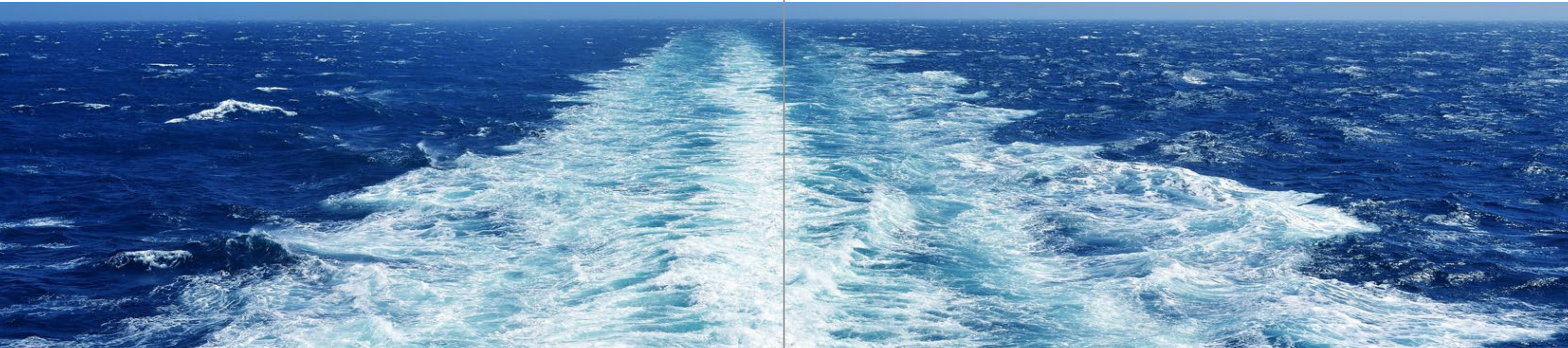


Diesel-Electric Propulsion Systems



Power under Control



Wärtsilä has been leading the way to ever more efficient shipping since 1834. Wärtsilä's extensive portfolio of diesel-electric propulsion solutions allows us to select the ideal configuration to meet any vessel's needs. From high power systems for cruise vessels, to low noise systems for research vessels, to high redundancy systems for offshore vessels, Wärtsilä has the solution. And with advances in energy storage systems, we are now able to supply Hybrid Systems using Wärtsilä's Energy Management Systems to increase the vessel's efficiency.

Our innovative diesel-electric propulsion systems provide up to 28 MW of power for a wide variety of vessels with special requirements. With more than 200 installations worldwide, our propulsion systems deliver power for cruise liners and ferries, cable laying vessels, heavy-lift jack-up vessels, research and offshore vessels and mega yachts – with a combined total of more than 3.000 MW.

Diesel-electric propulsion systems are used on ships with special operational requirements. These systems are based on the principle of speed controlled AC 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 as well as the mains consumers are connected directly or via transformers to this bus bar.

For propulsion power on board of, for example, cruise liners, ferries, pipe layers and multipurpose vessels, 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.



All you can ask of a propulsion system



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

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 propeller speed and propeller reversals during at manoeuvring and positioning can be carried out at optimum acceleration rates.

OUTSTANDING MAINS QUALITY

Minimal 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 can be achieved by operation of the diesel generators at the optimal operational range as the propulsion load varies.

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 prevent 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.

Propulsion motor 18 MW, 133 - 142 rpm on cruise liner "Royal Princess"



Wärtsilä low loss hybrid.





CONVERTER TOPOLOGIES:

