Shaft alternators on board ships are alternators driven by the main engine to supply power to the mains. The mains must be supplied with constant voltage and frequency by the shaft alternator even at changing speeds of the main engine, i.e. when the vessel travels at different speed ranges or if the propeller speed fluctuates very greatly in heavy seas.

On ships with fixed pitch propellers, the speed is set via the propeller speed. If using controllable pitch propellers, the shaft speed and the propeller pitch are adjusted simultaneously in order to achieve optimum propeller efficiency in this so-called combinator mode. Even with this type of propeller, it is thus economical to use shaft alternator systems with frequency converter for variable speed in order to permit combinator mode.

SAM Electronics, partly a successor of AEG Marine Division, has been delivering shaft alternator systems with frequency converter since 1967. Over 340 ships have been equipped with them to date. Renowned shipyards and shipping companies have used our systems repeatedly.

The basic concept has remained unchanged since it has proven its advantages very well. System components have been improved constantly so that our shaft alternator systems are always state-of-the-art.

All requirements of a ship's mains are met unrestrictedly during shaft alternator operation:

- Generation of the required active power and reactive power.
- Selective tripping of short-circuits without failure of the overall system.
- Starting and shut-down of large consumers without inadmissible voltage and frequency fluctuations.
- Constant voltage and frequency when subject to main engine speed variations as the result of heavy seas and when manoeuvring.
- Unrestricted parallel operation with other mains generator sets in the entire shaft speed range and in heavy seas.
- Operation, including synchronization, in the same way and with the same operating controls as on diesel generator sets.
- Simple integration in automated power generation systems
- Automatic changeover to diesel generator operation if the actual shaft speed drops below the speed limit.
Benefits at a Glance

Using shaft alternators is a particularly economical and environment-friendly method of generating electrical power. For this reason, more and more ships are being equipped with such systems.

The use of shaft alternators affords many advantages:

- **Lowering of fuel costs:** Main diesel engines are operated with heavy diesel oil (and not with more expensive diesel oil as are most diesel generator sets). In addition, they operate with a far better efficiency. By comparison with power generation using auxiliary diesel engines, we thus obtain a substantial saving in fuel costs.

- **Reduction in maintenance and lubricant costs:** The operating time of the diesel generator sets is reduced as a result of sole operation of the shaft alternator at sea and even during manoeuvring.

- **Safety for ship and crew:** Shaft alternators are less susceptible to malfunctions than internal-combustion engines. The availability of the power generation equipment is thus improved.

- **Saving in operating personnel:** Personnel levels can be reduced thanks to the simplification of ship machine operation and powering the mains solely from the shaft alternator.

- **Low noise level power generation:** By comparison with diesel generator sets, shaft alternators are extremely quiet since they produce only few additional noise. This means that shaft alternators are also advisable from the point of view of ecology.

- **Smaller and/or less diesel generator sets:** Diesel generator sets are only needed for peak load of the mains consumers in parallel operation with the shaft alternator system and in harbour condition. This results in smaller and/or less diesel generator sets.
Shaft alternator systems with frequency converter supply three-phase current of constant voltage and frequency to the mains at variable main engine speed. The useful speed range of the shaft alternator can be defined on the basis of the requirements of ship operations control. For example, it is possible to select a shaft alternator speed range of 60% to 100% with constant system output and 60% to 30% with reduced system output.

Shaft alternator systems of SAM Electronics have a number of special characteristics which are of advantage both to shipping company and to shipyard:

### High flexibility
All shaft alternator systems have one thing in common: The active power required for the mains is generated by the main engine. However, the shaft alternator can be arranged and can be driven by the main engine in very diverse ways:

- Arrangement of the shaft alternator in the shaft line between low-speed main diesel engine and propeller. This configuration with a large air gap between stator and rotor and without additional bearings has proven very successful and is the most frequent configuration used. It is particularly simple and sturdy and requires little maintenance. By contrast with certain other arrangements, torsional vibration problems relating to design and operation are not anticipated with this configuration.

- Drive of the shaft alternator by the power take-off of a reduction gear which is arranged between medium-speed main diesel engine and propeller. This is the usual and appropriate configuration for medium-speed main diesel engines.

- In addition, other arrangements of the shaft alternator are also possible in principle:
  1. Drive directly from the crankshaft or via a reduction gear on the front end of the main diesel engine.
  2. Drive via a gear unit arranged in the shaft line between low-speed main diesel engine and propeller.
  3. Drive via a power take-off of the main diesel engine with integrated gear reducer.

