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 manoeuvres 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

**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 feedback 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
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
fed with the electric 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 signi-
ficantly.

For ships with improved maneuvering requirements without conventional rudders
podded propulsion drives with 360° rotating
angle are provided with synchronous or
asynchronous propulsion motor incorporated in
the podded propeller. Power supply from ship to
the rotating pod and 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 masts.

LCI Converter System

Frequency converters with line controlled inverters
(LCI converters respectively synchron-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
rectifier 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
- Much better mains quality with THD < 5 %
- No supply transformer for 12-pulses or
- 24-pulses configuration, no chopper with
correction system and breaking resistor for
-颇有 power consumption necessary
- Much better mains quality with THD < 5 %
- Without additional measures
- More economic operation by better efficiency

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
correction system and breaking resistor for
-颇有 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.
### 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 transformers with 2 secondary windings and corresponding phase deviations
- The main alternators are designed with reduced subtransient reactance $x_d^*$ to achieve low commutation reactances
- The propulsion transformers and DC reactors (if provided) are designed with improved reactance $x_k$
- 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

### System Description

**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**
System Description

Electric Propulsion Systems

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 diagram 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

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