1. LCI Converter System

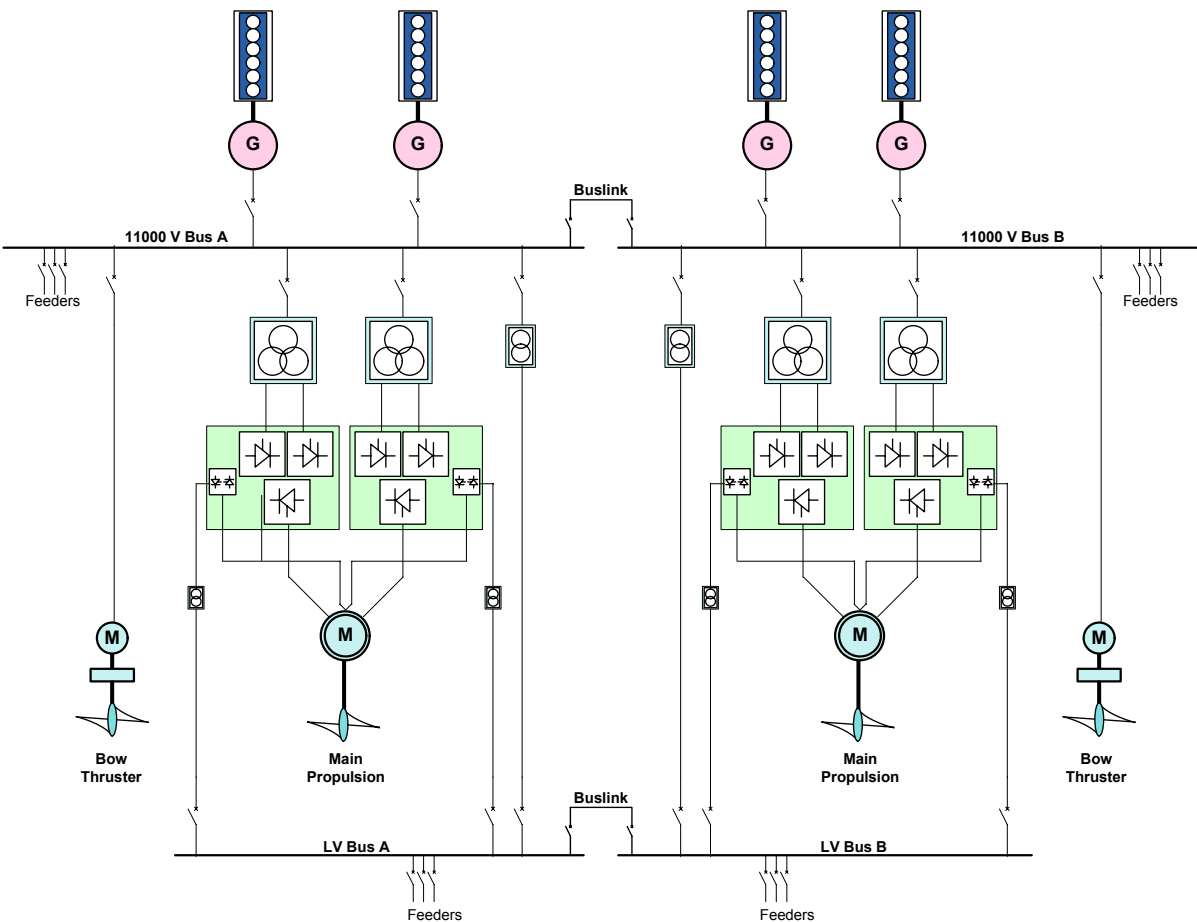
Frequency converters with line controlled inverters (LCI converters respectively synchro-converters) are designed with direct current (DC) intermediate circuit and consist of thyristor rectifiers at the mains side, thyristor inverter at the motor side, DC reactor in the intermediate circuit, excitation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

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

LCI converter systems have following advantages:

- Economic in the high power range
- Acceleration and braking in both directions of rotations (four quadrant operation) without additional measures

Single line digram of electric propulsion system with LCI converters



2. PWM Converter System

Frequency converters with pulse width modulation (PWM converters) are self-controlled converters designed with DC voltage intermediate circuit and consisting (in the DFE 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 to power either asynchronous or synchronous motors. In case of a synchronous motor, an excitation converter is also provided.

PWM converter systems have following advantages:

