Diesel-Electric Propulsion Systems

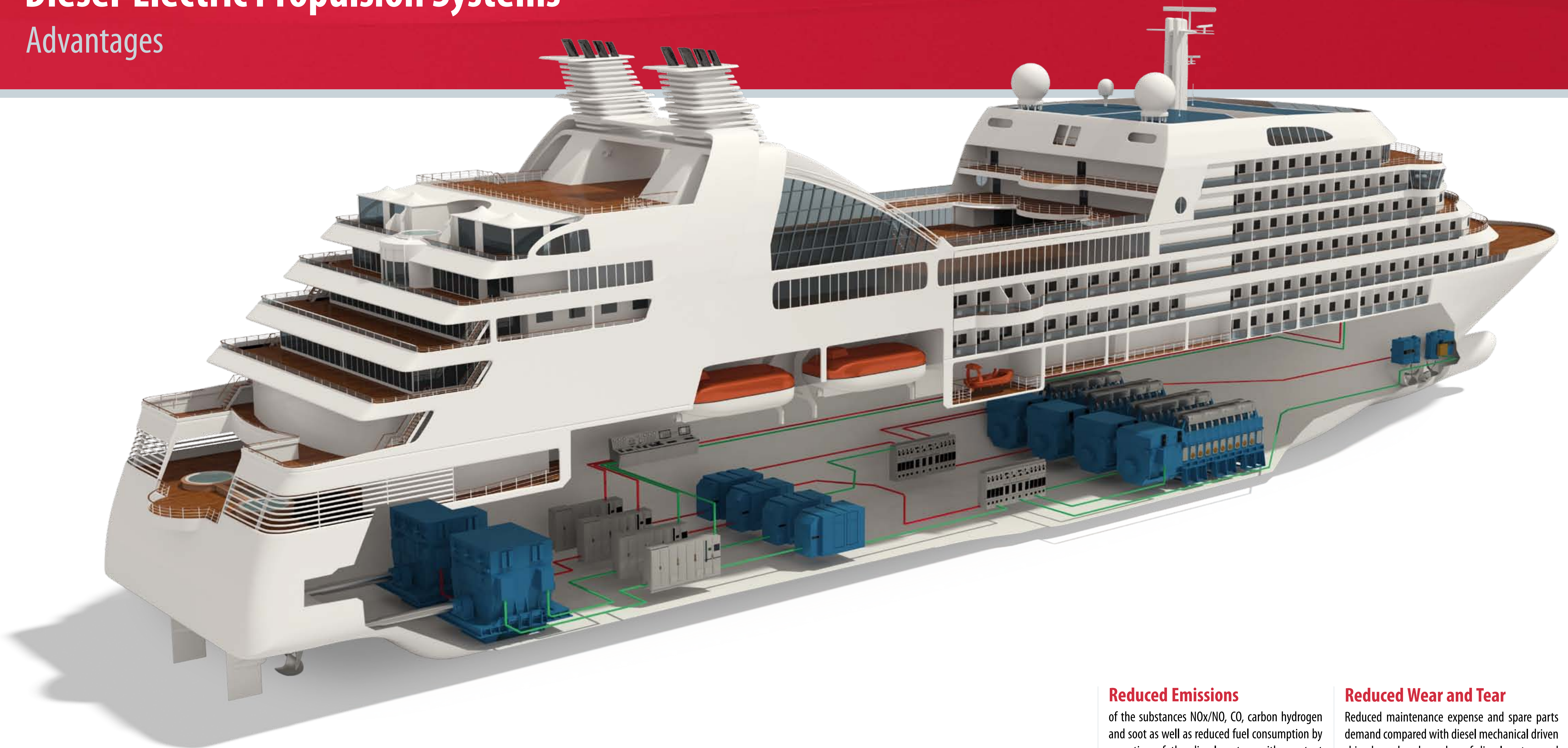
Power under Control

SAM Electronics

an L3 communications company

Diesel-Electric Propulsion Systems

Advantages



Low Noise and Vibration

Electric propulsion drives are unsurpassed for their quietness of operation.

Maximum Pay-load Capacity

and optimal utilization of available space by reduced volume and decentralized arrangement of components of the propulsion system.

