Digital Learning Paths

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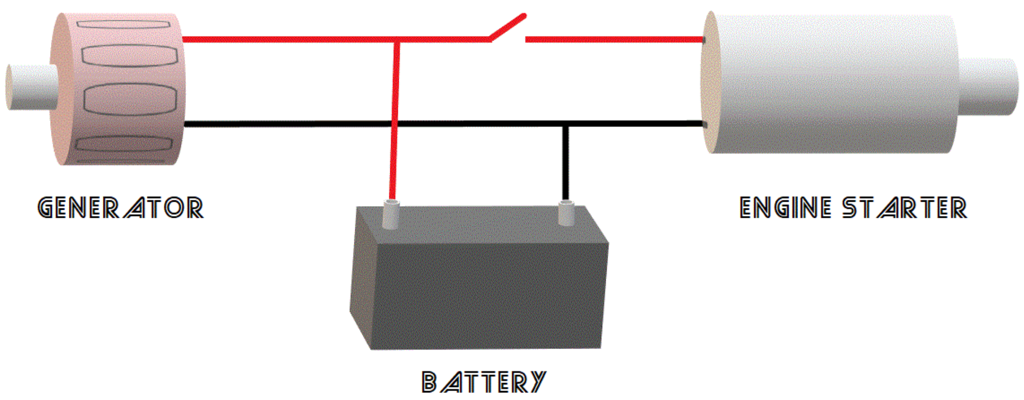
Field	**MARINE TECHNICS**
Chapter	**DC INSTALLATIONS ON SHIP**
Subtitle	**All**

DC ELECTRIC SYSTEMS ON-BOARD

ELEMENTS OF DC INSTALATION ONBOARD

BASIC DC ELECTRIC SYSTEMS ON-BOARD

Smaller ships and boats are mostly electrified by DC electric systems. The main advantage of DC compared to AC systems is ability to store electric energy in batteries.
To provide possibility of connecting usual home electric devices supposed to be supplied by AC 230V electrical sources on ship, there is usually DC/AC converter and AC system integrated in DC system.
The simplest DC electrical system is consisted of DC generator, battery and engine starter.



The task of the generator is to supply the ship with electricity during the operation of the propulsion engine.
Generator also replenishes the energy consumed from the battery while the propulsion engine was turned off.
Batteri saves electric energy and delivers that energy to consumers only while propulsion motor is off. When propulsion motor is on all electric energy is delivered by generator.
Engine starter uses electric energy from the battery for starting propulsion motor.

WIRING OF DC INSTALATION

In all DC systems, including marine systems, red joins the plus pole and black the minus pole.

Often the minus pole is connected to the hull of the ship if it is technologically feasible and acceptable.

It is not technologically feasible for ships and boats with hulls made of insulating materials (fiberglass, wood ...) and it is unacceptable for materials where such a method of distribution would lead to the destruction of the hull (aluminum).

When it comes to systems in which the minus pole cannot be connected to the hull of the ship every line (electric circuit) on the switchboard starts with two-pole circuit breakers, which means that both, the plus and minus poles are connected to a circuit breaker.

Also all the switches and the relays in that circuits are two-pole ones.

The total installed power and complexity of the distribution of the DC system on board depends on the size and purpose of the ship or boat.

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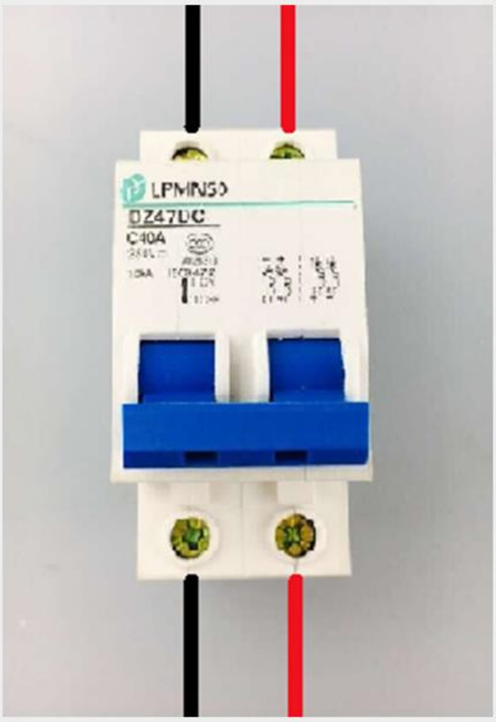


Modern ships and boats, even in the smallest versions, require significantly more in terms of production and distribution of electricity.

