

# Wärtsilä LLC helps achieve highest possible ERN number

**AUTHORS:** Inge Skaar, Director, Project Development and Naval Architecture, Wärtsilä Ship Design  
Kjell Angeltveit, Global Discipline Leader Electric and Automation, Wärtsilä Ship Design  
Margareth Urheim, Naval Architect, Hydrodynamics, Wärtsilä Ship Design

Wärtsilä has developed a platform supply vessel design which achieves the highest possible Environmental Regularity Number (ERN) score without increasing the installed engine power. Benefits for ship owners and operators include fuel savings and lower levels of emissions as a result of reduced losses in the vessel's electrical system, improved dynamic positioning capability in both normal and failure scenarios, reduced weight and space requirements, and increased levels of safety for crew members.

To avoid the occurrence of rig impacts in operations in the offshore sector, as well as other similar incidents resulting from loss of the propulsion power required to maintain station, conventional marine power-supply configurations in offshore vessels equipped with dynamic positioning (DP) systems consist of a split main switchboard divided by bus tie breakers.

In the worst single failure condition, shown in Figure 2 - failure of Bus A - two out of the vessel's four gensets have become unavailable and power to all thrusters and the propulsion system on the faulty side of

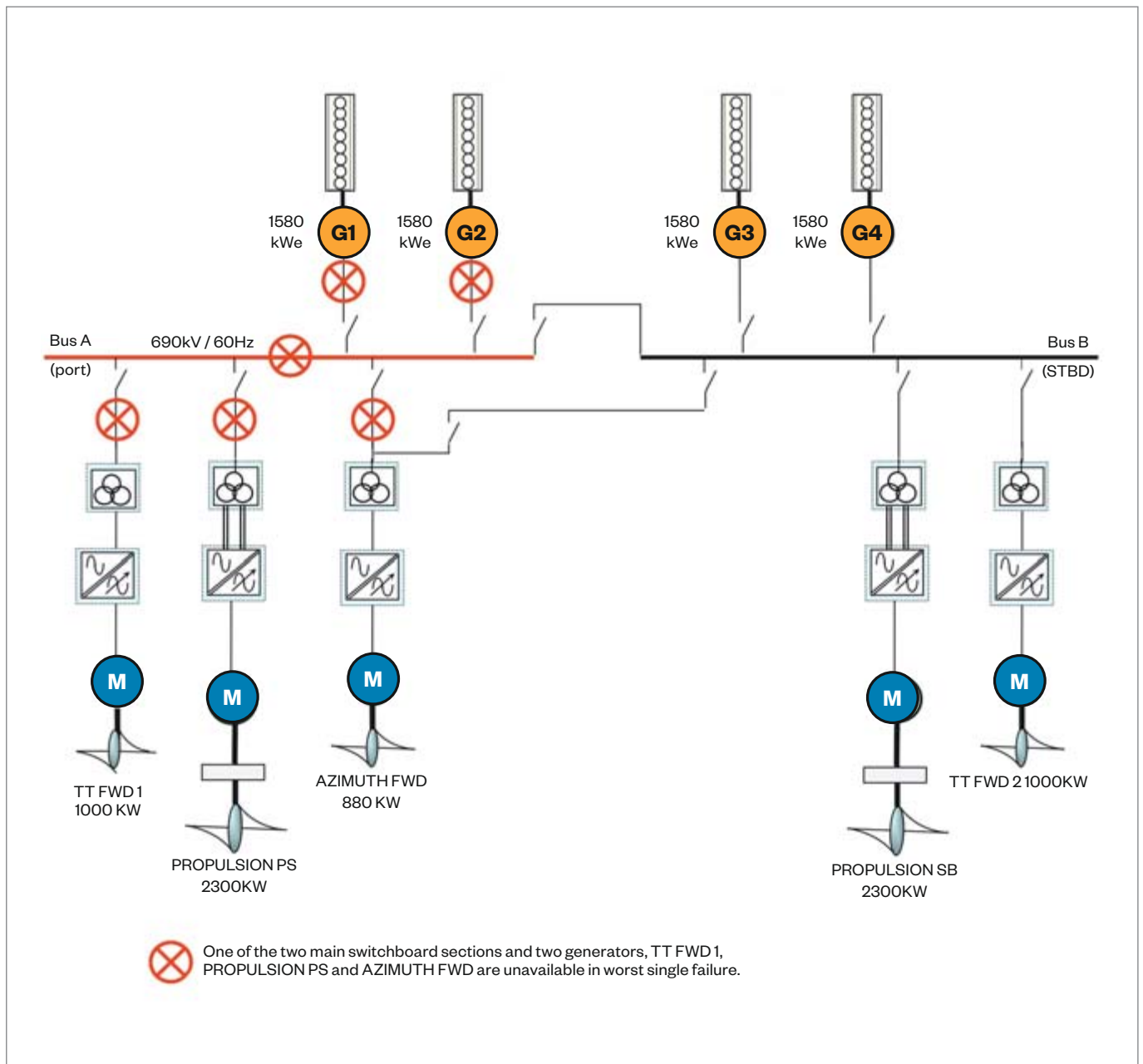
the main 690V switchboard has been lost. Power for all systems connected to the 450V and 230V switchboards on the faulty side has also been lost.

