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A FLEXIBLE FUTURE

Flexibility is a multi-faceted word, meaning "the quality of bending easily without breaking," "the ability to be easily modified" and a "willingness to change or compromise." When we talk about our approach to the fuel flexibility of our engines, all these definitions are relevant.

Wärtsilä was first on the scene with a dual-fuel engine, and now we are setting the trend and changing the marine market once again by being the first with a marine engine running on ethane. Power plants are also becoming more fuel flexible to be able to run on propane, methane, biofuel and ethane. Many of the adaptations we have made have been at the request of our customers, whose specialised needs sometimes require a unique, flexible solution.

The fact that our products have been modified to operate – and not merely run but function efficiently – on a range of fuels is the epitome of flexibility. Furthermore, the willingness of our company to make changes to incorporate these new possibilities shows a flexible mind-set within the organisation as well. We do not want our customers to be dependent on one particular fuel being available today. Therefore, we are willing and capable to find ways to meet not only the demands of the present but the future needs as well.

Now we are taking our strategy for flexibility further into the future. For example, engine-solar PV hybrids complement each other to increase the efficiency of a power plant and help install renewables. Currently, the industry is looking at what energy storage and batteries can bring, but the future may reveal additional ways to store renewable energy so that it is not wasted.

One such opportunity may be to store excess energy as different types of liquid and gaseous fuels that then become energy storage. For now, we are making our products as ready and efficient as possible so that, whenever new energy sources come about, we are able to find ways to integrate them with our fuel-flexible technologies.

Ilari Kallio
Vice President, Technology
Engines, Wärtsilä Marine Solutions
Editor-in-Chief of In Detail

A PILGRIMAGE TO HACKING HEAVEN

Wärtsilä's Digisauna hackathon winners travelled to San Francisco to find ways to take their idea to the next level.

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With Wärtsilä JOVYATLAS' load resistor manufacturing expertise, Wärtsilä can provide better in-house packages to customers

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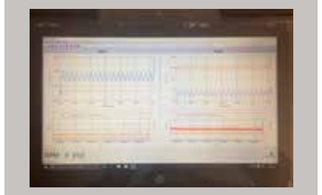

Flexible alignment monitoring on the go

Catch, identify, and diagnose misalignment issues while the vessel is operating the vessel is operating

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Wärtsilä has generating sets with a unit power up to 19 MWe. The Wärtsilä 18V50DF shown in the photo is the ultimate 'fuel flexibility' engine and can be run on natural gas, light fuel oil (LFO) or heavy fuel oil (HFO). The dual-fuel technology allows the plant operator to change from liquid to gas fuel and back at the flick of a switch. The Wärtsilä 18V50DF engines are used in the IPP4, IPP3 and Quisqueya plants referred to in this article.

Fuel flexible power plants from Wärtsilä

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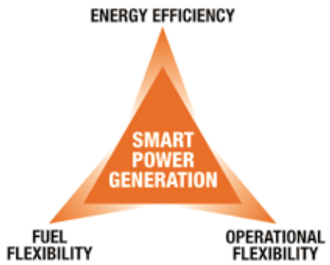
Fuel flexibility is one of the three cornerstones of Wärtsilä's Smart Power Generation, the other two being operational flexibility and energy efficiency. Whereas the main global energy trend today is toward the use of natural gas, Wärtsilä's fuel flexible engine portfolio is well prepared to go beyond the conventional liquid and gas fuels and use various alternative liquid and gas fuels. The company emphasizes the option of using dual- and tri-fuel technologies allows plant owners to hedge for the future. In many cases, liquid fuels are used during the first years of operation until gas becomes available at the site, and thereafter liquid fuel is used as backup in case of interrupted gas supply. In this article, we explore the range of fuel flexibility offered by Wärtsilä.

The world's largest internal combustion engine combined cycle plant, the Wärtsilä Flexicycle plants at the Quisqueya I and II power plant complex in the Dominican Republic have a total combined output of 430 MW. The plants were built by Wärtsilä under EPC contracts and were delivered in 2013. Both plants operate on Wärtsilä 18V50DF dual-fuel engines.



Fuel flexibility is one of the three cornerstones of Smart Power Generation.

A brief history

The first engines designed by Wärtsilä in the 1960s were diesel engines used primarily for ships. The diesel engine platform was soon developed to accommodate a wide range of liquid fuels, from light diesel fuel to heavy fuel oil (HFO), crude oil, refinery bottom oils and, more recently, liquid biofuels. During the same time, the engines were increasingly used in land-based power plants, and by the 1980s, it became clear that there was great business potential in gas engines. Wärtsilä already had a solid diesel engine platform, which was used as a base for the development of three gas engine technologies in the 1980s and 1990s. Today, the gas-diesel (GD) engine, spark-ignited gas (SG) engine, and dual-fuel (DF) engine all have long track records, with more than 3500 units in the reference lists. The technologies are continuously being refined for higher efficiency, lower emissions, better reliability and even greater fuel flexibility.

Alternative fuels for power generation

Many clean fuels besides natural gas are being burned in Wärtsilä's fuel-flexible installations across the world. These include LPG (propane), ethane and methanol, to name a few. Central America, where Wärtsilä's first LPG-powered plant went into operation in early 2016, provides an interesting example of the use of one of these fuels. In spring 2016, the company contracted another 28 MW, LPG-fuelled plant in Honduras. Such plants are well-suited for regions where LPG is available and has long been used for heating and cooking in homes but, so far, rarely has been put to use in larger-scale power generation. An important feature of the Wärtsilä LPG plants is that they can be modified easily to use natural gas as fuel, in case gas becomes available in the future.

Important development of alternative fuels is also happening in the shipping industry, where Wärtsilä's Marine Solutions business uses the same flexible-fuel engine products. For example, the US shale gas boom and the possibilities to export ethane from the US triggered an order of a series of liquefied ethane gas (LEG) carriers. Now, the natural choice of fuel for these carriers is ethane, and since early 2016, the first Wärtsilä engines burning ethane are in service propelling the ships.

In addition, a major ship owner operating in an environmentally-sensitive area with limitations on fuel sulphur content (SECA) requested Wärtsilä to develop a technology for burning methanol. As a result, Wärtsilä developed a retrofit for existing engines to

Wärtsilä's first propane-fired power plant is in operation in Central America.

The JS INEOS INTREPID, one of four new 27,000 cubic-metre, Evergas Dragon series, multi-gas carriers. The Dragon series of vessels are powered by Wärtsilä engines and are the first to use ethane as a fuel. © INEOS 2016, reproduced with permission. All rights reserved.

The Wärtsilä 34SG is the first large medium-speed engine capable of running on LPG (propane).

use methanol and retrofitted the first engine in spring 2015. The fourth and last engine will be retrofitted in 2016.

Wärtsilä's role in the shift toward gas

Environmental concerns, particularly emissions output, play a key role in the trend toward gas. But significant savings can also be achieved using gas, which is cheaper than liquid fuels. The development of major gas fields and large-scale LNG shipping during the last 15 years has brought gas to locations lacking their own gas fields. Wärtsilä's LNG solutions make an important contribution to the small- and medium-scale LNG terminal business by making gas available for power plants and other consumers in areas without a gas pipeline connection.

An example of this is the Tornio Manga LNG terminal. Located in the port of Tornio, Finland, hundreds of kilometres from the nearest gas pipeline, the LNG terminal will make gas and LNG available for power generation and industry in northern Finland and Sweden. Wärtsilä is building the terminal under an Engineering, Procurement and Construction (EPC) contract that includes unloading, a 50,000 cubic meter storage tank and regasification equipment. Wärtsilä seeks to replicate the Tornio model in other remote locations without their own fuel resources.

Putting Wärtsilä technologies to use in the Oil & Gas business

With excellent technologies for burning natural gas, associated gas and crude oil, Wärtsilä has been active in the Oil & Gas business for years. Wärtsilä is focusing especially on efficient utilisation of associated gas, due to the great potential for reducing flaring and the industry's overall carbon footprint. Today, gas turbine technology is often used for field power, which means that the electrical efficiency, in worst cases, can be well below 30%. This results in a very high carbon footprint. By contrast, Wärtsilä engines can achieve up to 45% electrical efficiency, reducing the carbon footprint by one-third compared to standard gas turbines. Depending on the operating regime, the reductions could reach 50%.

The many years of committed gas engine research and development at Wärtsilä have paid off in other ways, as the company has made major progress tuning gas engines to burn low methane number associated gas and/or gases with low lower heating value (LHV). A fascinating example of this is the 25 MW KivuWatt power plant at Lake Kivu in Rwanda, the only known lake in the world that sits atop a pool of trapped methane gas. One of the reasons why Wärtsilä technology was chosen for the project is that the company's engines can handle gases with low LHV. Powered by three Wärtsilä 34SG engines, KivuWatt has now been in

For the Eklutna Generating Station in Alaska Wärtsilä supplied Wärtsilä 50DF dual-fuel generating sets that will be operated primarily on natural gas with light fuel oil (LFO) as back-up. The flexibility of the equipment in its ability to maintain high efficiency output during wide daily and seasonal swings in load, was another key consideration in the customer's decision to choose the Wärtsilä engines. With loads swinging from 145 MW peaks in the winter, to as low as 50 MW during hot summer nights, the Wärtsilä multiple-unit plant configuration maintains high efficiency by matching the number of operating engines to the actual load demand. Another important factor in the award of this contract was that the Wärtsilä generating sets meet the strict environmental requirements specific to the project.

operation since early 2016, providing low-cost electricity and increased energy security to Rwanda, which has traditionally relied on expensive imported diesel and HFO.

Looking ahead to a cleaner, cheaper energy future

A relatively new area with great potential for innovation is engine-solar hybrid plants, which pose a novel way to both reduce emissions and save fuel during sunny hours. This is the case in Jordan, where, in 2016, Wärtsilä contracted a 46 MW solar extension of the existing 250 MW, IPP4 tri-fuel plant, making it the world's largest engine-solar hybrid plant. The flexibility of the IPP4 plant's Wärtsilä 18V50DF units allows the engines to be started and stopped depending on the output of the solar plant. It complements the country's IPP3 plant, a 575 MW Wärtsilä 50DF tri-fuel plant – also the largest of its kind worldwide in 2014 – which was originally built to run on HFO until Jordan's gas infrastructure was completed.

