM) according to IEC 62020:2003-11 are used. These residual current monitoring systems, typically multi-channel, continuously monitor the fault current (also AC/DC sensitive) and signal when a preset value is exceeded. In this way an unexpected shutdown can be avoided also in earthed systems. Such systems are additionally used to monitor the central earthing point in TN-S systems, to detect possible disturbances in the ship electronics or to recognise potential fire hazards caused by stray currents at an early stage.

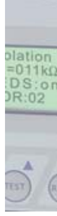
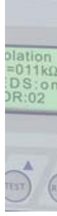


TABLE 1: **AC distribution systems types on ships and offshore facilities**

AC systems							
Standard	Primary and secondary systems		Primary systems up to 500 V				
			Secondary systems up to 500 V				
	3ph 3 wire isolated	3ph 3 wire N earthed	3ph 4 wire N earthed without hull return	1ph 2 wire isolated	1ph 2 wire one pole earthed	1ph, 2 wire, mid-wire earthed, for supplying lighting and socket-outlets	1ph, 3 wire mid-wire earthed without hull return
Basic system	**IT**	**TN**	**TN**	**IT**	**TN**	**TN**	**TN**
IEC 60092-201:1994-08 Electr. installations in ships - System design general	X	X	X	X	X	X	X
IEC 61892-2:2012-03 Mobile / fixed offshore units	X	X	X	X	X	X	X
LR Part 6: July 2011 Control, electrical ...	X		X	X	X		
LR Part 6: July 2011 Control, electrical tankers	X			X			
DNV part 4 chap. 8 :2012 Electrical installations ...	X	X	X	X	X		

TABLE 2: **DC distribution system types on ships and offshore facilities**

DC systems					
	2 wire isolated	1 wire with hull return	2 wire one pole earthed	3 wire middle-wire earthed, without hull return	3 wire middle-wire earthed, with hull return
Basic system	**IT**	**TN**	**TN**	**TN**	**TN**
IEC 60092-201:1994-08 Electr. installations in ships - System design general	X	X	X	X	X
IEC 61892-2:2012-03 Mobile and fixed offshore System design	X		X	X	
LR Part 6: July 2011 Control, electrical	X				X
LR Part 6: July 2011 Control, electrical tankers	X				
DNV part 4 chap. 8 :2012 Electrical installations ...	X	X	X		



Unearthed power supplies (IT systems)

In unearthed power supplies (IT systems), there is no active conductor directly connected to the protective conductor (PE). This has the following advantage: A first fault (insulation fault) does not lead to the tripping of a fuse (circuit breaker) and does not lead to automatic disconnection of supply. In practice this means, the lighting remains switched on, electrically controlled processes can be stopped safely or electric motors or drives are not abruptly stopped. In this way, it may also be possible to avoid secondary accidents, such as injury, falls etc. However, much more important, in medical areas on the ship possible life-threatening complications caused by the failure of medical electrical devices and equipment can be prevented.

In order to achieve that an insulation fault RF does not remain undetected and that a possible second fault at another active conductor leads to an unwanted disconnection, the insulation resistance between active conductors and earth is continuously monitored by an insulation monitoring device (IMD) and initiate a signal when the value falls below a preset limit value.

The tables 1 and 2 show that the IT system is the only distribution system type that is consistently used in the listed standards and regulations.

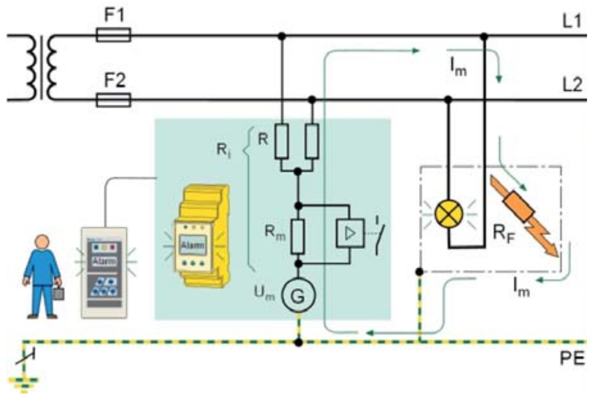
TABLE 3: Required monitoring equipment in different power supplies