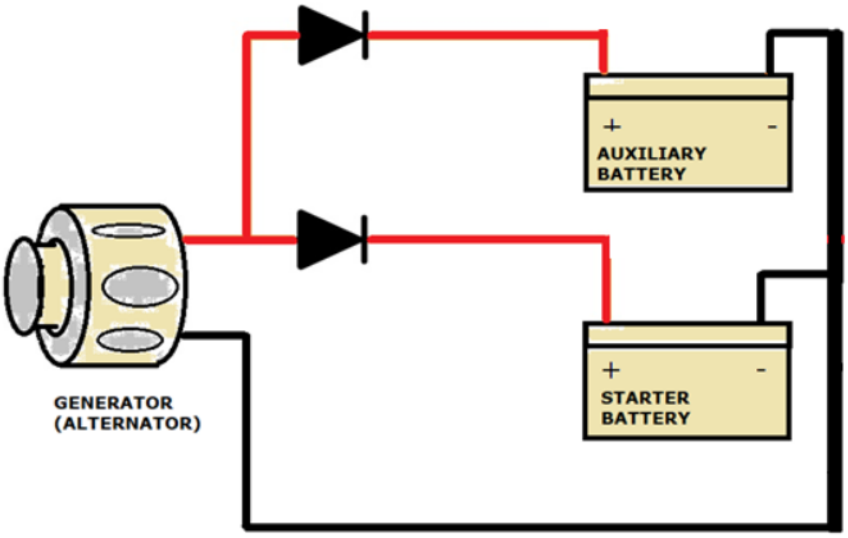
There is primarily the issue of powering signaling and luminaire lighting, powering navigation, other auxiliary devices and various devices to achieve the comfort of a longer stay on board.

DC GENERATION SYSTEMS AND BATTERIES CHARGING PROCESS

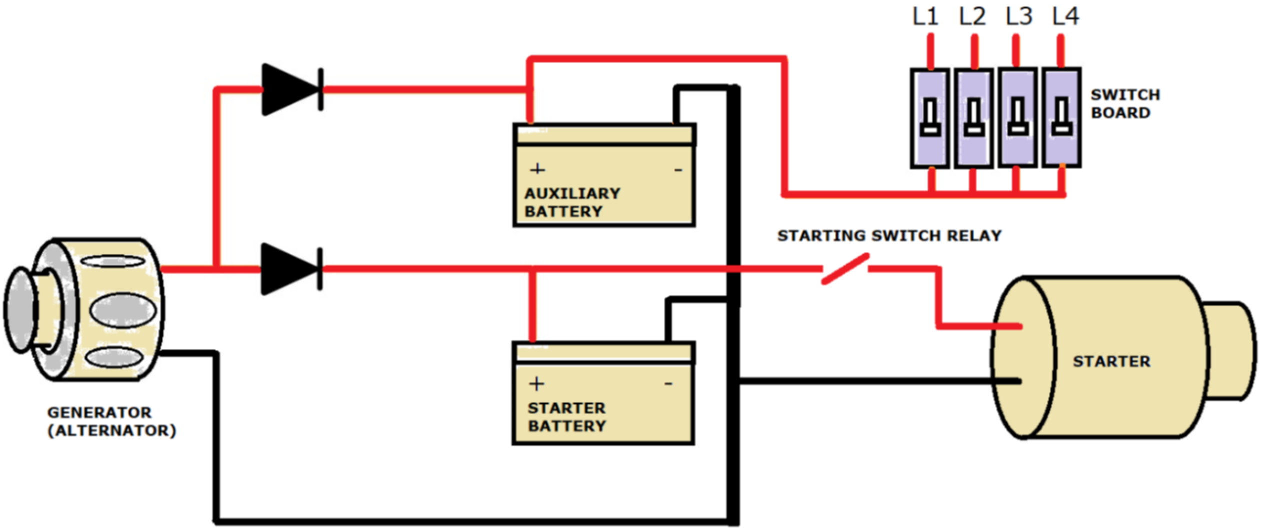
If all these devices were powered by only one battery while the propulsion engine was off, there would be a risk that the battery would be so discharged that it would not be able to deliver enough electrical power to the starter to start the engine.