#### Low Loss Concept - a unique solution

In Wärtsilä's patented Low Loss Concept (LLC) system (Figure 3), the main switchboard is constructed with four separate sections, each of which is connected to the output of one genset. Thrusters are connected to the four switchboard sections in such a way that each drive is fed by two gensets. Using this

■ Fig. 1 - The Wärtsilä VS PSV 485 MKIII design platform supply vessel features the Wärtsilä Low Loss Concept solution.





■ Fig. 2 - Conventional switchboard failure.

configuration, even if one main switchboard section fails completely, the thrusters can be driven using just a single supply. While this feature makes the LLC solution unique, other subsidiary and auxiliary systems installed in the vessel have to be constructed in the correct way, a Wärtsilä design speciality.

Even with the loss of one genset, the sophisticated construction techniques employed in LLC and Wärtsilä's frequency drive systems allow thrusters or other propulsion systems to be driven while the 450 V or 230 V switchboard sections remain

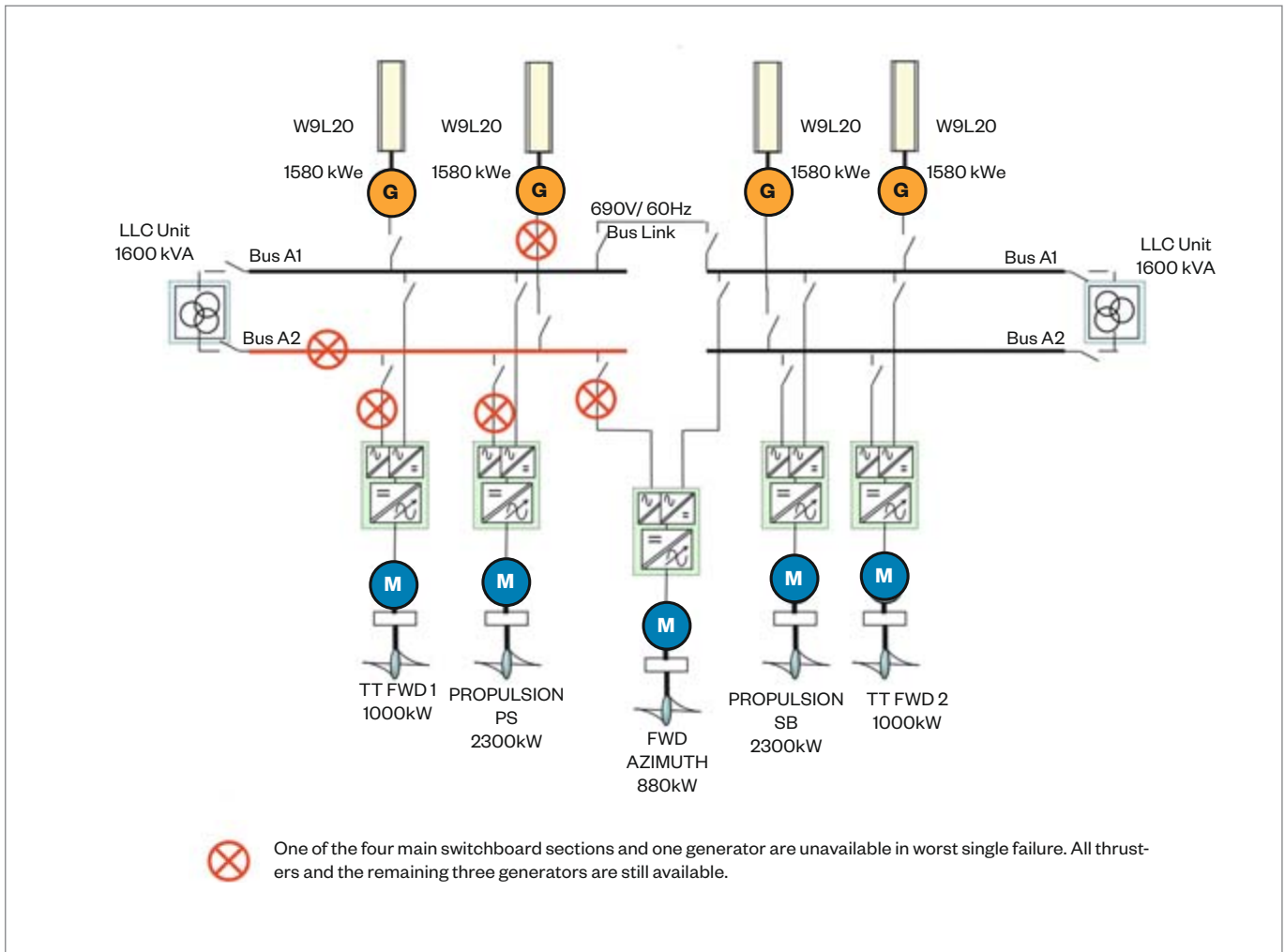
available. A figure of 99 for the "d" element in the vessel's ERN is therefore possible. This condition is shown in Figure 3. While engine auxiliary systems are designed to meet the demands for higher levels of redundancy, no increase in the size of either gensets or thrusters is required, and in some cases they can even be smaller.