Regulation	Application	Insulation monitoring	Earth fault detection	Residual current monitoring
Supply system	-	Unearthed	Unearthed	Earthed
Lloyds register	Ships	Part 6 Ch. 5.4		
IEC 61892-2:2012-03 - System design	Offshore	Ch. 5.7	Ch. 5.7	
IEC 61892-5:2010-08 - Mobile units	Offshore	Ch. 8.4	Ch. 9.10.1.4	Ch. 9.10.1.4
IEC 61892-7:2007-11 - Hazardous areas	Offshore	Ch. 5.2.2		
IEC 60092-201:1994-08 - System design	Ships	Ch. 7.2		
IEC 60092-502:1999-02 - Tankers	Ships	Ch. 5.3.2		Ch. 5.3.2
IEC 60092-507:2008-01 – Small vessels	Ships	Ch. 7.2.3.1	Ch. 7.2.3.1	
Det norske veritas Ships / high speed, Light craft and naval surface craft: 2012	Ships	Pt 4 Ch. 8 Sec 2 102		Pt 4 Ch. 8 Sec 2 102
Det norske veritas - Oil carriers: 2012	Ships	Pt. 5. Ch. 3 Sec 8 A 200		Pt. 5. Ch. 3 Sec 8 A 200
Lloyds register: 2011	Ships	Part 6 Ch. 5.4.1		Part 6 Ch. 2.6.1

Measurement technique of insulation monitoring devices

Insulation monitoring devices are defined in the product standard IEC 61557-8:2007-06. This standard stipulates that these devices must feature an active measurement method. Active, in this case means, the devices generate a measuring voltage which is superimposed on the system between the active conductors and earth. In the event of an insulation fault, the insulation fault R_F closes the measuring circuit generating a measuring current Im that is proportional to the insulation fault RF. When the insulation resistance falls below the set response value, a message is generated (Figure 1). In order to ensure a safe and reliable insulation monitoring in the case of application in the field of variable-speed drives (ship drives), it is necessary for these devices to have a special measurement method, the so-called pulse code measurement method. Insulation monitoring devices using a pure DC measuring voltage fail to function in this application and lead to false alarms.

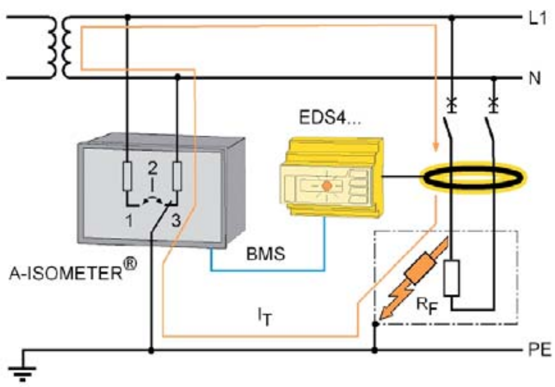
FIGURE 1:
Operating principle of an insulation monitoring device with superimposed measuring voltage



Equipment for insulation fault location in IT systems

Electrical installations on ships and offshore facilities often are widely distributed and hence physically very large. In the event of an insulation fault, the responsible electrician will require an enormous amount of time or the insulation fault cannot be found at all. The IEC 60092-507:2008-01 “Electrical installation in ships – Part 507: Pleasure craft” stipulates, for example, in chapter 7.2.3.1 “Non-earthed systems: Insulation monitoring devices shall be fitted to give warning of earth faults and assist in the location of a fault”. In practice, insulation fault location systems are used in accordance with IEC 61557-09:2009-01. These are capable of localising insulation faults automatically and precisely within a very short time. For this purpose, a locating current injector and the respective measuring current transformers are used, that are to be installed in the respective circuit. In the event of an insulation fault, a locating current IT is generated by the locating current injector which flows through the variously arranged measuring current transformers via the insulation fault R_F. By assigning the measuring current transformers to the circuits, the point of fault can easily be localised (figure 2).