The comfort of using other devices in this case would be significantly reduced because the user should always monitor the discharge of the battery.

Therefore, on ships with DC systems, a second battery or a bank of several batteries is installed to power all other devices, and the starting battery retains only its basic purpose - powering the engine starter.



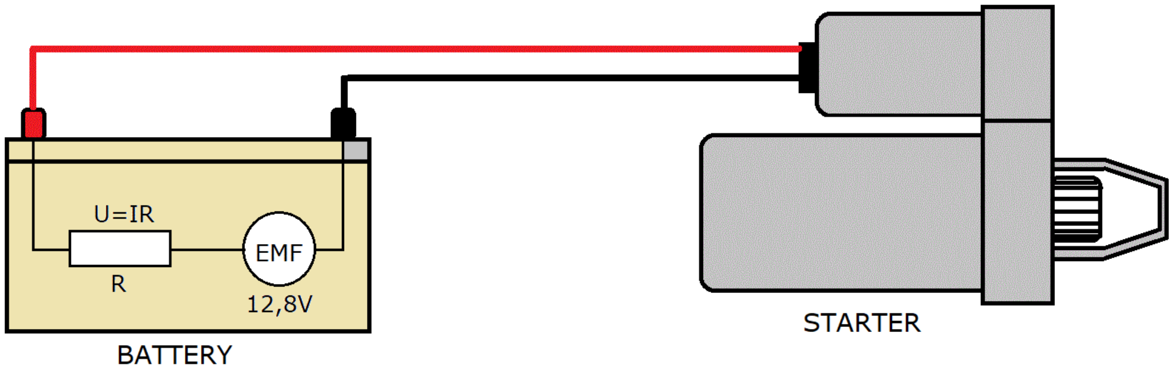
A simple scheme of electricity distribution in the ship's DC system, which also includes other consumers connected to an additional battery, is shown in the following figure:



The diodes in the circuit in the picture have the role of enabling the charging of both batteries at the same time, and on the other hand in the process of discharging completely separate the circuits of the two batteries.

Otherwise, the starter battery would be discharged along with the auxiliary battery and could not provide enaugh power to starter, which would not be the biggest problem.

A bigger problem would be the danger of destroying the starter due to overvoltage.



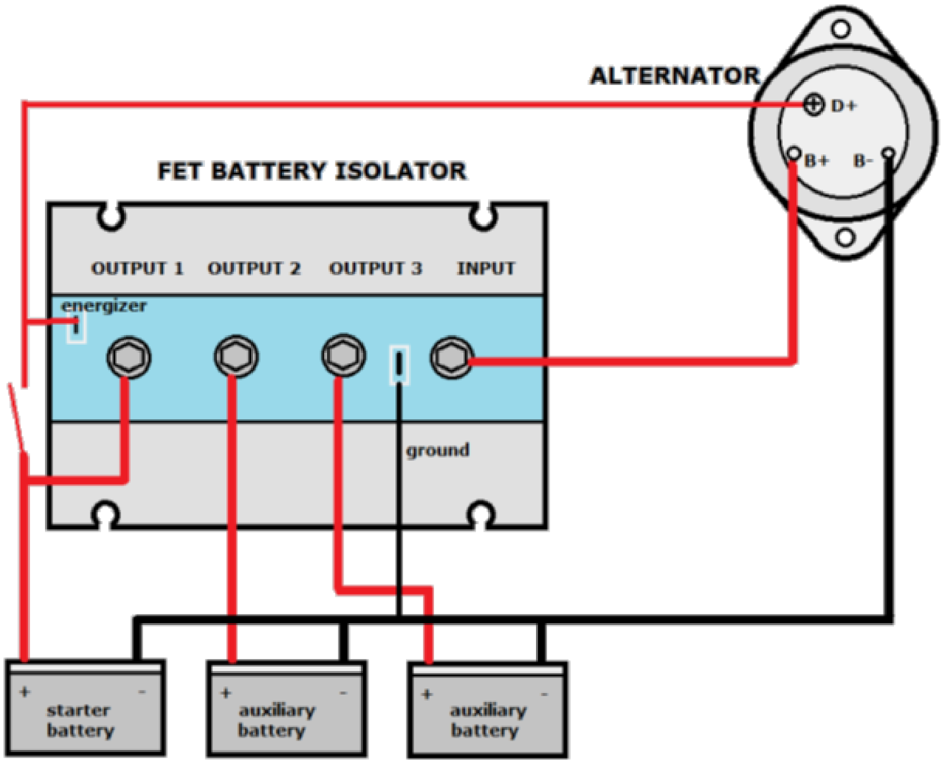
The electric starter is installed in a system with a battery of a predefined capacity and is dimensioned so that a certain voltage drop on the battery inner resistance is already taken into account in starter construction.