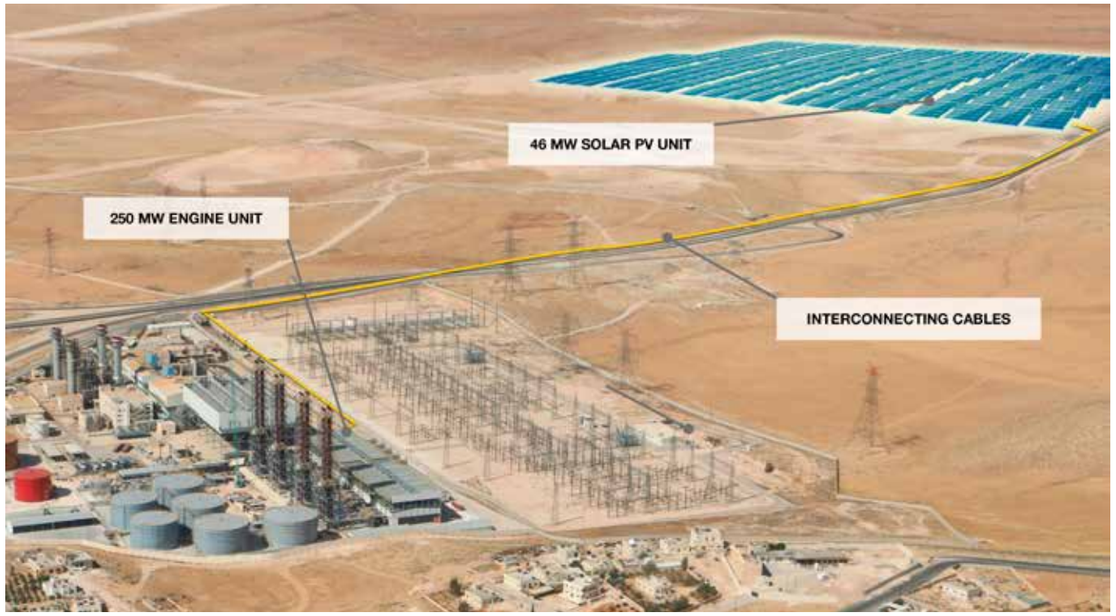
In the case of both the IPP3 and IPP4, if the flow of gas ever stops, the plants can immediately be switched over to run on diesel or HFO as backup until the gas supply is restored. Also, the operational flexibility of the IPP3 and IPP4 plants will facilitate a future, larger-scale development of renewables in Jordan.

Both plants demonstrate the practical value of Wärtsilä's fuel and operational flexibility in helping make Jordan's grid sustainable and cost effective in the long term. They are perfect examples of why the future of Wärtsilä's fuel flexibility initiatives remains so bright. Read more about Wärtsilä's engine-solar PV hybrid solutions on the article "Bright future for PV solar power".

Conclusion

As regional fuel availability often is an important factor in many power plant projects, Wärtsilä continues to encourage its customers to engage in dialogue about the use of alternative fuels and multi-fuel technologies. Throughout its history, the company has been at the forefront of innovation and fuel flexibility, and it intends to maintain that position.

The KivuWatt plant with three Wärtsilä 34SG engines. The tuning possibilities offered by the advanced control system of the Wärtsilä 34SG engines allows for use of pipeline gas and associated gas with a wide range of gas compositions.



Wärtsilä delivered IPP4, the 250 MW multi-fuel plant to AES Jordan on a fast-track, turnkey basis in 2014. The 46 MW solar PV extension scheduled to be delivered in 2017 will be connected to the existing power plant and makes the IPP4 plant the world's largest engine-solar PV hybrid plant.

[ENERGY / IN DETAIL]

LNG value chain optimisation – Case Aruba

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Reducing the cost of LNG or gas at its final destination requires optimising an often complex LNG logistic chain with lots of variables. Wärtsilä's LNG value chain optimisation tool takes into account key parameters, like LNG purchase price, terminal EPC cost and charter rates, to work out the optimal solution that gives the lowest cost of LNG at the final destination.

Introduction to value chain optimisation

The liquefied natural gas (LNG) value chain, from gas well to consumer, is complicated and investment intensive. This adds a considerable amount of cost to the end user, if one does not understand how it can be optimised. Therefore, the most economical solution can often be overlooked if one focuses only on infrastructure investment costs.

Economy of scale plays a big role in LNG logistics. Larger liquefaction plants, larger LNG carriers and larger terminals all contribute to a lower unit cost. However, to be able to deliver LNG to smaller consumers that are unable to utilise the large terminals or receive a large LNG carrier in their small harbour, there needs to be a medium- and small-scale logistic chain in place before they can get their gas.

The cost of delivering LNG to its final destination largely depends on the length of the logistic chain, with the following main parameters:

- Source cost of LNG
- Location of the LNG liquefaction plant in relation to the final destination
- Size and route of the LNG carrier
- Size and location of receiving terminal(s)
- Utilisation of boil-off gas (BOG) in the process and the end customer's requirements for gas availability

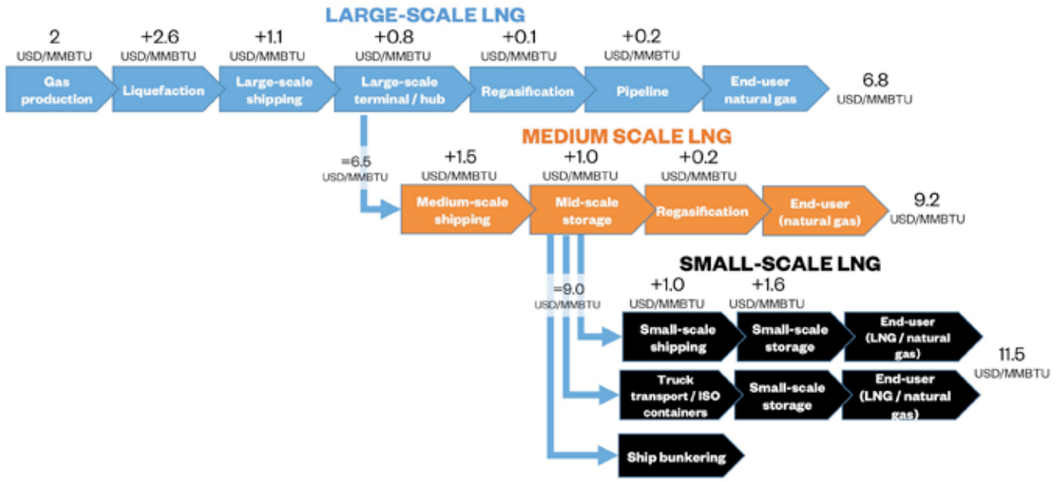

Fig. 1 - Typical values for the cost contributors or "add on costs" in the LNG logistic chain between the USA (Henry Hub) and a location somewhere in Asia.

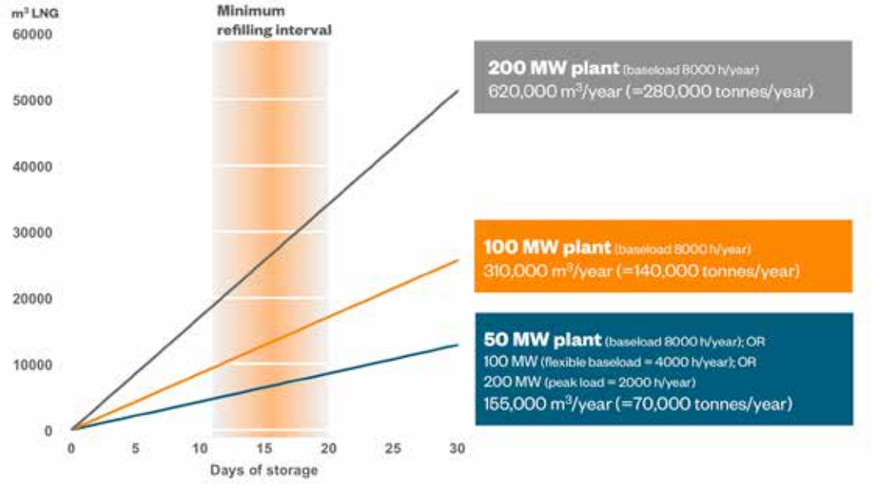

Fig. 2 - Typical consumption and storage size for gas power plants.

Large-scale LNG operations

Liquefaction plant: A large-scale LNG operation typically includes production trains with single capacities between 1 and 6 MTPA (million metric tonnes per annum), and they can include multiple trains. For example, in Qatar, the world's biggest supplier of LNG, Qatargas and Rasgas have a total production capacity of 77 MTPA from their production sites. Cheniere's newly opened Sabine Pass liquefaction plant will have a nameplate capacity of 27 MTPA, once it opens all 6 trains of about 4.5 MTPA each. Large liquefaction sites are always located in coastal areas since the only practical method of large-scale transportation is using LNG carriers, with capacities ranging from approximately 120,000 m^3 (54,000 tonnes) for older vessels to up to as much as 267,000 m^3 (120,000 tonnes) for the largest Q-max vessels. As an example, this means that Cheniere's Sabine Pass plant could deliver more than a Q-max vessel of LNG every second day.

Receiving terminal: Conventional receiving terminals (LNG hubs) in the large-scale LNG chain are also located by the coast so that LNG carriers can arrive and unload the cargo. Main hubs include LNG storage facilities, typically in the range of 120,000 m^3 or larger, designed to receive at least the full capacity of the allocated LNG carrier. The LNG is re-gasified at the hub, and the main distribution channel for the consumers is normally a national, high-pressure, natural gas pipeline.

Medium-scale LNG operations

A medium-size LNG logistics chain includes terminal up to 120,000 m^3 in size, which are supplied by small-scale LNG carriers, starting from sizes of 1000 m^3 to up to around 40,000 m^3. Here again, the vessel size and loading frequency play an important role in determining storage capacity.

Medium-scale liquefaction is not so common today, due to the challenge with high, specific production costs. In any case, these will probably play a larger role in the future for decentralised solutions, to which extending the large-scale logistic chain would not be feasible.