FIGURE 2:
Operating principle of an insulation fault location system



The requirement for a fast localisation of an insulation fault also is stipulated in IEC 60364-4-41:2005-7 in chapter 411-6.3.2. There the explanatory note states: "It is recommended that a first fault be eliminated with the shortest practicable delay".

Figure 3: Insulation monitoring device with integrated locating current injector for insulation fault location (Photo supplied by Bender, Germany)

Monitoring of disconnected loads

On ships and off-shore facilities, winches, motor pumps, generators etc. are typical tools that are installed on deck and are exposed to rough sea conditions. Such particular conditions are high ambient humidity, seawater, extreme temperature differences, high UV radiation, aggressive chemicals and exhaust emissions. The electrical insulating material of the motors resp. generators is constantly subject to high mechanical/chemical stress. This also applies to the insulation of cables which may become brittle due to high UV radiation. Not to forget the connection boxes which can get soaked with salt water without being noticed. As a result of these possibilities insulation faults may occur unnoticed, which may trigger a fuse when the motor is switched on, for example, and in this way prevent an important startup (e.g. fire extinguisher pump). If the fault current is not sufficient for the fuse to trip, there is the danger of overheating at the point of fault which can result in an acute risk of fire.

In order to avoid this risk, the insulation resistance of the load is monitored during standstill and an alarm is initiated when the value falls below a relatively high-resistance value (≥ 1 MΩ). This so-called offline monitoring can be used in unearthed as well as in earthed systems (Figure 4) because the circuits are electrically isolated on all poles.

FIGURE 4:
Insulation monitoring of a motor winch in offline mode

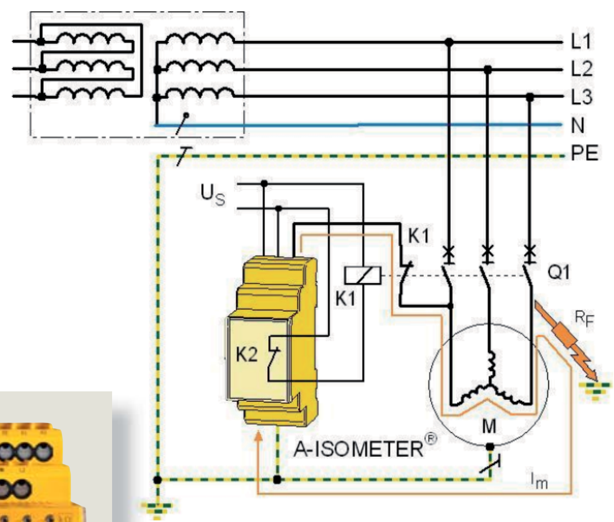
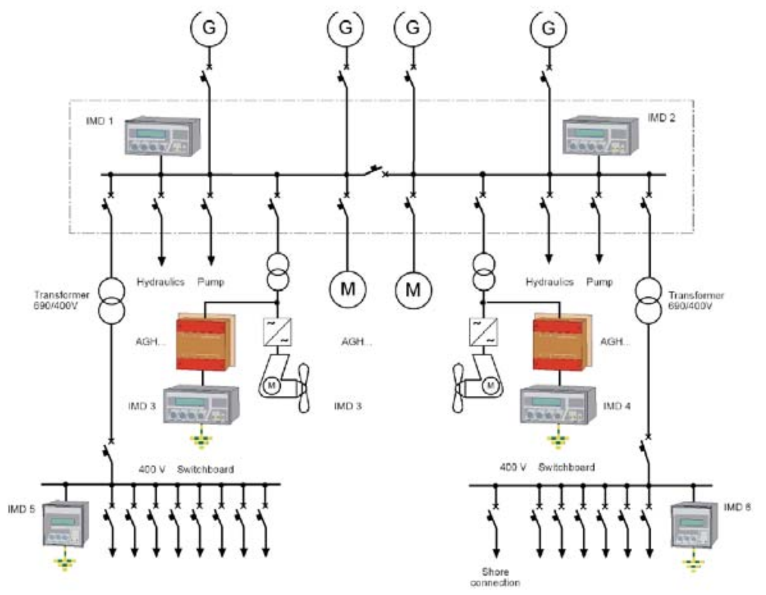