**Achieving the same ERN with conventional technology**

To achieve the same ERN number for worst single failure in a conventional system, the

vessel's two forward tunnel thrusters would have to be more than doubled in size from 1000 kW to 2100 kW. Each of the four gensets would also need to be approximately 40% larger, with outputs of 2440 kWe rather than 1580 kWe. This configuration is shown in Figure 4.

The need to increase genset output and thruster size results in a heavier and more expensive configuration, which is more costly to operate. On the electrical side, the additional power demand could mean that a high-voltage system, rather than →



■ Fig. 3 - Switchboard failure with the Wärtsilä Low Loss Concept.

a low-voltage one, could be required. As well as restricting access to the vessel's power plant - personnel with the training required to operate such systems are hard to find - other possible consequences of having to install larger gensets and thrusters include increased initial levels of investment, increased operating costs, and the need to provide more space for generating equipment and power transformers.

**Improved station-keeping capability**

The Wärtsilä vs 485 PSV MKIII vessel design features the Wärtsilä LLC solution with the gensets and thrusters shown in Figure 3, giving an ERN of 99,99,99,99. If this vessel was equipped with the conventional switchboard solution shown in Figure 2, it would have an ERN of 99,99,99,55. To achieve the highest-possible ERN of 99,99,99,99 with a conventional switchboard solution, the

gensets and thrusters would have to be significantly larger and heavier, would cost more and would occupy additional space. This option is shown in Figure 4.