Small-scale LNG operations

A small-scale LNG logistics chain is comprised of LNG distribution to local users. In practice, this means highway truck transportation or small sea-going vessel distribution to the end-user's local LNG tanks, which can be from the smallest container sizes of 20 m^3 to up to a set of pressurised steel tanks with total capacities of up to a few thousands of cubic metres.

Small-scale liquefaction is becoming popular due to the liquefaction of biogas and other smaller pockets of stranded gas. Small-scale liquefaction can be modularised and, to some extent, standardised. The systems are similar to the re-liquefaction process used in large terminals to handle the BOG (boil-off gas).

Logistic chain optimisation

There is a huge difference to consumers if the cost of fuel is 2 USD/mmBtu versus 11.5 USD/mmBtu. It is in the end user's interest that this value chain be as cost-efficient as possible.

There are several things that can be done to optimise the LNG logistic chain in order to reduce the cost of LNG or gas at its final destination. A logistic chain that incorporates the large-, medium- and small-scale chains can be very complex. To be able to optimise this complex chain with lots of variables, Wärtsilä has developed an LNG value chain optimisation tool. This tool estimates, through an iterative process, the cost of LNG at the final destination(s). The tool needs various inputs such as the following:

- Consumer characteristics (location(s), consumption profile, cost vs. feasibility)
- Gas availability requirement
- Supply (location(s), suitability, cost)
- Receiving terminals (need for break-bulk, location, type, sizes, investment cost)
- Shipping (vessels available, charter rate, fuel consumption)
- Boil-off gas (BOG) handling
- Financing (ownership arrangements, cost of capital, payback time)

The tool works so that you start by defining the consumers, the locations and the anticipated consumption profile. Based on this, you analyse the logistics, deciding where to get LNG and where the receiving location(s) are. Dependent on the exporting terminal compliance with smaller LNG carriers, you also decide if a breakbulk terminal is needed in between.

Based on the number of terminals and their sizes, you can finally propose the size of LNG carriers and the route.

With all basic parameters and the setup in place, the optimisation/iteration takes into account the parameters like LNG purchase price, terminal EPC cost and charter rates to work out the optimal solution that gives the lowest cost of LNG at the final destination, dependent on various scenarios.

LNG consumption & load profiles

When optimising the logistic chain, we need to start from the consumers. It makes sense to cluster together as many consumers as possible to improve the economy of scale in the LNG logistic chain.

By clustering together several consumers and increasing the volumes, we can potentially buy LNG at a better price and utilise larger LNG carriers with a lower specific shipping cost. But at the same time, with several consumers in the loop, you add complexity to the logistics and need a plan for how to break up the distribution of the larger amount of LNG into many smaller consumers. This might call for some additional infrastructure to be built. Additional cost of this infrastructure has to be balanced versus the lower cost of the source LNG.

Consumers will, unless forced by legislation, normally decide whether it is worthwhile to change fuel based on the estimated cost of LNG.

When it comes to LNG supply, it is important to understand that it is only a few of the existing export terminals that are able to take small size (<40,000 m^3) LNG carriers. There are some technical issues to overcome with the jetties planned for large LNG carriers in order to handle the smaller LNG carriers, but the main reason why the large terminals do not take small size carriers is the risk of disturbing or taking time away from the profitable large-scale operations.

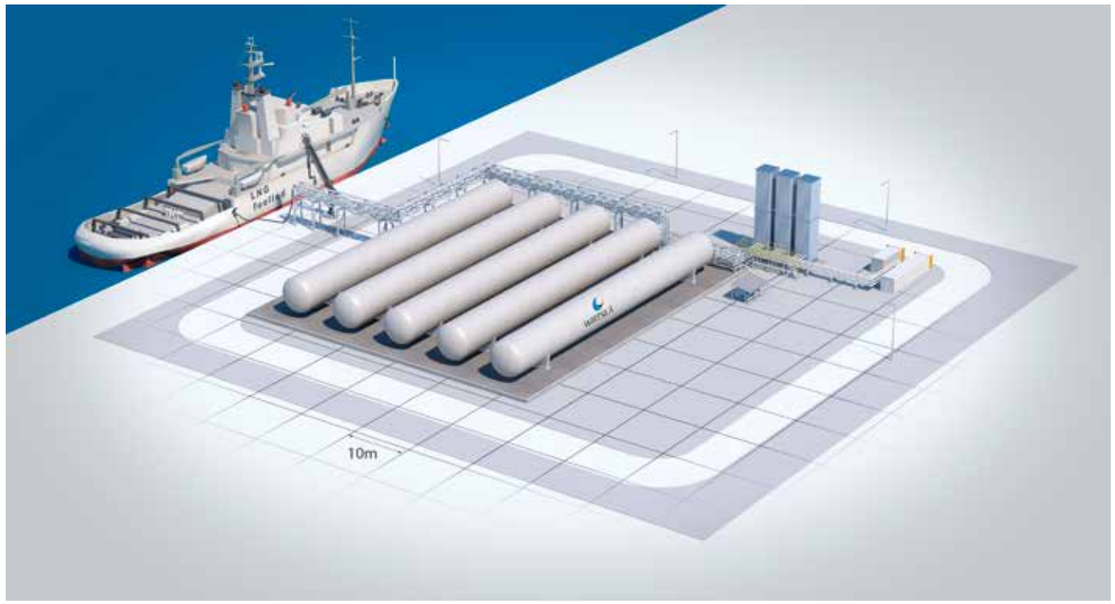

Fig. 3 - Possible layout for a small-scale LNG terminal in Aruba, capable of regasification and bunkering.

Fig. 4 - Actual shipping distances between Aruba and supply ports (estimated according to www.sea-distances.org).

LNG shipping

Large-scale shipping is well established, and today there is an overcapacity of large-scale carriers. For the older, less efficient steam turbine-driven LNG carriers, we have seen a drastic reduction in charter rates during the last year. But when it comes to small-scale LNG, there are only a few small-scale LNG carriers available today. In many cases, the charter rate for them might be the same as for an older, larger LNG carrier.

LNG shipping between the free on board (FOB) sales hub and a new terminal can be arranged in three ways:

1) Operating your own LNG carrier
2) Chartering a carrier from the market place
3) Arranging transport through an LNG provider (DES Contract)

For the first two options, freight volumes should be significant in order to establish in-house organisations to manage this. The third option is the norm when volumes are small or moderate. In this case, the entire supply chain and associated risks can be sub-contracted as an entire package to the LNG provider.

Case Aruba

The customer in this case study is the island nation of Aruba, located just north of Venezuela. It is a Caribbean country, with slightly more than 100,000 inhabitants in an area of 179 km², which means it is densely populated, especially on the more sheltered western and southern coasts of the island. Aruba has one of the highest standards of living in the Caribbean region. The island's economy is built on three main industries: tourism, aloe export, and petroleum refining. Unlike many other islands in the region, it has a dry climate appreciated by visitors looking for warm, sunny weather.

Aruba does not yet have an LNG terminal. For this exercise, we will envision the optimisation options that the developers of such a project would face. The island produces its electricity largely using power plants that today are operating on heavy fuel oil (HFO), but could be converted to gas. There are ambitious plans to increase the share of renewable energy, mainly through wind power, to harness the constant trade winds, but also some solar. In the future, cruise ships might switch over to LNG for environmental reasons, and increased demand for district cooling at hotels is expected to drive up electricity consumption. We have assumed that the annual gas consumption could be approximately 81.1 million Nm³ of gas or 62,400 tonnes per annum (TPA) of LNG. To give an idea of this amount, it corresponds roughly to the consumption of a 45 MW power plant running baseload at 8000 h/year.

The Caribbean is an interesting area to use for a case study about small-scale LNG since there are many stranded markets there that are not feasible to reach by building pipelines. The main reason why there is not already LNG on these islands is that there has not been a supplier willing and able to supply LNG in suitable quantities. One would have to import LNG either in ISO containers, which is expensive due to the logistics involved, or in large-scale LNG carriers that carry much more LNG than would be demanded. All this changed as of October 2016, when the AES Andres LNG terminal in the Dominican Republic started offering reloads to small-scale LNG carriers. Furthermore, in August, the 138,500 m³ Golar Arctic arrived at its new position as a floating storage unit (FSU) outside Jamaica and will most likely be made available as a supply point for other small-scale LNG projects in the area.

To make this case study more interesting, we have chosen to include four additional suppliers that could become available in the future:

- Eagle LNG in Jacksonville, Florida, USA. This mid-scale LNG plant is specifically targeted at supplying the Caribbean small-scale markets and could be in service in 2019.
- The Altamira terminal is today a large-scale terminal importing LNG to Mexico. If improved pipeline connections to the US are built, Mexico will need less LNG, and this terminal could be reconfigured to offer small-scale reloading.
- The Costa Norte LNG terminal in Panama is under construction and, according to the initial time plan, it should be ready in 2018. There have been plans to offer LNG bunkering near the Panama Canal, and its service could also extend to small-scale reloading.
- Atlantic LNG in Trinidad & Tobago is a large-scale LNG plant that currently is neither willing nor able to supply the nearby small-scale markets. However, the plant has been suffering from gas supply shortages and, with some long-term LNG contracts expiring in the next few years. These problems, in combination with stiff competition from US LNG projects, might force a change of strategy to include small-scale customers in the future.

About the simulations

As we described in the beginning, when optimising a solution, one has to weigh in the Free On Board (FOB) LNG price, logistical costs and the investment costs of building a terminal. Logistical costs are affected by the choice of LNG carrier, charter rates, port costs, distance, loading/unloading time and time spent inactive. Terminal investment costs depend on the choice of technology, local labour costs, size of storage needed, civil and marine infrastructure needed and risk mitigation measures.

There are many things influencing which solution will be best, but this case study examines the factors in isolation to see the impact of each one on the delivered LNG price. First, we will look at how much the distance between supplier and customer influences the costs. The second element is the time horizon, i.e. how many days of storage, we should select to optimise the project.