### Protection
The shaft alternator systems are equipped with a thyristor protection integrated in the inverter which protects the thyristors and the inverter fuses against overcurrent. Continued operation of the shaft alternator system without "black-out" is possible even in the event of a short-circuit in the mains after selective disconnection of the faulty consumers. The integrated thyristor protection of SAM Electronics is a patented system.
This concept of short-circuit protection requires no chokes in the DC link to damp short-circuit currents and no controlled rectifier with thyristors and the electronic circuitry required for this. This has made it possible to package the power circuitry simply and in space-saving manner and to achieve a very good efficiency. The efficiency characteristic is computed individually for each system.

**Test and simulation**

The monitoring, test and simulation tableau integrated in the shaft alternator panel permits monitoring of the system during normal operation. But also with the main engine out of operation even when the ship is not running, operability of the system can be tested and virtually all system functions can be simulated.

For monitoring, test and simulation a colour display as thin film transistor (TFT) liquid crystal display (LCD) is provided with the 6 different operation functions “Overview”, “Status”, “Values”, “Alarm”, “Test” and “Setup”.

**Improved availability**

The shaft alternator systems are equipped with a central, microprocessor-based computer for fully digitalized closed-loop control and open-loop control and for test and simulation. As compared with previous versions, this has dispensed with a large number of PC boards with relays for logic operations and with elements for analog and digital functions. This drastic reduction in the number of components results in a substantial improvement in reliability and availability.
**Low overall volume**
Only shaft alternator systems of SAM Electronics are designed with uncontrolled rectifiers between shaft alternator and inverter. This means that no control or firing circuitry is required for the rectifier, thus greatly reducing the complexity of the electronics. The losses of diodes are less than those of thyristor rectifiers which are used on similar systems. The rectifier is mounted on top of the shaft alternator in spacesaving manner, thus providing a compact shaft alternator panel.

**Less harmonics**
The harmonic content at the output of the shaft alternator system has to be effectively reduced to admissible levels according to the classification rules to keep a mains voltage distortion factor within the limits prescribed by classification societies. Therefore the shaft alternator system is configured depending on the load and the system data with:
- harmonic waves filter circuit or
- duplex choke.

**Trouble-free operation**
Trouble-free operation of even sensitive consumers is guaranteed by the high-frequency interference suppression filters.

**Commissioning without main engine operation**
Large 2-stroke main engines cannot be operated with no-load for longer time. To perform the commissioning of the shaft alternator system at the pier with the main engine being out of operation a special supply system can be provided to supply the frequency converter. During commissioning the connection between shaft alternator and converter is switched-off and the converter is supplied from the mains. In this configuration the shaft alternator system can be tested as under load conditions as well as in parallel operation with a diesel alternator.
Closed-loop control of the shaft alternator system maintains the mains voltage and the mains frequency constant. The automatic voltage regulator is incorporated in the compensator and operates in the same way as at a normal mains alternator.

The frequency controller acts on excitation of the shaft alternator. If the mains frequency is too low, as the result of a load increase the excitation of the shaft alternator is increased and it supplies a higher active current at constant voltage. The higher active power fed into the mains as the result of this causes a rise in frequency until a state of balance is reached between power fed in and power consumed, dependent upon the frequency set value. In the reverse case, excitation of the shaft alternator is reduced if the mains frequency is too high so that the shaft alternator supplies a lower active current at constant voltage and so that the mains frequency drops accordingly.

The frequency set value can be set manually as on a diesel generator set or by the superordinated active-power load controller of an automatic power supply system. The active power between diesel generator sets operating in parallel can be distributed in such a way that the shaft alternator, as the most economical source of energy, is fully loaded first and only the power required over and above this is supplied by the auxiliary diesel generator sets. In this case, the actual load does not drop below the minimum load required for the auxiliary diesel engines.
Arrangement

2000 kW, 840-1400 rpm shaft alternator on the polar research vessel "Polarstern", driven via the power take-off of a reduction gear

Synchronous compensator with pony motor on the container vessel "Zim America"

Shaft alternator systems of SAM Electronics can operate unrestrictedly in parallel with other mains generator sets. Voltage and frequency droop are provided for this, as also for diesel generator sets. This voltage reduction as a function of reactive power for reactive load distribution and frequency reduction as a function of active power for active load distribution is adjustable and can thus be adapted to other mains generator sets.

Parallel operation of two shaft alternator systems on ships with two propellers is also possible unrestrictedly and such a configuration has already been implemented in several cases.