Figure 5: Offline monitor for disconnected loads (photo supplied by Bender, Germany)

FIGURE 6:
Design of a power supply system of ship drives with insulation monitoring

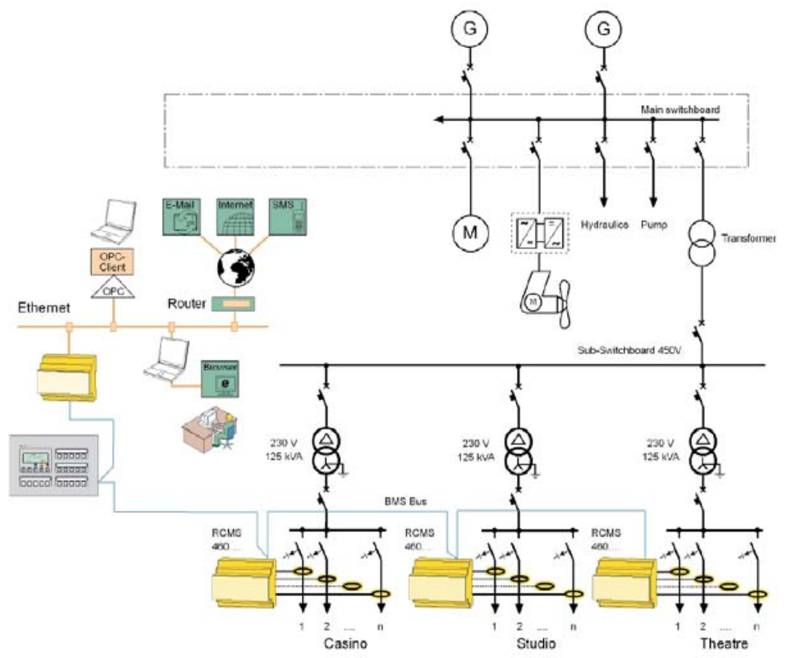


Practical applications

IT systems with insulation monitoring are applied in many areas on ships. Typically these are drives of ship propellers. But also in subordinated areas in the area of pumps etc. IT systems with insulation monitoring are commonly used (Figure 6).

In earthed systems, residual current monitoring is used to control AC 230 V systems, for example, to prevent protective devices from tripping resp. to recognise any impending disturbances at an early stage. These systems also use the modern communication structures and send this information to a central control technology (Figure 7).

FIGURE 7:
Residual current monitoring in earthed systems of a cruise ship



SUMMARY

On cruise ships, tankers and offshore oil platforms, the operators have a common goal: To protect passengers and the crew against the hazards from electric current and to ensure operation of the electrical systems with as little disturbance as possible. When using the IT system with insulation monitoring or residual current monitoring in earthed systems, there are multiple possibilities for achieving these objectives. ■

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IEC 60092-507:2008-01	Electrical installations in ships – Part 507: Small vessels
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Det norske veritas	www.dnv.com, Rules for classification of ships – Part 4 Machinery and systems Chapter 8 Electrical Installations (Ships), 2012 – Part 5 Special service and type Chapter 2 Passenger and Dry Cargo Ships (Ships), 2012 Chapter 3 Oil Carriers (Ships) July 2012
International maritime organisation	www.imo.org International Convention for the Safety of Life at Sea (SOLAS), 1974

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