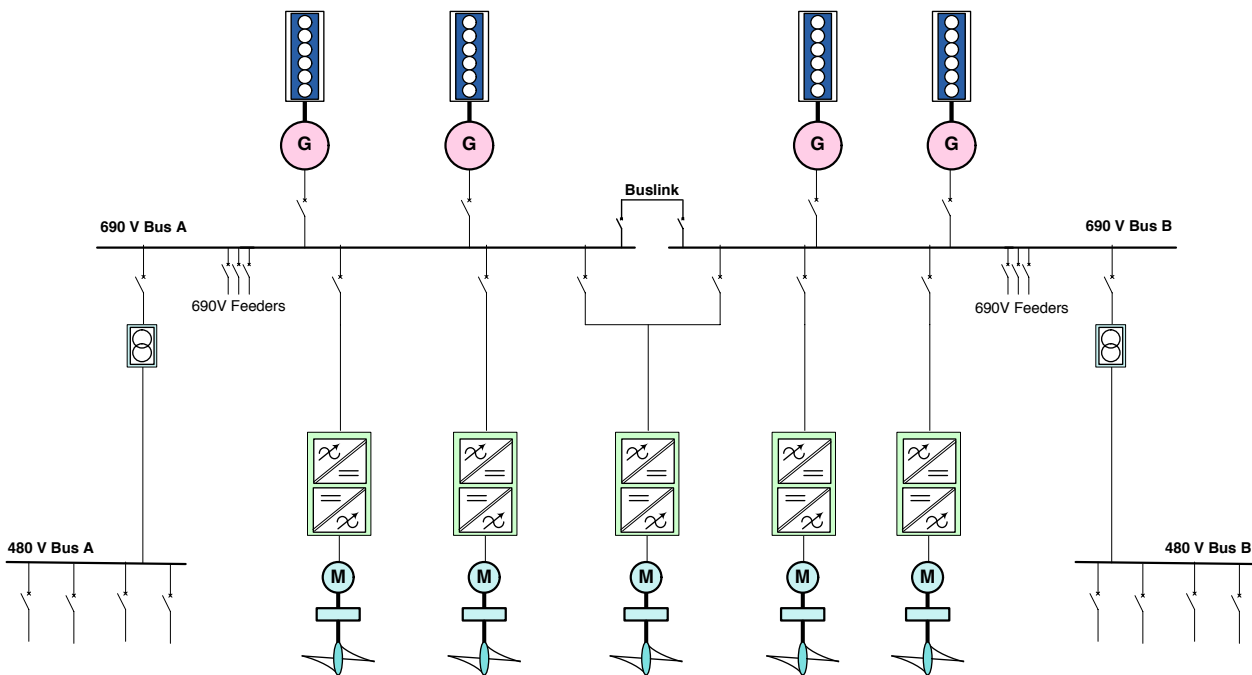
- Permits a low level of motor air gap pulsation which results in a low vibration level

- Allows acceleration and braking 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 braking resistor for reverse power consumption necessary
- Much better mains quality with THD < 5 % without additional measures
- More economic operation due to better efficiency

Single line digram of electric propulsion system with PWM converter in Active Front End Technology (AFE)



3. Low Loss Concept

For certain power system configurations the patented Wärtsilä “Low Loss Concept” (LLC) can be used, which is designed to remove the need to use either a bulky either the transformer of a DFE drive, or an AFE drive.

Wärtsilä has devised an ingenious way to overcome this problem by splitting the distribution bus into two sections and placing the transformer between the two buses = Low Loss Concept (LLC).

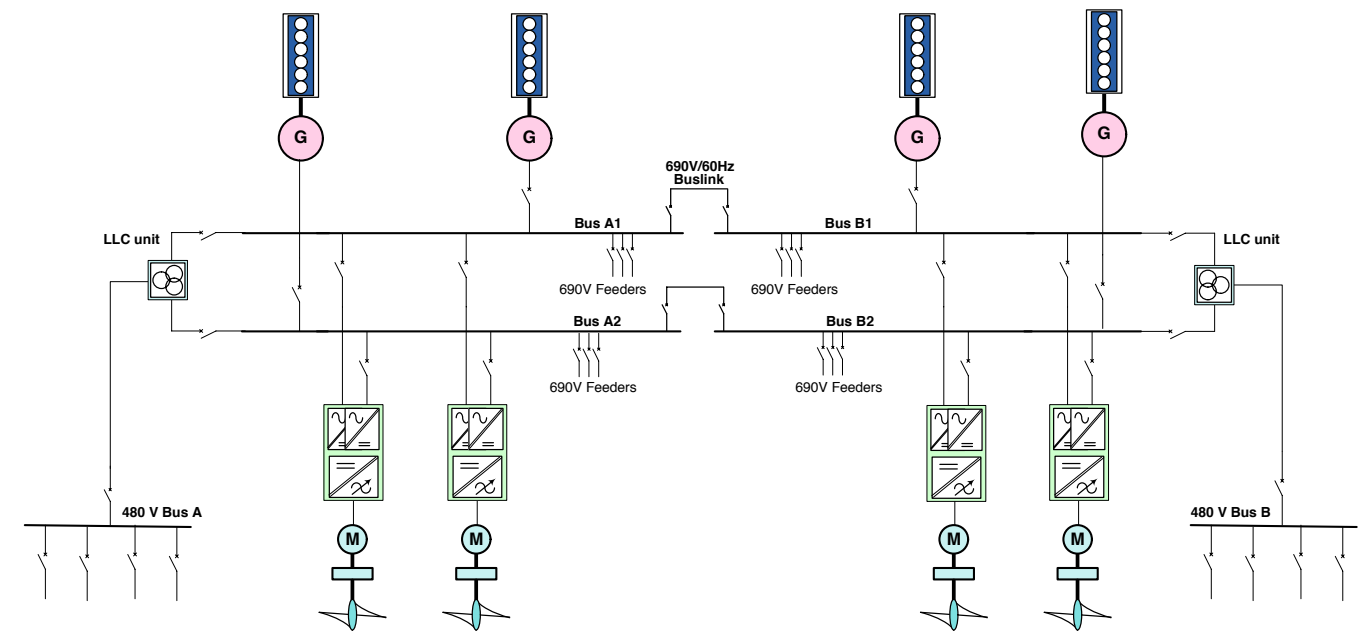
This gives a total reduction in transformers (lower footprint) for installations with more than two drives connected, compared to the DFE solution. Where more than two drives are installed, the advantage for reduced numbers of transformers becomes even more important.