Economical Operation

At reduced propeller speeds the number of supplying generators can be matched according to the power demand. This allows particularly cost-effective operation as an effective way of preventing loads of the diesel generator sets with low efficiency.

Redundant Configuration

Essential higher reliability and availability by redundant configuration of the propulsion system.

Flexible Use

of the torque-speed characteristic up to high over torques at standstill of propeller if required: The propeller can be driven at all speeds and torques within the design limits without any limitations.

Excellent Dynamic Characteristics

Changes in speed and reversals at manoeuvre and positioning can be carried out at optimum speed.

Outstanding Mains Quality

No interference of the mains due to inadmissible harmonics generation and voltage droops.

Reduced Emissions

of the substances NOx/NO, CO, carbon hydrogen and soot as well as reduced fuel consumption by operation of the diesel motors with constant speed in the optimal operational range also at partial load of the propulsion system.

High Degree of Automation

All propulsion drives can be controlled automatically by a superior ship navigation and command system or manually from any control console. All of the functions and operating states are monitored to obviate operating mistakes and overloads.

Reduced Wear and Tear

Reduced maintenance expense and spare parts demand compared with diesel mechanical driven ships by reduced number of diesel motors and cylinders as well as by operation of the diesel motors with constant speed.

As a result of these features electrical propulsion systems are used particularly for cruise liners, ferries, cable and pipe layers, research vessels, icebreakers, multipurpose vessels, patrol boats, supply and rescue vessels as well as for LNG tankers.

Electric Propulsion Systems

System Description

Cruise liner "Silver Spirit" with LCI propulsion drives 2 x 8.5 MW

Cruise liner "Seabourn Odyssey" with LCI propulsion drives 2 x 7.5 MW

RoPax Ferry "Coastal Renaissance" with double end propulsion drives 2 x 11 MW

Pipe layer "Solitaire "with LCI propulsion drives 10 x 4.3 MW

Control System

The control system of converter fed propulsion drives is designed for:

- Four-quadrant operation with reversal of torque and direction of rotation with feed-back of the reverse power to the main alternators and to the mains respectively to braking resistors in case of reversing manoeuvre and
- Continuous speed control from 0 to 100 % of rated speed

All operation requirements are achieved automatically by the electronic control device. Electronic control is made by microprocessor controlled devices and includes also the necessary I/O channels for monitoring and alarm functions integrated in the propulsion control system.

Propulsion Management System

Propulsion drives are conceived as subordinated consumers: The propulsion output is automatically reduced if the momentary consumption exceeds the power available by the supplying diesel generator sets. In combination with the power management system, diesel generator sets are started, synchronized and stopped automatically. In order to ascertain a stable operation of the power plant at any time, the power consumption of the propulsion drives are reduced if:

- The apparent current of the alternators reaches the nominal value
- The active power of the diesel alternator set exceeds the nominal value or
- The speed of the diesel engine decreases below the admissible value

In case manoeuvring or crash stop operation the reverse power generated by the propulsion motors is fed-back to the main alternators and to the mains. In order to ascertain a stable operation of power plant also during this operation, the reverse power generation of the propulsion drives is reduced if:

- The speed of the diesel engines increases above admissible values

Monitoring Screen Displays

For monitoring and auxiliary local control of the propulsion system colour touch screen displays as thin film transistor (TFT) liquid crystal displays (LCD) are provided at each propulsion control panel and on the ECR control console with following mimics and functions:

- OVERVIEW with general overview based on single line diagram with position of circuit breakers, measuring values and alarms
- MOTOR and CONVERTER with detailed view on propulsion motors and frequency converters with measuring values and alarms
- FAULTS with detailed explanation of the alarm event, alarm history and detailed help function
- CONTROL with start, stop and speed control by push buttons acting like a motor potentiometer
- SETUP with parameter settings as acceleration ramps, lever characteristic, speed set points, power limitation, temperature limits as well as controller settings
- Display of measured values for failure diagnostics

From Bridge to Propeller

Diesel-electric propulsion systems are used on ships with special requirements. These systems are based on the principle of speed controlled AC or DC motors driving the propeller directly or by gearing. The most reliable and low noise design is the direct drive.