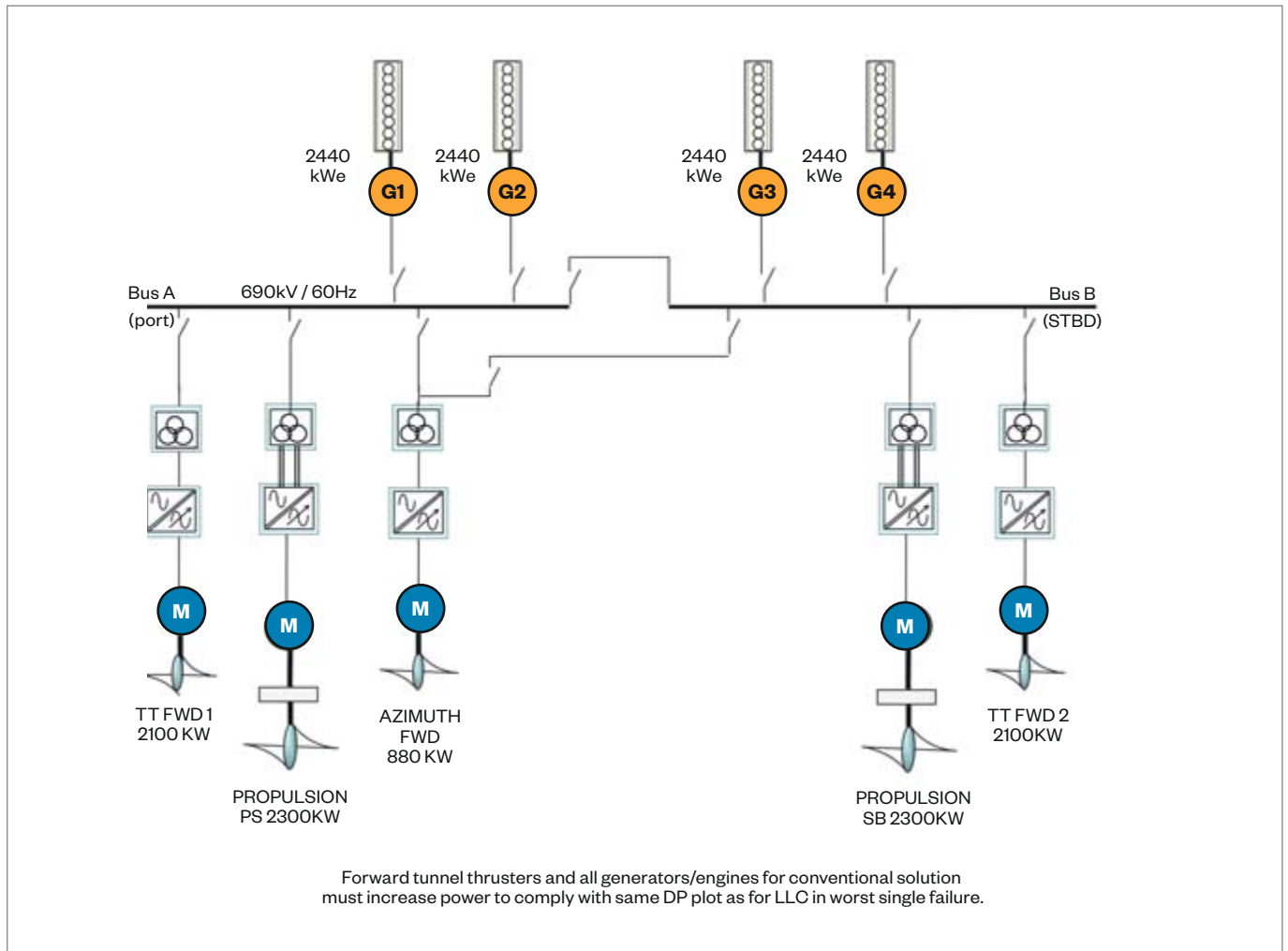
Although DNV's ERN is one way of defining a vessel's ability to maintain its station in different weather and sea conditions, another way of doing this is to use a DP capability plot. Three DP plots are shown in Figure 5. The green envelope represents the Wärtsilä LLC solution when one switchboard has failed (Bus A1 out of operation) as is shown in Figure 3. The blue envelope in Figure 5 also represents the Wärtsilä LLC solution, but in the case where the most important thruster - the forward tunnel thruster - has failed.

While both these failure cases result in an ERN with 99 for the "d" element, i.e. the highest possible result, the blue envelope shows that losing the forward tunnel thruster results in a lower DP capability than the

loss of one of the vessel's four switchboards. This means that for the Wärtsilä LLC solution on this vessel, the worst single failure condition (and the condition that yields the fourth ERN number) involves the loss of this propulsion device.