Advantages of this design include:

- Fewer transformers mean less electrical losses in the system hence lower fuel consumption for any given engine configuration. Volume and space availability in the vessel is also saved thanks to less installed equipment.

- Improved system redundancy; as power distribution is split into 2 x equal top and bottom sections with the drive connected to both, 50 % of the power comes from 1 source with the other 50 % coming from the other. This means that in the case of failure in one of the switchboards, the drive can continue to operate unaffected albeit with reduced power.
- The owner can reach higher redundancy & ERN number compared to other systems on the market with same power installed or reduce amount of installed power to achieve equivalent DP plot when compared to other systems on the market.
- Significant savings in space and weight; number of transformers/converters in propulsion area; low voltage system makes more flexible switchboard room; less components saves weight; easier and safer operation; centralised placing enables easy and secure commissioning, operation, control and maintenance; lower short circuit level; total harmonic distortion lower than 5 %.

Single line diagram of Low Loss Concept technology



4. Hybrid Energy Storate Systems (ESS)

Hybrid power systems can combine different power sources with energy storage devices. The introduction of the hybrid power system, and its integration with conventional diesel-electric propulsion can offer significant improvement in efficiency by running the engines on optimal load and absorbing many of the load fluctuations through batteries.

The introduction of new Hybrid Power Systems with energy storage is a new and attractive way of reducing both fuel and exhaust emissions.

Wärtsilä system design takes care of energy storage capabilities in the form of a battery pack, hybrid control system, power transfer system and an energy storage system.

The key element in hybrid type of power systems is how to store the energy safely and efficiently. The most available technology at present is batteries.

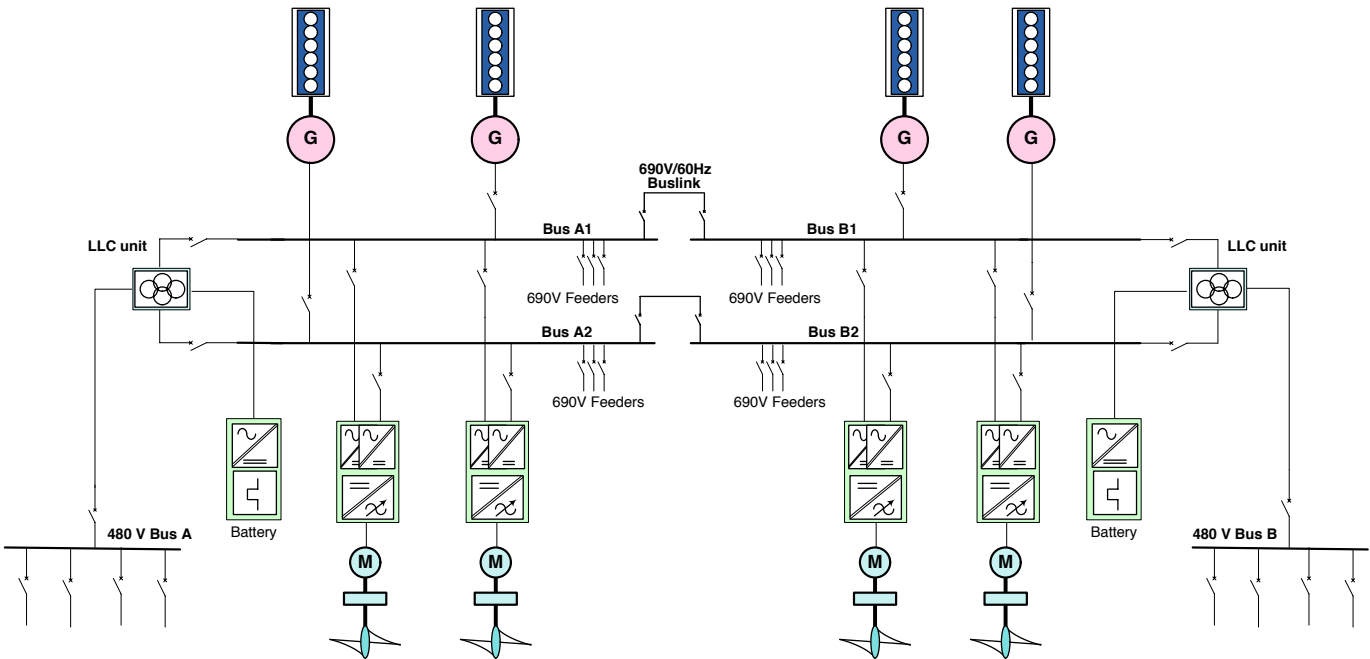
The design and the capacity of an energy storage system will depend on how the system is to be used. Knowledge about the actual vessel operation is therefore important.