There are few small-scale LNG carriers available in the world today, but for this case, we assume that there is a shipping company willing to build a carrier and charter it to us. We also assume that there is no other project to share it with, so we also need to pay for the days when it is idle. The LNG carrier sizes available for this simulation are the following:

- 5000 m³
- 7500 m³
- 10,000 m³
- 15,000 m³
- 30,000 m³
- 40,000 m³
- 60,000 m³

Charter rates, port costs, ship speeds, fuel consumption and time spent in port loading/unloading have been estimated according to available data about today's situation. An FOB LNG price of 9 USD/mmBtu has been used for the simulation. This figure was chosen because it is an even number expected to be quite close to the actual price of LNG in small quantities today. LNG consumption is assumed to be constant over the year.

[ENERGY / IN DETAIL]

	28 days storage		14 days storage	
	FOB Price (USD/mmBtu)	Logistics	FOB Price (USD/mmBtu)	Logistics
Altamira LNG	8.51	2 trips with 7,500 m³ LNGC	8.64	1 trip with 7,500 m³ LNGC
Eagle LNG	8.59	2 trips with 7,500 m³ LNGC	8.73	1 trip with 7,500 m³ LNGC
Jamaica FSU	8.91	3 trips with 5,000 m³ LNGC	8.88	2 trips with 5,000 m³ LNGC
Casa Norte LNG	8.92	3 trips with 5,000 m³ LNGC	8.89	2 trips with 5,000 m³ LNGC
Atlantic LNG	8.95	3 trips with 5,000 m³ LNGC	8.93	2 trips with 5,000 m³ LNGC
AES Andres	9.00	3 trips with 5,000 m³ LNGC	9.00	2 trips with 5,000 m³ LNGC
Delivered price (USD/mmBtu)	11.27		11.41	

Table 1 – FOB price differences and LNG carrier selection.

Distances

The simulation shows that AES Andres, the nearest LNG supplier, is unsurprisingly the least expensive alternative. But just how much lower must the FOB prices from the other locations be before they cancel out the logistical advantage of AES Andres? And what is the LNG carrier selection that gives the best delivered price? In this example, we will look at two options: 28 days of LNG stored at site and 14 days of LNG stored at site.

Table 1 shows that the FOB price advantage of AES over Altamira is 0.49 USD/mmBtu for 28 days of storage and 0.36 USD/mmBtu for 14 days of storage. AES Andres has less of an advantage over Jamaica FSU, Costa Norte LNG and Atlantic LNG who are all within 0.12 USD/mmBtu of AES Andres' FOB price. It is also interesting to see, that the Altamira and Eagle LNG options require a larger LNG carrier that allows for fewer trips, but less travel does not cancel out the other costs.

Time horizon

The time horizon indicates the number of days of consumption for which the LNG storage tank is designed. If you have a time horizon of 14 days, it means that after you have consumed the theoretical daily demand for 14 days, there is still enough LNG in the tank to keep it from heating up. This so-called "heel" is often designed to be 10% of the time horizon's total demand in bullet tanks and less in flat-bottom tanks.

When choosing a time horizon, one has to weigh in factors such as distance to the supplier, reliability of deliveries, e.g., due to weather, storage tank investment costs and the size of LNG carriers available. By using a larger LNG carrier, one can lower the shipping cost per mmBtu, but that affects the length of your time horizon and investment costs.

A simplified case is presented on how the system costs (TotRoutingCost) can be minimised for deliveries from AES Andres and Altamira respectively.

Figure 5 shows that 10 days' time horizon gives the minimum total cost (TotRoutingCost = ShippingCost + InvCost) for deliveries from AES Andres to Aruba. The blue line (ShippingCost, includes e.g. charter fees, fuel consumption, port costs) illustrates the cost impact of LNG carrier types and the number of trips. The selection of these is made by the algorithm on the basis of what combination, capable of delivering the necessary quantities of LNG, produces the lowest costs. With a time horizon of 13 days or less, one can use a 5000 m³ LNG carrier that makes one trip during that period. From 14 to 26 days, the same 5000 m³ LNG carrier needs to travel twice, from 27 to 39 days requires three trips, etc. Here, the same ship is optimal throughout, so the later local minima in the Shipping Cost curve correspond to multiples of the optimal 10 days horizon.

In Figure 6 a 15-day time horizon gives the minimum total cost (TotRoutingCost = ShippingCost + InvCost) for deliveries from Altamira to Aruba. In this example, the blue line shows some interesting features with peaks for certain days. It is not feasible to make the deliveries in less than 12 days with this setup, and for 12–13 days, a fairly large LNG carrier is needed in order to complete the deliveries in such a short time. Therefore, we start from 14 to 19 days, showing more feasible configurations where a 7500 m³ LNG carrier travels once, from 20 to 26 days a 10,000 m³ LNG carrier travels once and for 27 days twice, hence the peak. This is because there is not enough time to complete the trip with a smaller and slower LNG carrier. From 28 to 39 days, there is enough time for a 7500 m³ LNG carrier to make the deliveries by travelling twice. For 40 days, a 10,000 m³ LNG carrier travelling twice is needed, as for 27 days, and, therefore, we again see a peak. Above 41 days, a 7500 m³ LNG carrier needs to travel three times.

An interesting observation when comparing the graphs for AES Andres and Altamira is that if AES Andres is chosen as the supplier, one can safely firm up a contract for a 5000 m³ LNG carrier before the final configuration of the terminal size. On the other hand, the Altamira case illustrates the inherent complexity of identifying the configuration corresponding to the minimum costs, as the fleet changes with the time horizon.

Optimisation becomes increasingly difficult when more factors are considered. In upcoming issues of In Detail, we will present a case where the terminal size is simultaneously optimised with the time horizon and the fleet configuration.

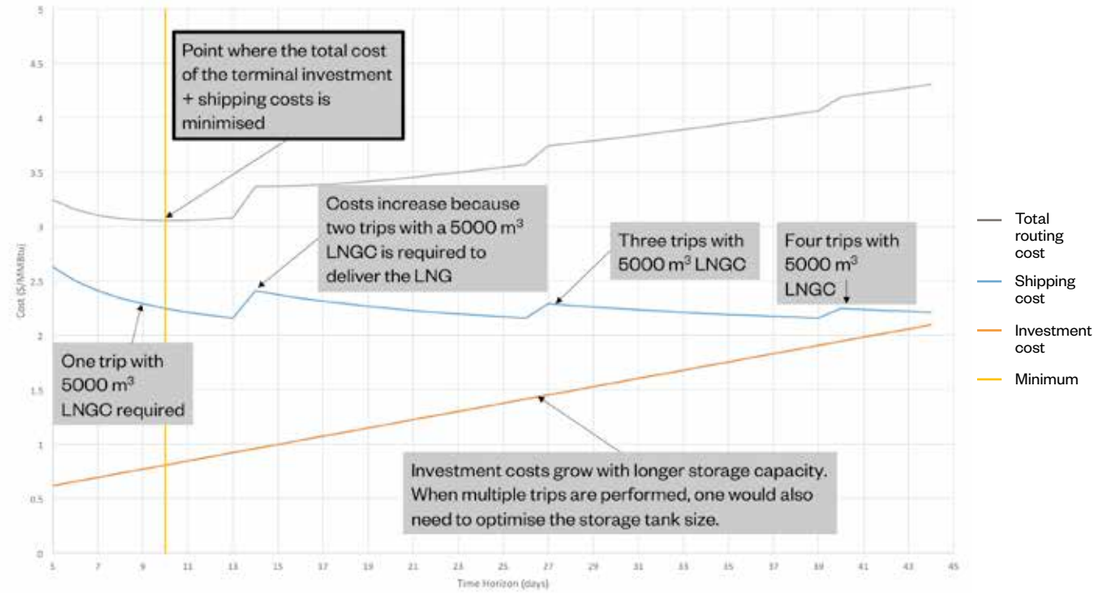

Fig. 5 - Optimised system cost for deliveries from AES Andres for a fixed annual consumption of 62,400 TPA LNG.

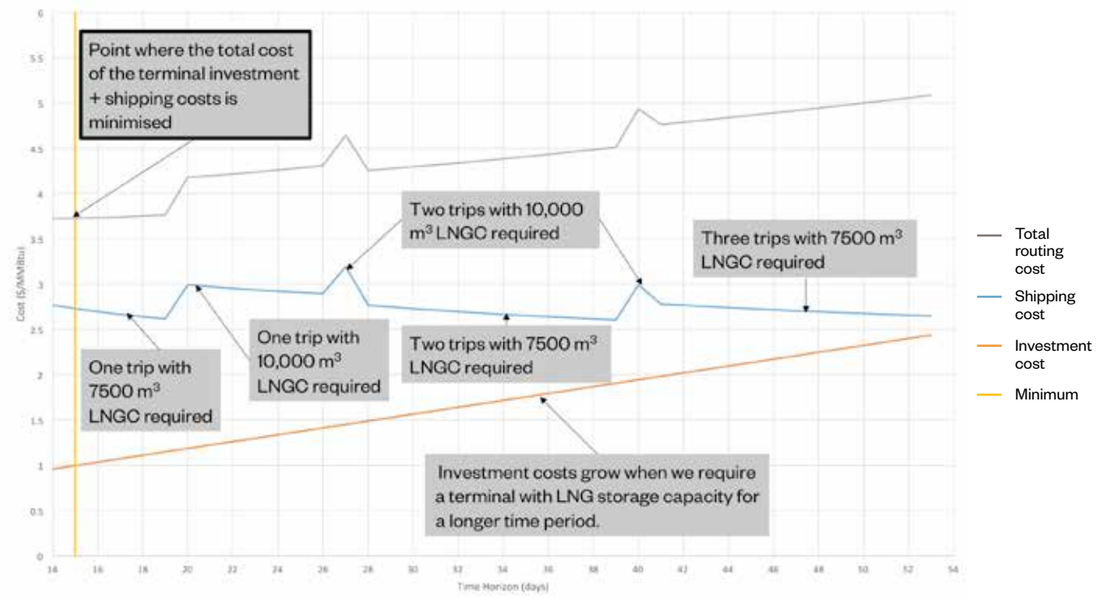

Fig. 6 - Optimised system cost for deliveries from Altamira for a fixed annual consumption of 62,400 TPA LNG.