If this battery is replaced with one of higher capacity or if other batteries are connected directly to it in parallel, the voltage drop across the batteries will be too small and the starter will be endangered by excessive voltage.

The voltage drop of 0.7 to 1,7 volts on the oridinary silicon diode is quite large since the alternator is not constructed for this additional voltage drop, so the batteries will be charged much slower then in normal charging without diode in charging circuit. Also, the power that is converted into heat on the diode is significant. To reduce these negative caracteristics, manufacturers usualy embed Schottky diodes instead of oridinary diodes in this kind of battery isolators. Schottky diodes have voltage drop between 0,15 and 0,45 volts and are much more acceptable in this purpose.

Therefore, instead of diodes, FETs (Field Effect Transistors) are used, which act in the same way as diodes in the device, but have a drop of voltage on them from an acceptable 0.02 V to 0.1 V.

An example of a battery isolator with FET transistors is shown in the following figure.



FET technology is known as static electricity sensitive and in regard of that requiers additional caution.

The alternators have to be energized at their D + terminal (excitation coil).

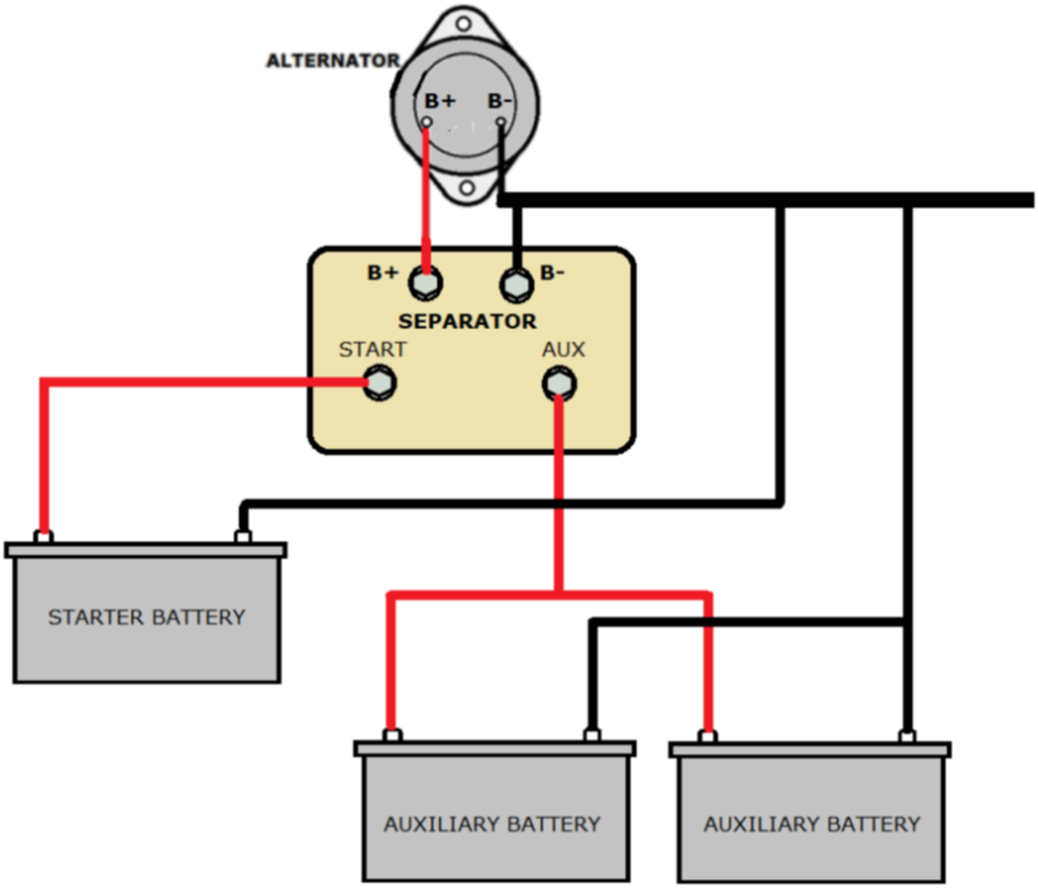
However, due to the diode, current cannot flow from the battery to the alternator, as it is the case with a single-battery system (without diodes), and it does not receive excitation current needed for process of electromagnetic induction.