Electric propulsion systems are designed according to the „power station principle“. That means that under normal conditions all alternators are feeding a common bus bar system. The main propulsion drives, thruster and other drives and the mains consumers are connected directly or via transformers to this bus bar.

Depending on power, characteristic and noise requirement converter fed propulsion systems are used with synchronous, asynchronous or DC motors.

DC motors are well proven as especially low vibration and low noise propulsion drives of research vessels and other special ships.

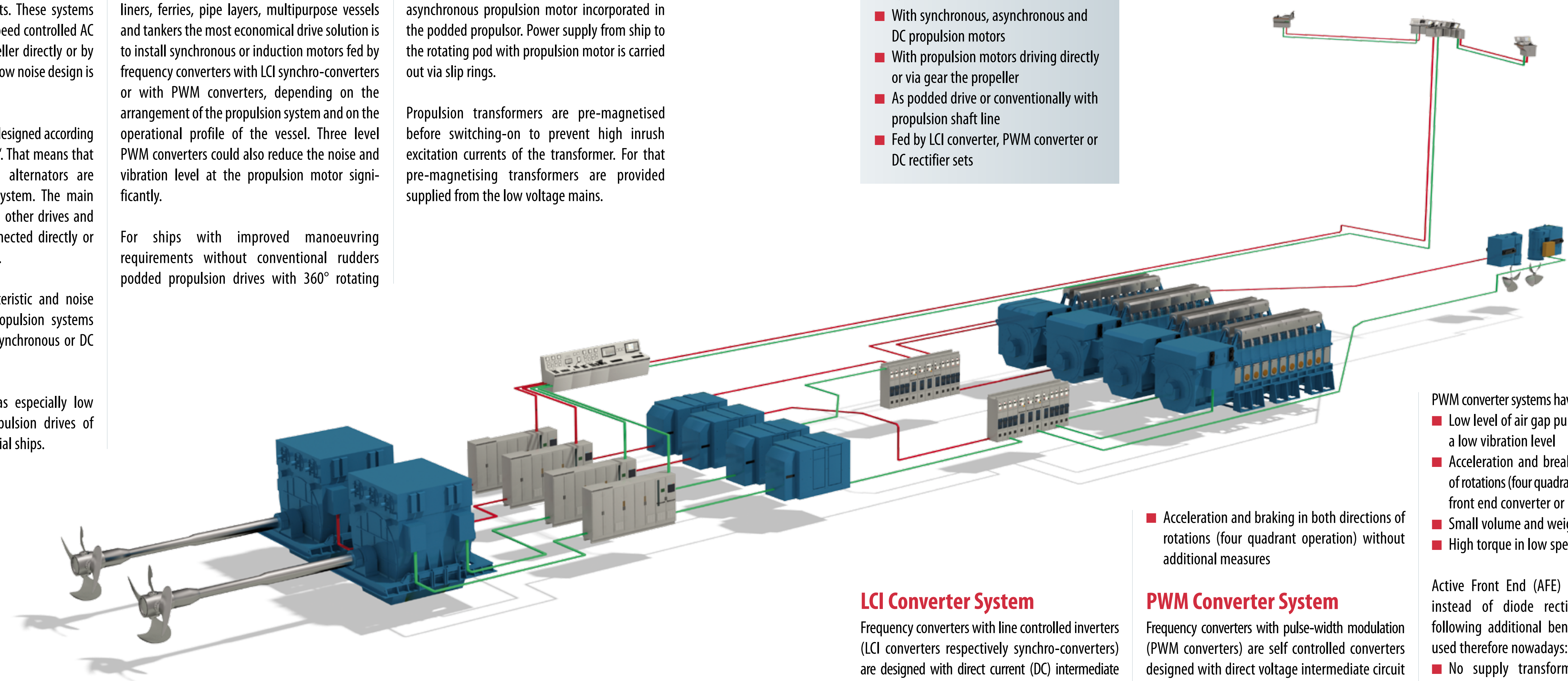
For propulsion power on board of e.g. cruise liners, ferries, pipe layers, multipurpose vessels and tankers the most economical drive solution is to install synchronous or induction motors fed by frequency converters with LCI synchro-converters or with PWM converters, depending on the arrangement of the propulsion system and on the operational profile of the vessel. Three level PWM converters could also reduce the noise and vibration level at the propulsion motor significantly.