Bright future for PV solar power

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Variations in solar irradiance, which cause sudden peaks and troughs in photovoltaic (PV) power generation, present a challenge to grids and operators. Wärtsilä's Smart Power Generation provides grid-scale solutions for this challenge and, by now entering the solar business, Wärtsilä can offer a one-stop-shop solution for both island mode and off-grid locations. This article outlines why PV-engine hybrids are the optimal solution for the solar challenge.

Although solar power is already growing exponentially, analysts say the biggest boom is yet to come. According to Bloomberg New Energy Finance, the installed base of large-scale solar photovoltaic (PV) power systems will grow from about 100 GW to 450 GW between 2015 and 2025. A large share of that growth is predicted to come from emerging markets in Africa, the Middle East, Latin America, and Asia.

Wärtsilä's existing power plant portfolio consists of an installed base of 60 GW across 176 countries. Moreover, the company is already well established in some of the regions in the world that have been identified as having the best potential for solar, including Africa, the Middle East, Latin America and Southeast Asia. As the only truly global player in the segment, Wärtsilä specialises in the delivery of utility-scale projects with a full Engineering, Procurement and Construction (EPC) scope.

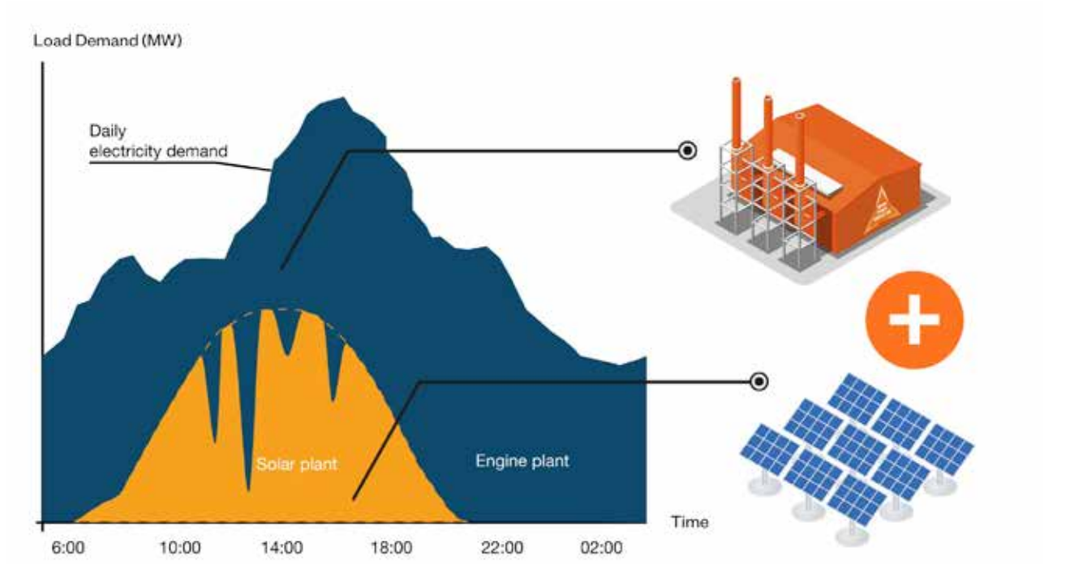

Fig. 1 -The engine plant provides baseline power and balancing while the PV plant displaces fuel.

Wärtsilä is now taking the know-how acquired from building hundreds of engine-based power plants in more than 100 countries into the solar market. It will continue to focus on customers with larger-scale PV requirements, including utilities, independent power producers (IPPs) and industrial customers. With a portfolio that includes standalone PV, PV-engine hybrid, and retrofit hybrid solutions, Wärtsilä's primary target market will be solar plants in the >10 MW range.

In addition to delivering full EPC for solar PV and PV-engine hybrid plants, Wärtsilä can also provide support in the form of project development and arranging financing. Wärtsilä Development and Financial Services (WDFS) is a global team with extensive experience of developing and co-developing IPP projects, now also including standalone PV, PV-engine hybrid and hybrid retrofit plants. WDFS can take development risk and equity positions, as well as providing a range of development and financial services.

How to overcome fluctuations?

While the fuel-saving, emission-cutting advantages of solar speak for themselves, the main drawback of the technology remains its inconsistent capacity, caused by the lack of irradiation at night or on cloudy days. The best way to balance these fluctuations is to invest in PV-engine hybrid technology, as opposed to standalone solar PV.

Standalone solar is a simple, robust technical solution that requires minimal maintenance and allows power plant operators to produce electricity with no fuel costs. While standalone solar may be a good option if the plant feeds into a local network, or a grid that is large enough or has flexible generation installed to cope with variations in production from the solar plant, the vast majority of power plants require a balanced flow of electricity and, in these instances, standalone solar is not ideal. This is due to the fact that solar power plants only produce energy during the day when the sun is shining. With no back-up power generation or storage solution, night-time production is zero.

Reliable solution

A PV-engine hybrid from Wärtsilä consists of a solar PV plant and a Wärtsilä Smart Power Generation power plant, with multiple internal combustion engines that can run on any gaseous or liquid fuels, including biofuels. The key advantages of PV-engine hybrid plants are their ability to achieve the same reliability as a normal thermal plant, making them an interesting solution for small grids and island mode or off-grid locations.

The engine and solar PV units of the hybrid are synchronised, with the solar modules taking priority but receiving back up from the engines. Whenever there is sufficient solar irradiance for the PV modules to produce electricity, the engines are ramped down or stopped, only to ramp up again when clouds cover the sun or once the sun has set. As a result, no fuel is consumed for the MW-hours produced by the solar plant but the engines are always there to provide the all-important baseline.

New build or retrofit?

PV-engine hybrid projects can either be implemented as new builds – where the engine plant and PV plant are both new – or as retrofits, whereby a solar PV plant is added to an existing engine plant.

The feasibility of both retrofits and new builds depend on the same economic logic: although building the additional solar-PV

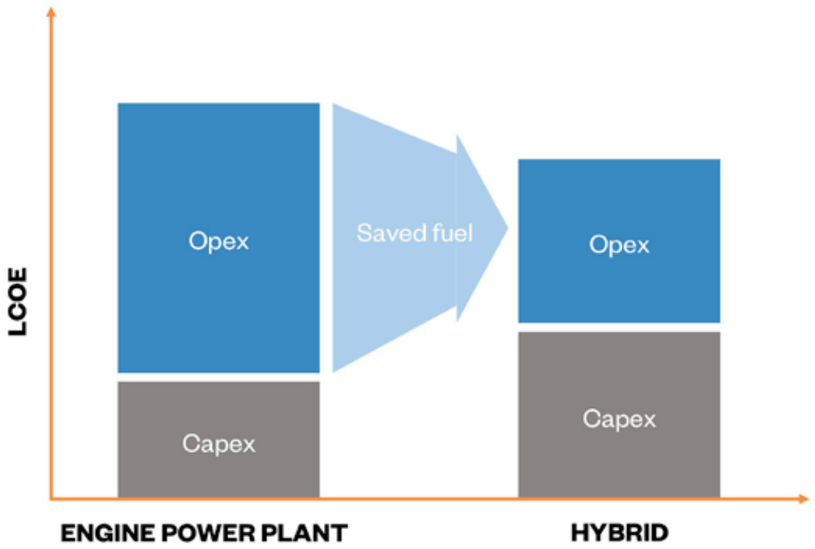

Fig. 2 – The economic logic of a PV-engine hybrid is based on fuel savings.

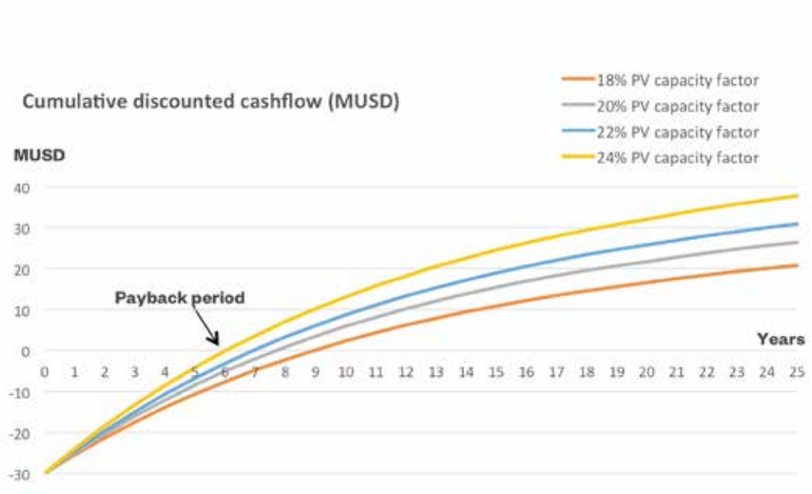

Fig. 3 – Feasibility study: the discounted payback period of adding a 20 MW PV plant to an existing Engine plant running on LFO.

plant incurs higher Capital Expenditure (Capex), this can be cancelled out by the reduced Operational Expenditure (Opex) resulting from the reduced fuel consumption.

A hybrid plant will become economically feasible once the lifetime value of the fuel saved by the PV plant exceeds the total investment in the PV plant. If the fuel cost is above that breakeven point, the PV-engine hybrid is more feasible than the comparative thermal plant on its own. Furthermore, hybrids also make it possible to leverage the synergies from shared Opex and Capex, by utilising the same interconnection point, substation, transmission lines and staff.

Smart Power Generation is the perfect solar complement

Wärtsilä Smart Power Generation is ideally suited to provide the baseload power in a PV-engine hybrid plant because a system of this kind requires engines that are ready to spring into action instantaneously. Unlike traditional power plants based on gas turbines and/or steam turbines, with less flexible capabilities, the engines in a Wärtsilä Smart Power Generation plant are flexible and very quick to start, ramp up and down, as well as load-following. This is key because solar irradiance and wind can come on very quickly and drop off suddenly and it is therefore crucial to be able to balance that in a minimal amount of time.

In order for the engine plant instantaneously and precisely to balance the power produced by the solar PV plant, an interconnection system between the two plants is needed. In smaller systems or island mode the engine automation system is adjusted for operating in isochronous mode, only ramping up and down to keep the frequency stable when solar output varies. The automation system can also be set to maintain the MW output from the hybrid plant by regulating engine output when solar output varies. For reactive power production, the reactive power of the solar plant can be kept constant in the inverter control, while the engines balance the reactive power for the entire plant.