Therefore, the device from the previous picture also has an "energize" connection, a terminal that provides a limited amount of power to the D + terminal of the alternator so that the alternator can start producing electricity.

SYSTEMS WITH SEPARATOR

There are generators without D+ terminal in which excitation coil is directly connected to B+ inside generator. In that case energize terminal is useless. For that generators solution is separating relay which electrically separates starting and additional batteries.

The starting battery is, in the first instance, directly connected to the generator over separator. When the starting battery shows full charge, the relay switches connection of generator to additional batteries and they are charging. So the starting and additional batteries are always electrically separated.



Separators vary from design to design and some provide additional features.

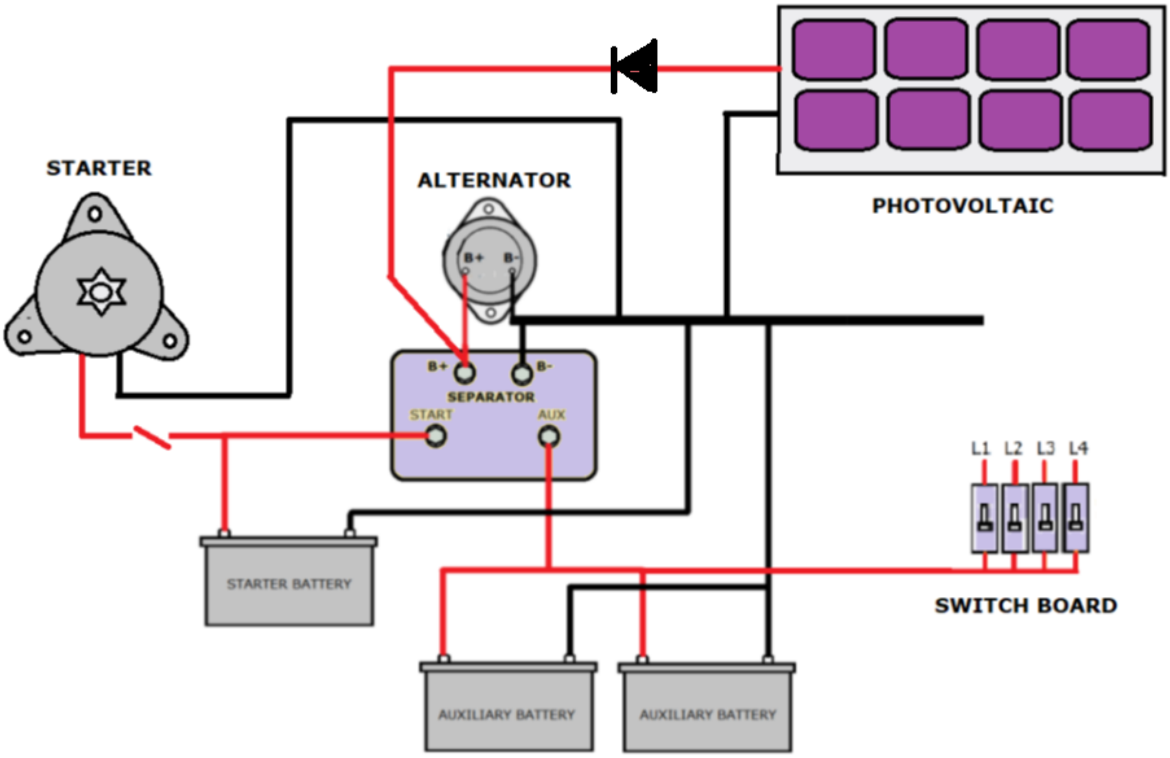
One of the possibilities is to use the starting battery in the power supply system of other devices up to a certain degree of discharge.