For ships with improved manoeuvring requirements without conventional rudders podded propulsion drives with 360° rotating angle are provided with synchronous or asynchronous propulsion motor incorporated in the podded propulsor. Power supply from ship to the rotating pod with propulsion motor is carried out via slip rings.

Propulsion transformers are pre-magnetised before switching-on to prevent high inrush excitation currents of the transformer. For that pre-magnetising transformers are provided supplied from the low voltage mains.

Since 1966 SAM Electronics is carrying on the technology and industry traditions of its predecessor AEG Marine branch (AEG Schiffbau) and has delivered more than 200 converter fed propulsion drives for more than 85 ships in all configurations and powers:

- With synchronous, asynchronous and DC propulsion motors
- With propulsion motors driving directly or via gear the propeller
- As podded drive or conventionally with propulsion shaft line
- Fed by LCI converter, PWM converter or DC rectifier sets



Propulsion motor 15 MW, 135 rpm on cruise liner "Norwegian Sun"

Propulsion motor 8.5 MW, 150 - 160 rpm on cruise liner "Silver Spririt"

Main alternator 6920 kVA, 720 rpm on cruise liner "Seabourn Odyssey"

LCI Converter System

Frequency converters with line controlled inverters (LCI converters respectively synchro-converters) are designed with direct current (DC) intermediate circuit and consist of thyristor rectifiers at the mains side, thyristor inverter at the motor side, DC reactor in the intermediate circuit, excitation converter and control system. LCI converters are provided for supply of synchronous motors.

Synchro-converter based systems were also used in SAM Electronics' former shaft alternator system design with more than 385 delivered units since 1967.

LCI converter systems have following advantages:

- For highest power available
- Acceleration and braking in both directions of rotations (four quadrant operation) without additional measures

PWM Converter System

Frequency converters with pulse-width modulation (PWM converters) are self controlled converters designed with direct voltage intermediate circuit and consisting (in the standard solution) of diode rectifier at the mains side, insulated gate bipolar transistor (IGBT) or integrated gate commutated thyristor inverter (IGCT) at the motor side, DC capacitors in the intermediate circuit and control system. For improved mains quality and for reverse power characteristics the diode rectifier at the mains side is replaced by an IGBT rectifier (active front end AFE design). PWM converters are provided for supply of asynchronous or synchronous motors. In case of synchronous motor supply an excitation converter is provided additionally.

PWM converter systems have following advantages:

- Low level of air gap pulsation which results in a low vibration level
- Acceleration and breaking in both directions of rotations (four quadrant operation) with active front end converter or reverse power resistor
- Small volume and weight
- High torque in low speed ranges

Active Front End (AFE) converters with PWM instead of diode rectifier input offer the following additional benefits and are typically used therefore nowadays:

- No supply transformer for 12-pulses or 24-pulses configuration, no chopper with control system and breaking resistor for reverse power consumption necessary
- Much better mains quality with THD < 5 % without additional measures
- More economic operation by better efficiency

PWM converters are also used in SAM Electronics' actual shaft alternator system design for low as well as for high voltage application in latest state-of-the-art technology.

System Description

Remote Control System

For remote control of the propulsion drives a combined speed control and telegraph system is provided as command and communication system designed for sending speed commands from the wheelhouse, bridge wings, engine control room (ECR) or local control consoles to the converter controls as well as operation plates with illuminated push buttons, warning lamps, emergency stop, safety device indications, overriding device, control transfer facilities, control switches, speed and power meters.

The telegraphs on the wheelhouse, bridge wing and ECR consoles are equipped with transmitter, receiver, speed command potentiometers for telegraph and control functions as well as electrical shaft system with signal interface by redundant serial connection.

Additionally manual service controls are provided in the converter control panel fronts.