The technical challenges of a solar plant

A customer that has been quick to take advantage of Wärtsilä's ability to deliver large-scale PV plants is AES Jordan, an energy company based in the Jordanian capital of Amman. In 2014, Wärtsilä delivered a Smart Power Generation plant comprising sixteen Wärtsilä 50DF engines to AES Jordan and, in April this year, the two companies signed a Memorandum of Understanding to build a solar PV farm. Wärtsilä's EPC scope includes 52 MW of solar modules, covering an area of 81 hectares, as well as inverters, switchgear, control systems and step up transformers.

Solar plants typically require a considerable amount of space, amounting to at least one hectare per MW. As a result, the most labour-intensive part of an EPC project of this magnitude is the civil engineering, which can be quite extensive.

Another major factor in the EPC project is the electrical work required to connect the panels with the cabling, inverters and transformers.

A Wärtsilä solar PV plant consists of solar panels, electrical cabling, inverters, switchgear, control systems, and transformers. The panels are not produced by Wärtsilä but sourced from Tier 1 global solar panel manufacturers. The solar panels are mounted on a structure, which is kept up by posts rammed to the ground. Challenging factors that affect the design of the system include wind conditions and soil properties. The panels are connected in serial to increase the voltage to the right level for the inverter. Panels in series are installed in a row with the panel strings connected to an outgoing DC cable. If individual string monitoring is required, the strings of a few rows are connected to combiner boxes from where the DC power is excavated. Wärtsilä solar plants are made up of a modular set-up of optimally laid out rows where the panels are connected to central inverters. Optimal cabling layout and voltage levels are key parameters for the solar plant design.

Wärtsilä is able to deliver two types of solar panel systems. The first, which is most common, is a fixed tilt mounting system, referring to solar panels that are mounted in a fixed position to the sun. The second option is a single-axis solar tracker solution, whereby the solar panels are mounted on an axis that changes its inclination during the day to ensure that the panels are always positioned in an optimal angle to the sun.

The principal tracking system is single axis tracking, where the panels follow the sun from east to west during the day. The tracking system can increase the energy yield from the panels by some 15–20 per cent or even more in some cases. The drawback is that the space required increases by more than 50 per cent per installed MWdc.

PV-hybrid feasibility study

A recent feasibility study by Wärtsilä has assessed the economic rationale for retrofitting an existing engine power plant with a solar PV plant to create a PV-engine hybrid.

The study examines a theoretical 70 MW engine power plant in the Philippines, operating on Light Fuel Oil (LFO) and retrofitted with a 20 MW solar PV plant, over a 25-year time period. It uses the historical five-year average fuel price of LFO to calculate the fuel savings, and thereby the payback period of the investment into the PV plant. The discounted payback period of the project was found to range from approximately six to nine years, depending on the capacity factor (irradiation levels) assumed for the PV plant. The highest level of irradiation resulted in the shortest payback period, whereas lower irradiation resulted in lower PV generation and, therefore, a longer return on investment.

The feasibility study shows that a retrofit PV plant is an economically feasible investment that will pay itself back well within its lifetime – although the payback time depends on the future cost of fuel. For plants running on LFO, or diesel, the payback period is shorter due to the higher value of the fuel, compared with using heavy fuel oil (HFO), for example.

There are three key factors that drive the feasibility of PV-engine hybrids. They are, as follows: Capex, where lower Capex improves feasibility; energy yield, where feasibility is improved by a higher yield; and, finally, fuel prices, where a higher cost of fuel increases the value of fuel savings and hence the speed of return on investment.

Current market trends favour the future of PV and PV-engine hybrids. As the capital cost of solar PV continues to decrease, while efficiencies and yields improve, payback periods are getting shorter, making PV and PV-engine hybrid plants increasingly viable.

These days, the solar PV panels account for some 50% of the total EPC cost of a solar plant, whereas just a few years ago, they represented as much as two-thirds. As the cost of solar panels continues to decrease, while their efficiency gradually improves, solar PV and PV-engine hybrid plants are only going to become more competitive in the years to come.

The US Bureau of Reclamation's Minidoka hydropower plant in Idaho, USA, where Wärtsilä is participating in the refurbishment programme. Photo: The US Bureau of Reclamation.

Customisable applications solve specialised problems faced by hydro power plants

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Through the Hydro and Industrial Services offerings, Wärtsilä is able to offer customised applications to solve the unique and specific problems faced by hydro power plants. While the solutions may vary plant-to-plant, the end result is always increased efficiency, decreased turbine downtime, and increased environmental sustainability.

The world is changing rapidly. Populations are growing and consuming more and more energy and demanding clean, renewable, and reliable sources of energy. Nations are working hard to reduce their carbon and environmental footprints, and global agreements require greenhouse gas emission reductions and cleaner technology that reduces the threat to the environment.

The Hydro and Industrial services provided by Wärtsilä help to meet these demands in a truly competitive way. Wärtsilä serves as an independent service and product supplier to the hydro and industrial market. On the industrial side of the offering, Wärtsilä provides standardized seals and bearings to the original equipment manufacturers. The products provided for the hydro market, however, are customized applications for the specific needs of the hydro power plants. The products are not standardized, nor are they tied to any specific brand of equipment, meaning that the service is flexible, customisable, and available to any type of customer with any type of problem.

The technology and materials used are state of the art and backed by decades of industry experience – Wärtsilä boasts 125 years of experience for bearings and more than 30 years of experience for seals. Wärtsilä also has the ability to test and validate applications and systems on our own rigs, giving customers the opportunity to witness the solutions. And as a truly global company, Wärtsilä is able to offer fast and reliable technical service regardless of where the plant is located.

Another big advantage that Wärtsilä offers is a package deal of water lubricated seals and bearings and a water quality system, something that few, if any, of our competitors offer. Beyond the convenience of being able to buy several products as a package rather than as separate products, the superior technology and quality of service provided by Wärtsilä ensures that any downtime in energy production is minimised. This includes downtime due to scheduled maintenance breaks. The water lubricated seals and bearings offered by Wärtsilä are available as composite units – that is, they are offered as a single system rather than two separate products. They are very lightweight and do not require any lifting equipment in order to install. This makes the process very fast and easy and requires little downtime for the turbine while the systems are put in place. Wärtsilä's extremely high operational reliability in water lubricated seal and bearing system also minimises risk of unexpected downtime due to equipment failure. This is why the Loup River Public Power District chose to refurbish and install this technology in their hydro power turbines. Figure 1.

Fig. 1 - Wärtsilä REsafe/Pumpsafe unique water lubricated composite bearing, with composite overwind housing and integral flange.

Conversion of oil to water lubricating technology at Loup River hydro power plant

During 2016 and 2017, Wärtsilä will refurbish three turbines at the Monroe Powerhouse of the Loup River Public Power District in Nebraska, US, by replacing all the oil lubricated seals and bearings with water lubricated seals and bearings. In recent years, the plant has suffered numerous losses due to equipment failure and outages. In oil lubricated systems, if the seal fails and water enters the system, the lubricating property of the oil is lost and the bearing is damaged, or in some cases, destroyed. The result is that the turbine must be shut down until the seal and bearing can be either replaced or repaired. This is a huge monetary loss, as a large hydro power plant (producing 100-800 MW/unit) can sell about EUR 100,000 of electricity per day.

In water lubricated seal and bearing systems, this is not a problem, as oil is removed from the system entirely. Additionally, water is a free and renewable source of lubricant that requires little to no maintenance and poses no threat of environmental damage. Oil lubricated systems, on the other hand, are limited by the life of the oil (about 1-2 years), after which the turbines must undergo maintenance to replace the oil. Oil changes require stopping and maintaining the units, which results in a reduction of production time. Additionally, as these seals and bearings are located at the interface between the environment and the hydro power turbine, an oil lubricated system poses a constant threat to the environment in the form of an oil leak into local water.

The lubricating water for the water lubricated seal and bearing systems is pulled from a local water source. In the case of the Loup River Power Plant, the only feasible water source is the Loup River, which is quite dirty. Clean water is a must in order for the seals and bearings to maintain proper

[ENERGY / IN DETAIL]

Fig. 2 - Wärtsilä's water quality system. This system cleans the water prior to its use as a lubricant in the seals and bearings, enabling the use of dirty water as the water source.

functioning. If dirty water containing a high sediment load is used as a lubricant, dirt and other particles will be pulled into the bearings along with the water. This will cause many problems, including damaged and destroyed seals and bearings and turbine shutdowns.

Wärtsilä's water quality system (WQS) solves this problem and will be installed at the Loup River Power Plant. This system will clean the water prior to it being used as a lubricant and provide the optimum water quality conditions needed for the seals and bearings to function properly. This will reduce wear and tear on the seals and bearings, prevent dirt from entering the system, prolong the time needed between maintenance checks, increase the lifespan of the seals and bearings, and increase overall efficiency of the hydro power plant. Figure 2.

Automation technology to increase the lifespan of seals and bearings

At the Allen E. Inman powerhouse located at the US Bureau of Reclamation's Minidoka hydropower plant, Wärtsilä will implement another life-span increasing technology in the refurbishment of two horizontal turbine runners on Kaplan turbines. Working with GE Renewable Energy, Wärtsilä will supply its REvolution system, which offers water lubricated mechanical face seals with a pressurised fluid film between the seal interfaces and a digital control system to optimise performance and manage the lifecycle of the seal. This state of the art, digital technology will fully automate and regulate the amount and pressure of the water entering the system. This system allows Wärtsilä to monitor the health of the equipment in real time and also allows maintenance to be planned well in advance.