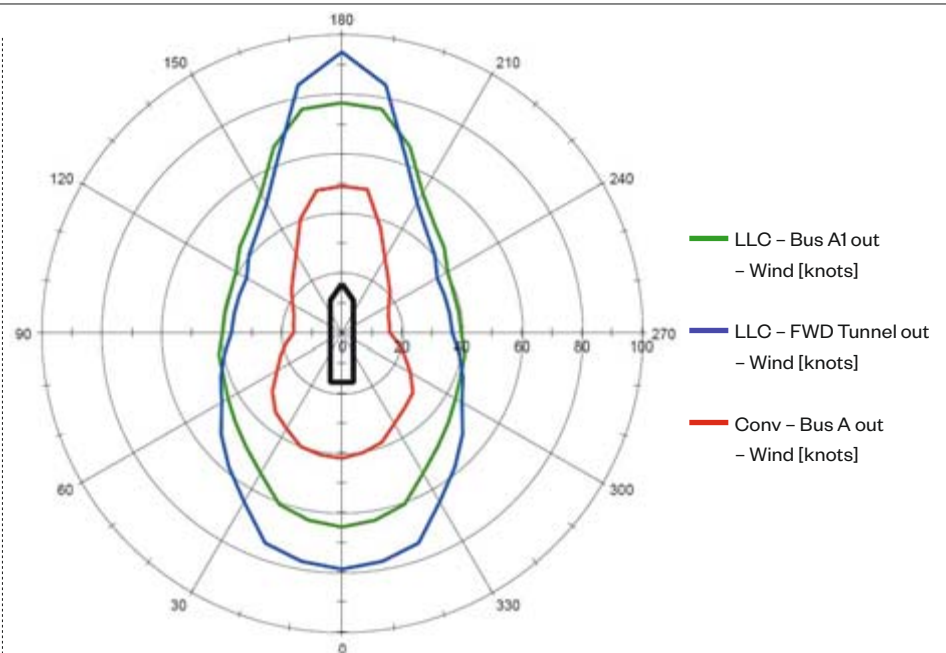
**Wärtsilä LLC solutions offer many benefits**

The red envelope in Figure 5 represents the conventional switchboard solution when one of the vessel's switchboards has failed (Bus A is out), with the loss of the forward tunnel thruster, main propulsion on the port side, and also the forward azimuth thruster. The red envelope is also a clear demonstration that DP capability in the worst single failure condition in a vessel equipped with a conventional switchboard solution is much lower than in a vessel equipped with the Wärtsilä LLC solution, as this enables all thrusters and gensets to remain available.



■ Fig. 4 - Conventional solution with larger generating sets and thrusters.

In addition to offering ship owners and operators higher levels of redundancy and safer operation, offshore service vessels equipped with sophisticated Wärtsilä LLC solutions are able to operate in harsh conditions with less installed power. LLC transformers add impedance to onboard power distribution arrangements, and short-circuit currents are therefore reduced, thus improving safety levels. Overall power levels also mean that engines will be running at higher loads and correspondingly higher levels of efficiency. Vessels equipped with Wärtsilä LLC also have increased operational flexibility as gensets can be taken out of service, thereby reducing accumulated running hours and associated maintenance costs. →



■ Fig. 5 - Alternative Dynamic Positioning (DP) plots.

# Environmental Regularity Number (ERN)

## Defining a vessel's ability to maintain its position

Developed in the 1970s by Det Norske Veritas (DNV), the Environmental Regularity Number (ERN, also ern) is a theoretical way of defining a vessel's ability to maintain its position in different weather and sea conditions. As only lateral forces are involved - wind, waves and current come in on the beam - the calculations involved are relatively simple.

The ERN consists of four groups of integers, each of which is stated by DNV to reflect "the probable regularity for keeping position in a defined area". The format of an ERN is a series of four numbers ranging from 0 to 99. ERNs are stated in shipping registers in the form ern (a, b, c, d), in which a represents the optimal use of all thrusters, b represents the minimum effect of a single-thruster failure, c represents the maximum effect of a single-thruster failure, and d represents the effect of the worst-case single failure(s). In a guidance note, DNV says: "The fourth number d shall represent the case where stop of the redundancy group resulting in the largest reduction of position and heading keeping has occurred. (106)"

In practical terms, a represents the probability that a vessel will be able to maintain a required position at a certain location in the North Sea when all its systems are fully operational, b indicates the probability that it will be able to maintain its desired position if the least-effective thruster fails, c indicates the probability that it will be able to maintain position if the most-effective thruster fails, and d indicates the probability that it will be able to maintain position in the worst-case single failure. The highest possible ERN rating - a score of 99 for a, b, c and d - is 99.99.99.99.