Some separators also have a button that connects additional batteries directly to the starter batteries and the starter for a short limited time (30 seconds). This option is used when the starter battery is damaged or worn out and cannot give enough power to the starter on its own.

The duration of this condition is limited because a longer duration would cause the extra batteries to discharge through the damaged starter battery.

SYSTEMS WITH ADITIONAL DC SOURCES

Each battery has a certain degree of self-discharge, ie discharge for a long time without being loaded. Ships with DC systems are often equipped with additional power sources such as photovoltaic panels and/or micro wind turbines. The example of DC system with added photovoltaic is showed on the figure



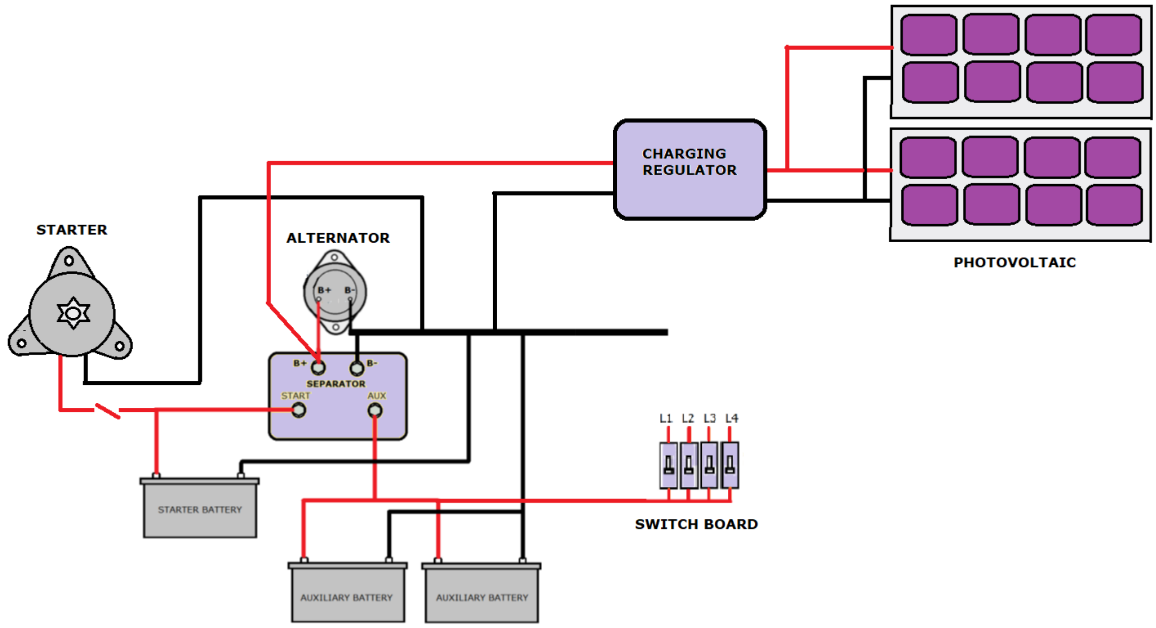
This additional sources also provide additional energy which then is not consumed from the auxiliary batteries and they slower discharge during the daytime.