Furthermore, the system fully regulates and corrects its own parameters, changing its operating profile to meet the changing demands of the turbine in which it is installed. In the current system, the amount and pressure of the water entering the system is constant no matter what the conditions. The new Wärtsilä REvolution system will match the conditions inside the plant with the environmental conditions outside the plant so that the seals are always operating at optimal conditions. This maximises the life of the system and the time between overhauls of the shaft seals. It will also increase the efficiency of the plant by reducing leakage and debris entering the seal interfaces, thereby reducing downtime

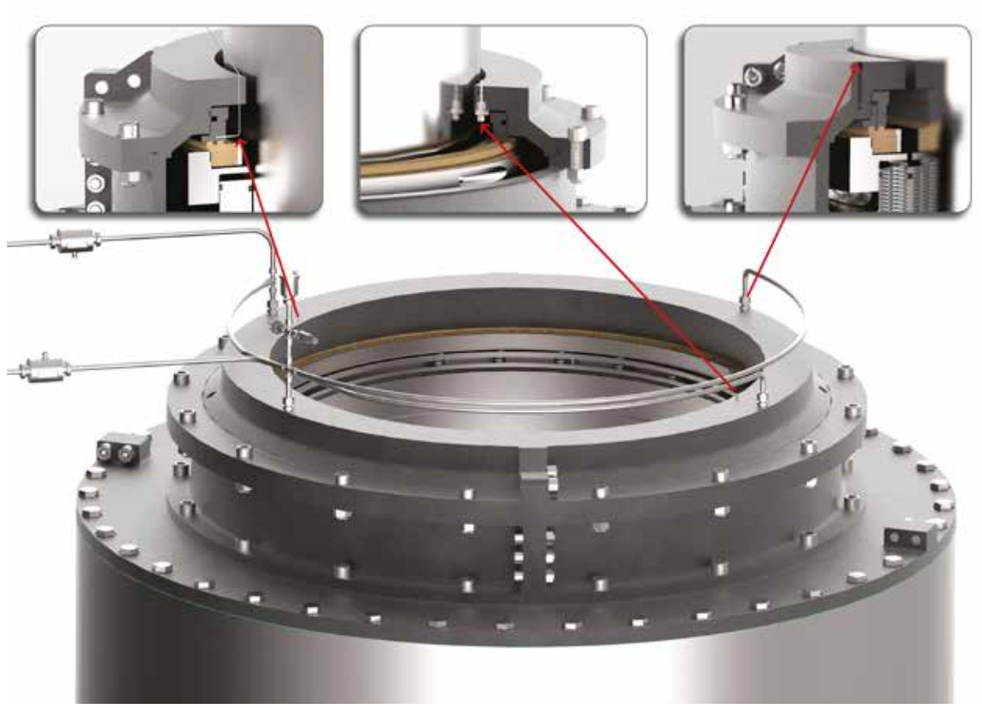

Fig. 3 - The Wärtsilä REvolution system utilises a REguard or Pumpguard mechanical face seal, a pressurised fluid film between the seal interfaces and a digital control system to optimise performance, shown here with the interface injection ports (top right), thermocouple (top left) and proximity sensor (top centre).

at the plant. The monitoring capabilities of the Wärtsilä REvolution digital control system will allow for remote operation of the plant as well as remote monitoring the state of the equipment. This reduces the number of personnel required onsite while making it possible to detect and correct problems before they result in a plant shutdown. Figure 3.

Conclusion

Wärtsilä's Hydro and Industrial Service offerings are highly customizable applications that can greatly increase the reliability, efficiency, and lifespan of a hydro power plant while ensuring that environmental standards are not only met but surpassed.

Wärtsilä's long history in marine and hydro solutions and its standing as a global company enables it to offer specialized solutions to meet the specific needs of individual hydro power plants. While the specific benefits that each plant receives from Wärtsilä's specialized solutions may differ slightly, all hydro power plants can expect to increase their energy output with a superior technology that has been proven to lessen the number of days that a plant experiences downtown due to equipment failure.

The water lubricated seal and bearing systems also reduce the amount of oil used in the hydro power plants, reducing the overall costs as well as the risk of environmental contamination.

From the perspective of the final end user of the electricity – the public – this also increases the positive publicity for hydro power plants. People want clean and renewable energy without sacrificing reliability or quantity, and Wärtsilä has a proven solution to meet these demands.

Fig. 1 - JOVYLOAD CONCEPT 500kW with transport and shock frame.

Wärtsilä strengthens its portfolio with load resistors

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Logo of JOVYLOAD CONCEPT

To get an edge in the competitive load resistance market, Wärtsilä expanded its offering to include load resistors. A part of Wärtsilä since 2015, Wärtsilä JOVYATLAS's long experience in the resistor manufacturing business enables Wärtsilä to grow its product portfolio and launch a new series of load banks in September.

Although manufacturing load resistors is a relatively new business for Wärtsilä, Wärtsilä JOVYATLAS has a history of load resistor manufacturing for more than seven decades. By incorporating resistor manufacturing, Wärtsilä is able to provide better in-house packages for customers, extending the scope of delivery and the scope of application for customers in different industries and business sectors. The production portfolio of Wärtsilä JOVYATLAS ranges from the marine sector to generator testing.

Recently, Wärtsilä JOVYATLAS implemented a standardizing project for load banks used for generator tests. The products will be launched in September under the name JOVYLOAD CONCEPT.

The standardized load banks are used for testing generators or uninterruptable power supply (UPS)- systems. For example, hospitals use a UPS-system as a backup so they need to be tested. Besides generator tests, load banks can also be used for balancing or minimum load purposes. For instance, during the day, power consumption is much higher than at night. However, for the generator to run smoothly, it needs a certain minimum load during the night as well. This can be achieved via a load bank.

JOVYLOAD CONCEPT and modular kit

The new JOVYLOAD CONCEPT includes basic load-bank-modules, with a wide selection of components and control units. The idea of a Modular Kit is to help customers choose the elements, as one would select the custom features on a new car, to meet their personalized needs for different applications. Basic modules range in power from 100 kW to 500 kW, load steps from 5 kW to 1 kW, and there are also different substructures, like a transport frame or vehicle trailer, castors or just feet for stationary use. Operation is possible directly at the load bank, by remote control or via web browser connection. The Modular Kit provides several more options, e.g. additional weather protection like air ducts, load cable sets with different plugs and control units with multiple options. A load bank module of 500 kW with transport and shock frame is shown in Figure 1.

Even though the maximum power of standardized load banks is 500 kW, it is possible to attain more power via a Master-Slave-Operation. This means connecting several load banks to one control unit at the same time. This is a special benefit to enable rental services to work with only one size/type of load bank, e.g. 500 kW, but have the opportunity to offer more power, i.e. 2 MW, to customers.

Standardized products enable Wärtsilä to sell load banks at a competitive price without extra engineering costs. For customers, the Modular Kit gives a clear picture of the range of options available. The variations and maximum power of the load bank series will be enlarged in the coming years.

The basic module consists of a switch cabinet and a load resistor compartment. The

Fig. 2 - CONCEPT 400 kW trailer version.

Fig. 3 - CONCEPT 400 kW trailer version rear side.

used tubular heating elements are assembled at the rear of the switch gear. The load resistor compartment is constructed with a double wall system for thermal insulation. The back is removable, and the switch gear mounting plate is hinged. This ensures easy maintenance of resistor elements.

The load fuses, contactors and all necessary control and monitoring devices are installed in the control cabinet. The load steps are wired in a star configuration onto copper bars with mounting holes or in a load cable connection. The star point is implemented as well and can tolerate full (100%) current load. Modules are provided with five different power ranges with load steps of 5 kW (cascading). In addition, load steps of 1 kW (cascading) are available. For the basic module, a substructure with an integrated fan is required to prevent overheating. All load levels of the load banks are secured and are switched off in case of a fan fault. Usual voltage is 3~400V, but versions for other voltage levels, like e.g. 3~480V or 3~690V or DC, are available upon request. A load bank trailer version of 400 kW is shown in Figure 2, and the same trailer version is shown from the rear in Figure 3.

The Modular Kit provides many options for control units and data logging. Several control and visualisation units like rotary switches, different touch panels and multifunctional meters are available.

Load banks can be either manually or remotely controlled. The basic manual control is to mount easy-to-use, rotary switches on the front door of the load bank. In an industrial area or at a project site, this configuration allows an operator of the load bank to use the switches even while wearing his protective gloves. A load bank with rotary switches mounted on the front door is shown in Figure 4 and 5.

Remote control is useful, for example, when a test is run outdoors but needs to be monitored from indoors. With a remote panel, it is possible to work at a distance of 25 meters and still access the important messages shown on the text display during a test run.

Furthermore, there are multifunctional meters available. They are installed in the switch cabinet of the load bank and show all important measurement data, such as current, voltage, power and frequency. In some models, the measurement data is stored in memory and can be read with a laptop via USB connection.

For more user-friendly functioning, there are touch-panel programmable logic controllers (PLC) available. The touch panels are installed at the switchgear of a load bank or within a remote controller with cabling of 50 metres. This type of control unit includes features like a data logger and programmable test runs. For instance, a program can be set beforehand to run the generator first for 2 minutes with 30% of the maximum load and then 2 minutes with 80%. In addition, program curves without any manual changes are possible to execute with the controller. Test data is stored by data logger and saved in the PLC memory. It can be read via computer and further processed as an Excel file or printed out. Moreover, control via web browser is possible with an internet connection, and it does not require any additional software.

Special technology of JOVYLOAD products

The technology of Tubular Heating Resistor Elements is very specific. Inside a heating resistor tube, there is an electrical wire. To ensure proper electrical insulation for the resistor wire, the tube is filled with magnesium oxide. A resistance wire of 80/20 NiCr composition provides a very high accuracy of the resistance value even during continuous operation. The outer case is made of stainless steel, guaranteeing a long life.

These resistor elements are hermetically sealed and assembled directly on the switch gear. Due to this particular construction, a protection degree of IP55 can be ensured. The tubular heating elements create a very compact construction with less weight than other load banks on the market. The special design and the arrangement of the elements enable a low air outlet temperature even in the case of full load selection.

The production of load resistors is based on our state-of-the-art manufacturing methods. By means of simulation models, resistant materials are used optimally in the manufacturing process, permitting a cost-optimized production of resistors that directly benefits our customers.

Wärtsilä JOVYATLAS uses also other resistor elements like stainless steel grids or wire wound resistors. The choice of elements depends on the application and customer requirements. In addition, Wärtsilä JOVYATLAS manufactures neutral grounding resistors, braking resistors, starting resistors, discharging resistors, damping, and filter resistors. All these different types are used at transformer stations, offshore platforms, wind energy plants, cranes, port facilities, test facilities, vessels, yachts, railway transportation and urban railways. Wärtsilä JOVYATLAS has a production area of 2000 m² just for resistor production, including CNC laser cutter and punching machines.