Operation Reliability and Availability

For improved operation reliability and availability different design measures are provided depending on the actual requirements:

- Each propulsion motor with 2 independent stator windings as double winding system for 1 winding supply with 50% propulsion torque in case of a failure of the other one (redundancy: 50% per drive)
- Each frequency converter with 2 independent converter parts for supply with 1 converter part with 50% propulsion torque in case of a failure of the other one (redundancy: 50% per drive)
- Each frequency converter with 2 power supplies from the main switchboard for power supply operation with 50% propulsion torque in case of failure of the other one (redundancy: 50% per drive)
- Each frequency converter with 2 independent excitation converters with excitation transformers and power supply as active/stand-by system for 100% propulsion torque (redundancy: 100%)
- Each frequency converter with 2 independent control systems as active/stand-by system for 100% propulsion torque (redundancy: 100%)

Mains Quality (THD)

All kind of frequency converters generate harmonics in the mains and therefore influence the mains quality. On the other hand the maximum harmonic content is defined by the classification rules. To reduce the harmonic content to admissible levels following measures can be provided depending on the propulsion configuration:

- Each frequency converter operates to the ship's mains as active front end system or with 12-, 24- or 48-pulses system with supply via tranformers with 2 secondary windings and corresponding phase deviations
- The main alternators are designed with reduced subtransient reactance xd" to achieve low commutation reactances
- The propulsion transformers and DC reactors (if provided) are designed with improved reactance uk
- The propulsion transformers (if provided) and mains transformers are designed with earthed screen winding between primary and secondary windings
- System simulation prior project start, taking into account the whole mains configuration including cable network results in a safe system design of all related components

Research & trial vessel "Planet" with permanent excited propulsion motors 4 x 1040 kW and permanent excited main alternators

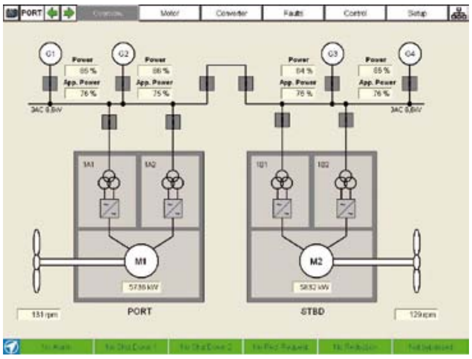
Research vessel "Sagar Nidhi" with PWM Active Front End (AFE) propulsion drives 2 x 1600 kW and 2 x 800 kW

Jack-up vessel "Windlift I" with PWM Active Front End (AFE) propulsion drives 4 x 1100 kW

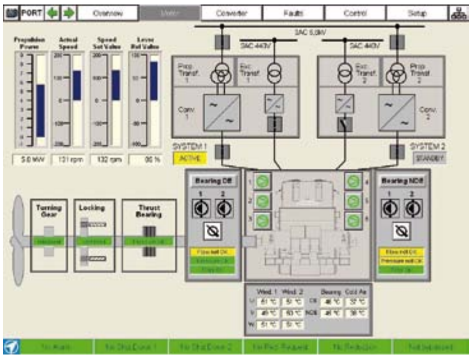
Research Vessel "Maria S. Merian" with podded propulsion drives 2 x 2050 kW