## Assumptions during calculation

ERN calculations assume that the forces resulting from wind, waves and current are coincident, with the magnitudes of wind and waves being of equal probability (103), and are intended to reflect a 'worst-case situation'. For monohulls, a guidance note by DNV says this is normally when the weather is on the vessel's beam (104), and the ERN is based on this situation "regardless of the vessel's ability to select other headings in operation. (104)"

Current is assumed to have a constant value of 0.75 m/s without differentiation into wind-induced and tidal components. ERNs are evaluated at the incidence angle of forces causing the maximum load on the vessel (104), and for a balance of forces while the vessel is maintaining both position and heading (105). According to DNV: "Thus there shall at the same time be a balance of forces and a balance of moments, i.e. including all moments generated by the thrusters, and those caused by environmental forces" (105). DNV also states "The ERN shall be based upon the thrust output that is under control, in the most efficient control mode. (107)"

Note: The reference numbers above are as given in Section 7 of the DNV publication Rules for classification of Ships, Part 6 Chapter 7, Dynamic Positioning Systems, July 2011, including amendments made in January 2012.

DET NORSKE VERITAS (DNV) is an autonomous and independent foundation with the objectives of safeguarding life, property and the environment, at sea and onshore. DNV undertakes classification, certification, and other verification and consultancy services relating to quality of ships, offshore units and installations, and onshore industries worldwide, and carries out research in relation to these functions.

# The Wärtsilä

Wärtsilä LLC is a fresh approach to supplying power to the variable frequency drives used in electric propulsion systems in marine applications. In addition to energy-efficient power distribution, it offers high levels of redundancy.

Featuring a transformerless design, the benefits of LLC include superb system availability. All power applications between 5 MW and 70 MW are covered in both the low-voltage and medium-voltage versions, and LLC is particularly effective in vessels such as OSVs, whose operating profiles require variable speeds and dynamic positioning capabilities. Low-voltage LLC systems have already been installed on approximately 100 vessels and medium-voltage installations are in the pipeline.

The invention on which the Wärtsilä LLC is based was made in 2003. The first complete LLC system was delivered in 2004 and installed on the 'Normand Skipper', a platform supply vessel. The main patent for LLC was granted in 2006, and patents have subsequently been obtained by Wärtsilä for both the Quattro LLC design and for LLC in medium-voltage applications.

## Saving weight and offering higher levels of efficiency

Traditional solutions for electrical vessel propulsion systems consist of two or more propulsion units - a number of generating sets and a drive system consisting of a propulsion transformer, a frequency converter for speed control, and a propeller system. The transformers in such systems are heavy and occupy significant amounts of space, and platform supply vessels of medium size employ at least four propulsion units, sometimes as many as seven.

LLC eliminates the need for propulsion transformers by allowing genset power to be applied directly to the frequency

# Low Loss Concept (LLC)

converters used for speed control. This approach means that system efficiency is 2-4% higher than in traditional transformer-based systems, in which each propulsion unit consists of a propulsion transformer, a frequency converter for speed control and a thruster unit. In LLC, current levels supplied to the frequency converters from the switchboards are 10% lower than in conventional solutions, and the transformers required are also smaller and lighter.

## Low levels of total harmonic distortion, fuel savings and weight reductions

The LLC solution employs transformers in which the main windings are phase shifted by 30° to cancel the 5th and 7th harmonic currents introduced into the network by rectifying bridges. The bridges are supplied from the two phase-shifted sides of the LLC transformer, with each side providing 50% of the required power. An LC (tuned circuit) filter combined with a filter winding in the LLC transformer results in total harmonic distortion (THD) of less than 5%, and the majority of the harmonic currents pass through the

transformer, not through the generators. This also means that LLC transformers can be smaller and lighter than those employed in conventional power-supply configurations.

Lower electrical losses in the system result in better fuel economy, thereby reducing the overall levels of emissions, and the need for auxiliary systems. Depending on the type of vessel and its operational profile, the reduction in electrical losses can yield annual fuel savings of between EUR 30,000 and EUR 100,000.