If there is installed a low power photovoltaic system it can be connected directly to the batteries as on the previous figure. Diode in that circuit stops the current flowing from batteries through the panels during the night hours

PHOTOVOLTAIC CHARGING CONTROLER

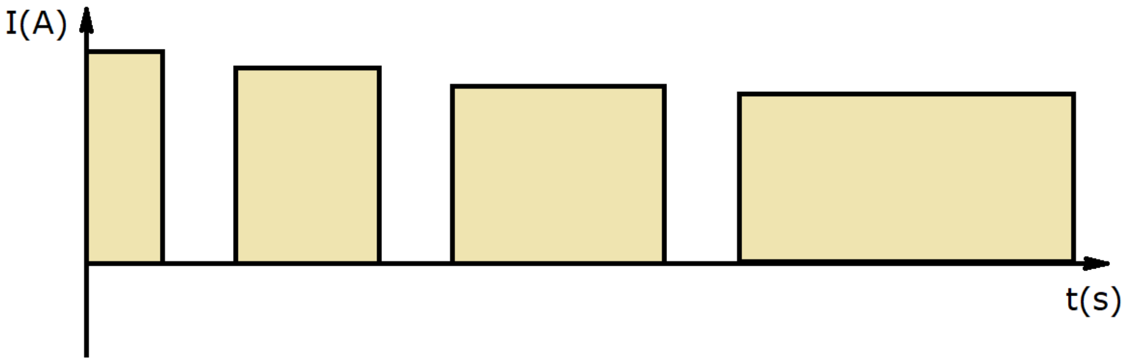
If there is installed a larger photovoltaic system with numerous panels, that panels have to be connected to the battery system via their charge controller.

When the battery is discharged to a certain degree of eg 50% the voltage on the battery drops.
The charging current would then be too high due to the large difference between the photovoltaic voltage and the battery voltage.
To limit this current, the battery is charged via the charge regulator.



There are two charging regulator technologies for this purpose on the market:

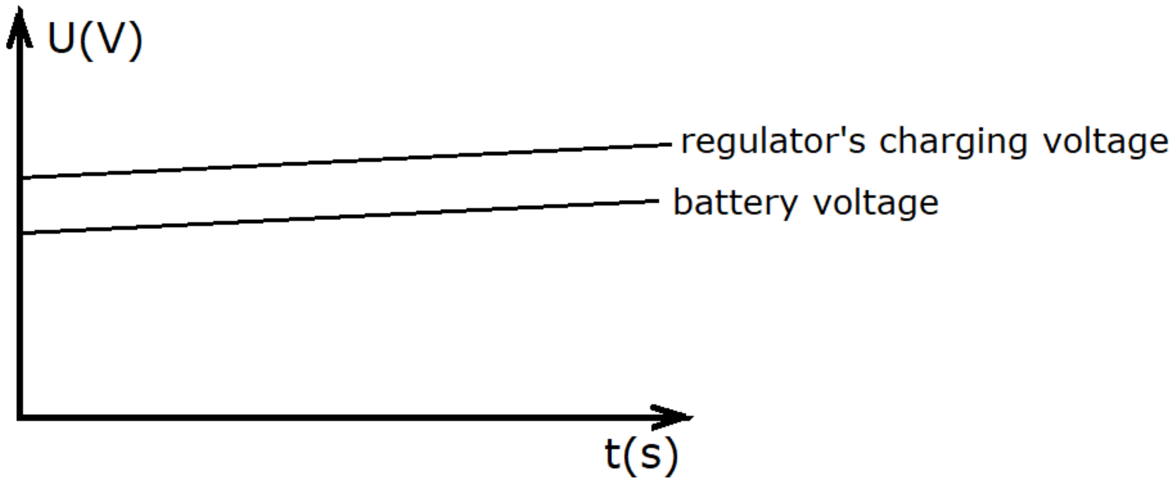
PWM regulator - Pulse width modulator works in such a way that while the voltage difference is still quite high towards the battery regulator delivers electricity to the battery in strong pulses between which it pauses so as to avoid overheating the battery. As the battery is charged, its voltage rises, the voltage difference decreases, and with it the current, so that the charging pulses get longer as on the next figure



The big disadvantage of these charge regulators is that during the flow of pulses of strong current, the cells in the battery heat up, and during the break they cool down. In the long run, this heating and cooling of the batteries means their expansion and contraction, which ultimately results in faster cell deformation and shorter battery life.

The advantage of these regulators is their lower price.

