Shaft Alternator Systems
with PWM Frequency Converter

Energy-saving Power Supply Systems

SAM Electronics
an L3 communications company
Shaft alternator systems are alternators driven by the main engine to supply power to the mains. The mains have to 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 strongly varies 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 from pier to pier.

SAM Electronics, partly a successor of AEG Marine Division, has been delivering shaft alternator systems with frequency converter since 1967. Over 380 ships have been equipped with them to date. Renowned shipyards and shipping companies have used our systems repeatedly.

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

- Unrestricted operation during main engine speed variations as the result of heavy seas and maneuvring
- Continuous parallel operation together (if 2 shaft alternator systems are provided) and with diesel generator sets
- 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
- 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

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.

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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 provides 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.

**Return of Investment in 3 to 4 Years**
A payback time of 2 to 4 years depending on the system power is possible under consideration of all costs for the shaft alternator system including yearly maintenance and financing costs.

A detailed calculation of the return of investment is available on request.

**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 by 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.

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**Bulkcarrier “Rosalia D’Amato”**

**Container RoRo vessel “Grande Ghana”**

**Chemical tanker “Bow Sun”**

**Shaft alternator being installed**
Shaft Alternator Systems
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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% of main engine speed with constant 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 various configurations.

- **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. Contrary to other arrangements, torsional vibration problems relating to design and operation are not anticipated with this configuration.

- **Operation of the shaft alternator via power take-off by 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.

- **Operation of the shaft alternator via tunnel gear unit arranged in the shaft line between low-speed main diesel engine and propeller.**
In general other arrangements of the shaft alternator are possible as direct drive from the crankshaft or via reduction gear on the front end of the main diesel engine as well as via power take-off of the main diesel engine with integrated gear. Due to the special design requirements of both the main engine as well as the shaft alternator this solution is not cost-efficient and therefore not recommended.

**Configuration**

SAM Electronics' shaft alternator systems are designed with PWM frequency converter in modern IGBT technology which need no longer an additional synchronous compensator for reactive power generation, short circuit current generation and voltage control as well as filter circuits for harmonics reduction to admissible values. This configuration results in features and benefits as follows:

- PWM frequency converter system with more economic power generation by improved efficiency
- High mains quality with excellent harmonic distortion content due to high IGBT pulse frequency
- Just 2 components - shaft alternator and the frequency converter panel - to be installed resulting in reduced volume and weight as well as less costs for foundation, cables and cable work
- Water cooling of the power electronic with connection to the ship's fresh water cooling system
- Geared shaft alternator as standard brushless synchronous alternator
Shaft Alternator Systems with PWM Frequency Converter

Test and Simulation
The monitoring, test and simulation display 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, operation of the system can be tested and virtually all system functions can be simulated. For monitoring, test and simulation a colour display as touch screen provided with the 6 different operation modes 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 analogue and digital functions. This drastic reduction in the number of components results in a substantial improvement in reliability and availability.

Better Mains Quality
The harmonic content at the output of the shaft alternator system has to be effective reduced to admissible levels according to the classification. SAM Electronics’ shaft alternator system is designed with PWM frequency converter and high IGBT pulse frequency resulting in a mains quality much better than required without any additional measures as e.g. filter circuit or duplex reactor. The THD in the mains is below 5% in all operational states.
Innovative Operation Principles

**Low Overall Volume**
SAM Electronics’ shaft alternator systems are designed with PWM frequency converter and uncontrolled diode rectifiers between shaft alternator and inverter. This means that no control or firing circuitry is required for the rectifier, resulting in reduced 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 space saving manner, thus providing a compact shaft alternator panel.

**High Voltage Technology**
For the actual container carriers with more than 7000 TEU the immense amount of electrical power for reefer containers and other consumers leads inevitably to an increase of electrical power generation. To reduce the rated currents and short circuit currents to admissible levels shaft alternator systems with more than 3,500 kW are to be designed in high voltage technology with advantages and features as follows:
- Shaft alternator systems with more than 3500 kW up to 9000 kW without supply transformer
- Shaft alternator and PWM frequency converter designed for 6.6 kV

**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 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.

![Shaft alternator panel front side](image)
![Shaft alternator panel rear side](image)

![Single line diagram: Shaft alternator system with test supply](image)
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Shore Connection for both 50 Hz and 60 Hz

For shore connection with 50 Hz or 60 Hz the frequency converter of the shaft alternator system can be used to adapt the shore frequency to the ship’s mains frequency. For that purpose the connection between shaft alternator and converter is switched-off and the converter is supplied (via cable reel, circuit breaker and transformer) from the shore. With this configuration the ship is full flexible for shore connection worldwide.

Shaft Alternator/Motor Operation

For additional shaft motor operation the diode rectifier is replaced by a PWM rectifier similar to the PWM converter and the system control is adapted accordingly. With this configuration motor operation is provided as follows:

- Booster propulsion operation parallel to the main engine to enlarge the propulsion power and the ship’s speed
- Take home respectively take away propulsion operation as emergency propulsion drive without main engine in case of a malfunction of the main engine. For this mode the main engine has to be decluctched from the propeller shaft

Fitting the shaft alternator poles on the propeller shaft
Shaft alternator mounted in the propeller shaft line
Shaft alternator driven via the power take-off (PTO) and reduction gear