In traditional systems, the use of low-voltage components is restricted to applications with a maximum of around 10 MW installed propulsion power. By using LLC, propulsion systems can be designed for higher installed power using low-voltage (690 V) components, reducing equipment weight and saving valuable space. In some applications, weight reductions of 35-40% can be achieved.

## A wider range of potential applications with Quattro LLC

Quattro LLC extends the range of applications for the LLC concept. Four LLC transformers connected in a ring

configuration maintain a constant 30° phase difference between the electrical distribution bus bars.

While Quattro LLC was originally designed for medium-voltage power distribution, it extends the low-voltage power range up to a total of 20 MW propulsion power. Components for low-voltage power distribution are significantly cheaper than medium-voltage components and crew training is less costly. There is also a shortage of personnel trained to operate medium-voltage equipment.

With medium-voltage components (6600 V), installed propulsion power using traditional design configurations can be in the range 30-40 MW. LLC enables the use of standard medium-voltage components in large vessels and offshore platform applications equipped with up to 70 MW of installed power.

## Advantages of the Wärtsilä LLC concept

1. Reduced losses in the vessel's electrical system (15-20%) result in fuel savings and lower levels of emissions.
2. Higher levels of availability when a major failure occurs increases thruster robustness.
3. Less-severe consequences in the worst single failure case mean that LLC solutions offers improved DP capability.
4. Increased operational flexibility and availability through a segregated, two-section switchboard and bus connections via buslinks.
5. Significant increase in levels of personnel safety because of the reduced likelihood of short circuits.
6. No inrush current at thruster start-up as the transformers are always energised.
7. Reduced weight and space requirements as the usual thruster transformers are not required.
8. Additional flexibility in vessel design as the LLC phase-shift transformers do not need to be located close to the electric drives for which they provide power. They also feature secondary windings which can be used to supply some of the vessel's auxiliary power requirements.
9. More efficient power distribution in damage scenarios.

# Assessing station-keeping capability in vessels with DP systems

Dynamic positioning (DP) systems are designed to maintain vessel position within an acceptable watch circle under defined operating environments. In practical terms, this means countering mean environmental loads and dampening out low-frequency surge and sway motions, reducing the likelihood of unplanned impacts with stationary installations such as drilling rigs or other offshore oil and gas facilities.

Vessel station-keeping characteristics are usually presented using capability

plots - polar diagrams in which envelopes depict a vessel's ability to maintain its position in a specific environment with a particular combination of thrusters. The grid on which the plots are displayed indicates wind speed. The speed of the current is usually fixed, as is the relationship between wind speed and wave height - wind speed is the easiest parameter to measure.

Each plot depicts the vessel's ability to withstand wind speeds from different headings, coupled with a

defined current and waves of height determined by the wind speed. All three environmental forces normally act on the vessel in the same direction.

Calculations carried out to obtain each capability plot include: the effect of wind forces acting on the vessel; the effect of wave drift forces and current drag forces; and propeller, rudder and thruster efficiencies in different directions.

## Analysis procedure

Steps involved in analysing the station-keeping capability typically involve:

1. Defining the operating environment and vessel heading
2. Calculating the global surge, sway and yaw loads due to wind, waves and currents
3. Determining the required output of each installed thruster based on appropriate thruster allocation algorithms
4. Determining the available thrust from each thruster
5. Calculating the total available thrust and comparing this to the global environmental load. For the intact condition, the global environmental load must be less than, or equal to, 80% of available thrust. For the damage condition, the global environmental load must be less than 100% of the available thrust.
6. Repeating the above for different headings and/or operating environments.

### SOURCE DOCUMENTS:

- Rules for classification of Ships, Part 6 Chapter 7, Dynamic Positioning Systems, July 2011, including amendments made in January 2012 (<http://exchange.dnv.com/publishing/RulesShip/2012-01/ts607.pdf>)
- Station Keeping Criteria for DP Vessels.pdf ([http://www.dynamic-positioning.com/dp2004/design\\_ubisch.pdf](http://www.dynamic-positioning.com/dp2004/design_ubisch.pdf))
- Low Loss Concept Comparison Study 2010.pdf ([http://www.dynamic-positioning.com/dp2010/newapps\\_vankeep.pdf](http://www.dynamic-positioning.com/dp2010/newapps_vankeep.pdf))