Platform Supply Vessel Viking Lady



The main objective of the Energy Management System is to keep a stable power transfer flow to the batteries with variable overlapping of the induction coils, a variable air gap and variable tilting.

Single line diagram of Hybrid Power Systems



CONTROLS

1. 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 operational 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.

2. Propulsion Control and Energy Management Systems

In the Wärtsilä Propulsion Control System the drives are configured as subordinated consumers for the power system: 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.

Where Hybrid systems are used, the Wärtsilä Energy Management System is used to optimize power flow in the system, including control of charging and discharging of the energy storage and setting the speed of the engines in addition to the standard functions of the Propulsion Control System and the Power Management System.

3. Monitoring Screen Displays

For monitoring and auxiliary local control of the propulsion system colour touch screen displays 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

4. Remote Control System

For remote control of the propulsion drives, a combined speed control and telegraph system can be provided as the 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. Additionally operation panels with illuminated push buttons, warning lamps, emergency stop, safety device indications, overriding device, control transfer facilities, control switches, speed and power meters can be included.

Heavy lift jack-up vessel "Innovation" with PWM converter drives 4 x 3.5 MW, 3 x 2.8 MW



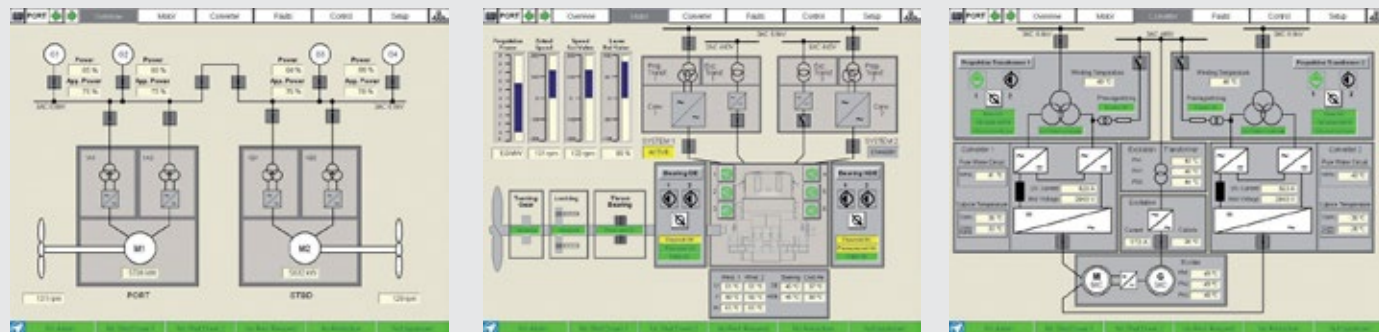
Cruise liner "Seabourn Odyssey" with LCI propulsion drives 2 x 7.5 MW



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



SCREENS



At Wärtsilä we strive constantly to do what is best for you. This includes optimising the lifecycle value of your installations by offering precisely what you need; a promise we can deliver on since we provide the marine industry's most complete portfolio of products, integrated solutions and global services.

By prioritising operational efficiency, environmental excellence, fuel flexibility and 24/7 support, we work with you to find your shorter route to robust growth, greater profitability and regulatory compliance. This is why today, every third vessel in the world has a Wärtsilä solution onboard.

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