Electric Propulsion Systems

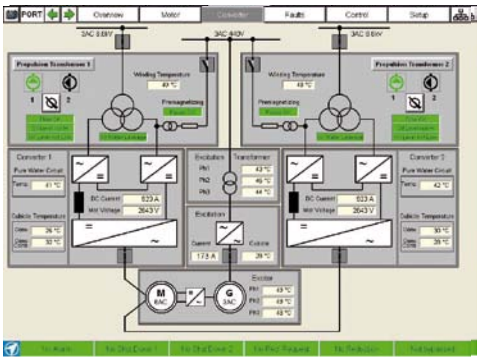
System Description



Mimic screen OVERVIEW

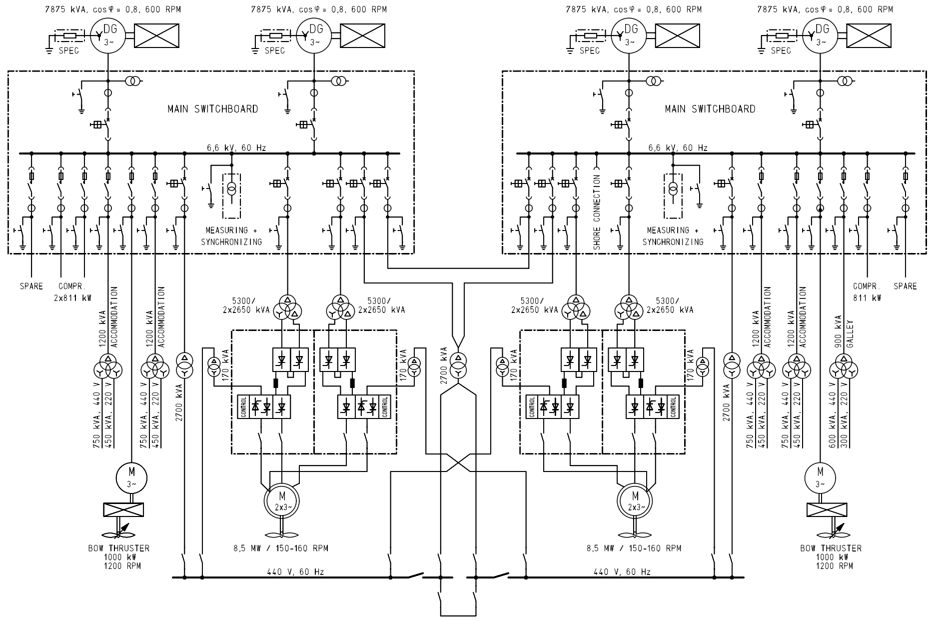


Mimic screen MOTOR

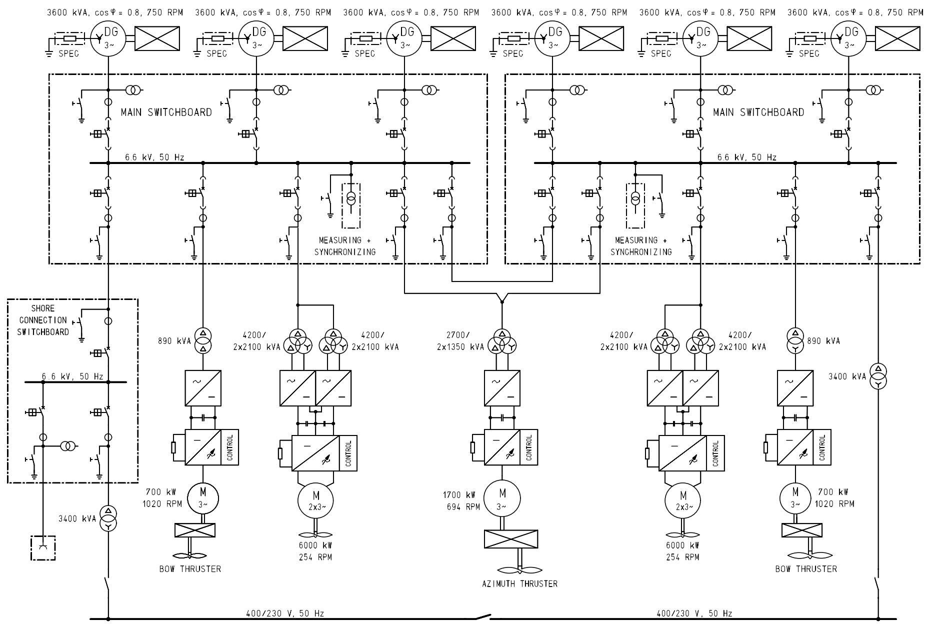


Mimic screen CONVERTER

Front page:
Propulsion motor 7.5 MW, 170 rpm on cruise liner „Seabourn Sojourn"



Single line digram of electric propulsion system with LCI converter drives 2 x 8.5 MW, 24-pulses (48-pulses for both shaft lines)



Single line diagram of electric propulsion system with PWM converters 2x6 MW, 24-pulses

SAM Electronics GmbH
Drives and Special Systems
Behringstrasse 120
22763 Hamburg · Germany

Phone: +49 (0)40 - 88 25 - 27 20
Fax +49 (0)40 - 88 25 - 41 02
DSS@sam-electronics.de
www.sam-electronics.de