MPPT regulator - a regulator with a DC / DC converter works in such a way that it regulates the charging voltage, ie lowers the voltage while powering a discharged battery, and as the battery charges and its voltage rises, so does the charging voltage on the regulator. In this way, the difference in voltages and thus the charging current is always the same, which ultimately means the same cell temperature during the charging process.



Very often ships with DC power systems also have an AC subsystem. Alternating current is obtained by means of DC / AC converters.
It is an electronic equipment connected to a DC voltage of 12V or 24V, and at its output gives an AC voltage of 230V, 50Hz or 110V, 60Hz.

BATTERIES

VRLA (Valve Regulated Lead Acid),

are lead batteries that are hermetically sealed. Only in the event of uncontrolled charging or a fault in the battery itself, when gas may appear in the housing, the excess is discharged through the safety valve.

Two types of VRLA batteries are mostly used in board DC systems: gel batteries and AGM (Absorbent Glass Mat)

Gel battery In the gel battery, the electrolyte is immobilized in a gelatinous mass. This means that in these batteries there is no rumbling of the liquid electrolyte (acid) as in an ordinary lead battery.

Ventilation requirements for these batteries are lower, but batteries must not be stored in a hermetically sealed cabinet.

As distilled water with electrolyte does not need to be added to these batteries, they are often labeled "maintenance-free".

In an **AGM battery**, the electrolyte is absorbed into a mass of cross-linked glass fibers. Compared to gel batteries, AGM batteries are characterized by the ability to provide short-term strong currents, which is important when starting stronger electric motors. Thus, AGM batteries are frequently used in the on-board starter system.

Classical lead batteries are usualy used only in the on-board starter system. They are not supposed to be deeply discharged frequently so can not be used as auxiliary batteries on-board.

However, gel batteries have a longer lifespan and offer more charge and discharge cycles.

Self-discharge batteries

This is a big problem for almost all batteries, which can gradually lose stored energy after charging, even without any connection.

Namely, the lost energy is lost by discharging, and the battery capacity is a theoretical value that indicates how much can be stored and extracted from the battery under certain conditions.

Battery capacity is reduced by mechanical and chemical changes in the battery, aging, ambient temperature, etc.

When we talk about self-discharge of 2% per month, we mean the nominal capacity of the battery.

For example, from a 100Ah battery, 2Ah is self-discharging per month.

As GEL-VRLA batteries use successful technology and very clean materials, charged batteries will last even in standby mode (eg in storage) a year without any replenishment.

Self-discharge doubles with each 10-degree rise in temperature.

In general, high temperatures adversely affect battery life during operation.

Depth of discharge

For on-board batteries, the discharge depth and the number of discharge cycles are extremely important.

In simple words, the depth of possible discharge indicates the extent to which the battery can be discharged without adversely affecting its operation or recharging.

If the VREL GEL is emptied up to 30% of the nominal capacity, then it will easily withstand about 1300 charging and discharging cycles.

However, if it empties up to 50% of the capacity, then it lasts 600 cycles. In case it is systematically pumped to complete discharge, it will only withstand 300 charges and discharges.

Obviously, thoughtful system design requires the application of higher total capacity or the installation of more batteries. In the long run, it offers greater security and longer battery life.

Battery charging current

The battery charging current must not exceed 0.2 C. In particular, for a 100 Ah battery it should not exceed 20% capacity, ie 20 A. It is recommended that if necessary it is not necessary to exceed the charge current value of 15% capacity.

Battery charge test

How to recognize the condition of the battery?

By measuring the voltage of the unloaded battery, as shown in the table:

Rated battery voltage 12 V

100% charged battery, 2 hours after charging: 12.8 V

Battery charged 50% 12.3 V

Fully discharged 11.7 V battery

Battery charging voltage is 14.2 V -14.4 V

Battery banks

Multiple individual batteries connected in series and / or in parallel is called a battery pack bank.

When forming a battery bank, the batteries are connected in series due to an increase in voltage, or in parallel due to an increase in capacity.

When connecting in parallel, it is very important that the batteries have the same capacity and the same charge state.

When connecting batteries in parallel, the important rule is that all cables from the + and - connectors of each battery to the hub must be the same length.