Flexibility

The new JOVYLOAD CONCEPT products offer notable benefits to customers, by allowing them to execute load tests quickly from almost anywhere at any time. Load banks are light, compact and easy to transport. Different frames and substructures enable flexible use and transportation of the load banks to different rooms and environments. For instance, load banks mounted on a trailer can be transported by a passenger vehicle or a van. A stable transport frame with lockable swivel castors can be moved for flexible use in direct proximity of the test sample. In other words, variations of the same load bank series can easily and flexibly be used in different places indoors and outdoors.

Maximum performance in a minimum space

Demanding requirements of a city environment can be met via our load banks. Load banks have low air outlet temperature and low noise level <70 dB(A) at a distance of 3 metres. These are important factors in a

Fig. 4 - CONCEPT stationary version and inside switch design.

Fig. 5 - CONCEPT stationary version.

Example configuration of CONCEPT loadbank	
Power	500 kW
Load step resolution	5 kW
Width [W]	1480 mm
Height [H]	2220 mm
Depth [D]	1480 mm
Weight, approx.	606 kg
Choosen modules with article no.	
Basic module 500/5kW	4.900.405
Base frame with fan	4.900.492
Transport base	4.900.504
Shock absorber frame	4.900.505
Rotary switch control	4.900.420
Current transformer for measurement	4.900.420
Multifunctional meter UMG 96L	4.900.451

small room or in an urban location, such as a data centre. Especially in a city environment, a low noise-level requirement can be hard to meet. In a small room, it is important that the ambient temperature remains stable. In addition, due to vertical air outlets no safety distances nor additional barriers to block exhaust air are needed. This also benefits customers using small rooms or spaces.

Reliability and safety

Load banks of JOVYLOAD CONCEPT type are robust, which enables reliable use under difficult conditions. The construction with transport and shock frames is designed for those frequently transported by forklift and either low lift truck or crane. The outside rubber elements prevent shock, and the protection class of the products is IP55. When used outdoors, various devices offer safety and protection against pollution and water penetration. The load banks have a perforated plate cover, air scoop with weather protection grid, high roof and weather protection border for the control cabinet door.

Control of the load banks is easy. Customers may choose a manual or remote control unit. Because of many options and switching stages, customers are able to achieve accurate test results. The load steps can be provided even with an accuracy of 1 kW.

Conclusion

By manufacturing load resistors, Wärtsilä can provide better in-house service for global customers and strengthen its share in the load resistance business. Load resistors are manufactured by Wärtsilä JOVYATLAS in Germany. Even if manufacturing load resistors is quite new business area for Wärtsilä, Wärtsilä JOVYATLAS has a history of manufacturing load resistors for more than seventy years. It provides load resistors for different industries and business sectors, including ships, trains and power plants.

Wärtsilä JOVYATLAS has implemented a standardizing project for load banks for generator tests and is launching a new series of load banks in September under the name of JOVYLOAD CONCEPT. For generator tests, the new JOVYLOAD CONCEPT provides a special load bank series from 100 kW to 500 kW in a very compact and easily transportable version.

If more than 500 kW power is needed, a combination of several load banks with one common control unit is achievable via a Master-Slave-Connection. The load bank modules are provided with a wide selection of components and control units in order to meet individual customer needs. They allow customers to perform load tests quickly, flexibly and reliably at any time and place. Demanding requirements of a city environment can be met via Wärtsilä load banks because of the low air outlet temperature and low noise level <70 dB(A) at a distance of 3 metres. Robust load banks can also be used under difficult conditions, and they can be manually or remotely controlled.

In the highly competitive load resistor business, Wärtsilä JOVYLOAD CONCEPT helps Wärtsilä broaden its scope of delivery and scope of applications for different projects, thereby providing better service for customers in the long run.

Wärtsilä 2-speed gearboxes optimise engine power for propulsion and electric power production.

Wärtsilä 2-speed gearboxes

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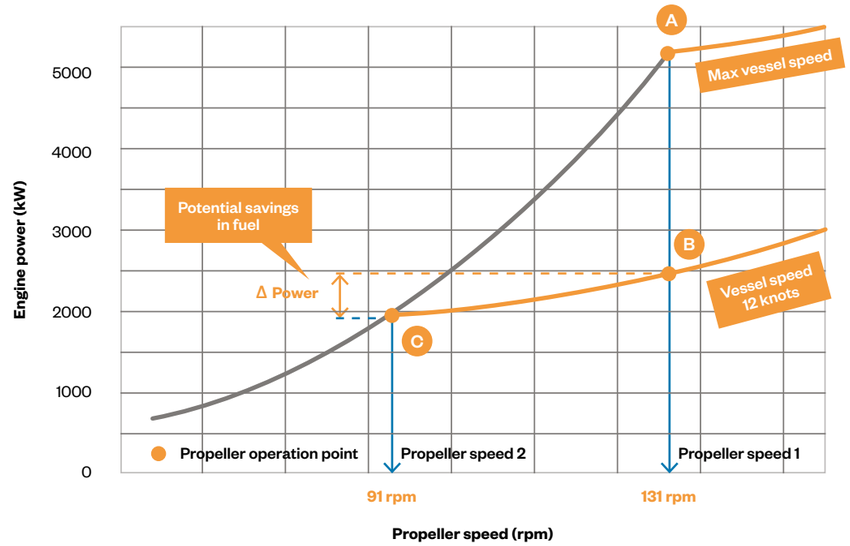


Fig. 1 - Basic propulsion characteristics.

The Wärtsilä 2-speed gearbox is an enabler for significant fuel savings, with a corresponding reduction in the environmental footprint. With its low technical complexity, it offers advance functionality to comparatively low investment cost.

Basic principles behind the fuel savings

Ships are normally equipped with a propulsion system designed for a certain maximum speed or towing requirement. However, many ships might only need this maximum propulsion power occasionally and are working in off-conditions at lower power and with less efficiency. For a controllable pitch propeller (CPP) installation, it is rather simple to reduce speed or thrust by reducing the propeller pitch. However, it is much more efficient to reduce the propeller speed at part load as indicated in Figure 1.

The propulsion system is designed for *Max vessel speed* (condition A). This requires a *propeller speed* of 130 rpm (Propeller speed 1) and a power of 5250 kW. However, the ship will frequently operate at the lower *Vessel speed, 12 knots*. This vessel speed can be achieved by one of the following:

1. Reducing the propeller pitch and keeping the propeller speed constant at 130 rpm (Condition B, *Propeller speed 1*)
2. the propeller speed from 130 rpm to 91 rpm with a corresponding increase in propeller pitch towards the propeller's optimal pitch (Condition C, *Propeller speed 2*)

The required propulsion power at condition B is 2450 kW, while for condition C it is only 1900 kW. The 550 kW reduction in the power requirement for the 12 knots sailing mode corresponds to 22% reduced fuel burned.

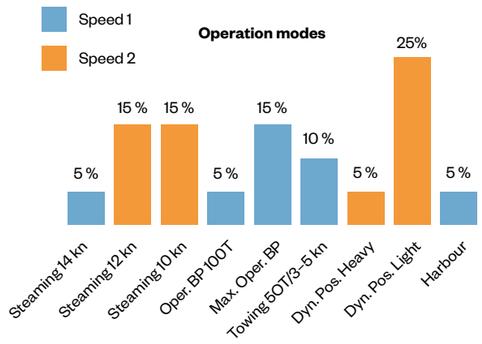
The condition C, Propeller speed 2 can be reached by reducing the engine speed as well by running along the propeller curve. However, this solution has certain drawbacks, such as the following:

- Reduced engine efficiency at lower engine speeds
- Slower engine power-ramp-up capability at lower engine speeds
- Requirement for electric power frequency conversion for Power Take Off or Power Take In through gearbox
- Limitations in optimizing main engine power for both propulsion and electric power production

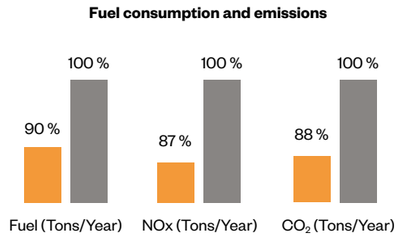
Some power savings can be achieved by allowing limited frequency variations, but similar savings can be obtained for a 2-speed system as well.

The total fuel saving for a ship depends on the operation profile of the vessel and the time it actually can be operated at the lower propeller speed. The AHTS vessel in Figure 2 has an operation profile allowing a 10%/750-metric-tonne reduction in annual fuel consumption. With a fuel price of 400 USD/mton (Marine Diesel Oil /June 2016), the annual savings is around USD 300,000. This means that the additional capex for the 2-speed functionality is payed back in less than one year.

AHTS -WSD 46 - Series



Propulsion system	Type	Power/dimensions
Main engine	Wärtsilä 2 x 9L32D	2 x 4500 kw
Reduction gear	Wärtsilä 2 x SCH100/2-P68	2 x 4500 kw
Shaft generator	Combined PTO/PTI	2 x 2000 kw
Propeller	Wärtsilä 2 x WCP1000	Ø 4.0 m 136/101 rpm



■ Fig. 2 - Wärtsilä 2-speed installation – Operation modes and potential savings compared to a single speed installation.

The contribution of the fuel savings to the environment is significant as well, with reduction of NOx and CO2 emissions in the same order. This is just one example. For other vessel types, the potential savings can be even higher, depending solely on their specific operation profile.

The Wärtsilä 2-speed gearbox design

Our 2-speed gearboxes are not new in the market. The first Wärtsilä 2-speed gearbox, the EVC84/2-P55, was designed in 1994. This was actually the first Wärtsilä gearbox ever. It was designed in cooperation with Valmet in Finland.

The second generation of Wärtsilä 2-speed gearboxes was introduced in 2003 with the SCV95/2 gearbox.

The development of the third generation of Wärtsilä 2-speed gearboxes started in October 2011. It was triggered by increasing attention to environmental emissions and fuel costs.

The design of the first size, the SCV90/2-P58, was released during the first half of 2012, and the first gearbox was delivered to the customer in December the same year. The lead time for design and production of this pilot was less than 15 months.

The latest design is characterized by the following:

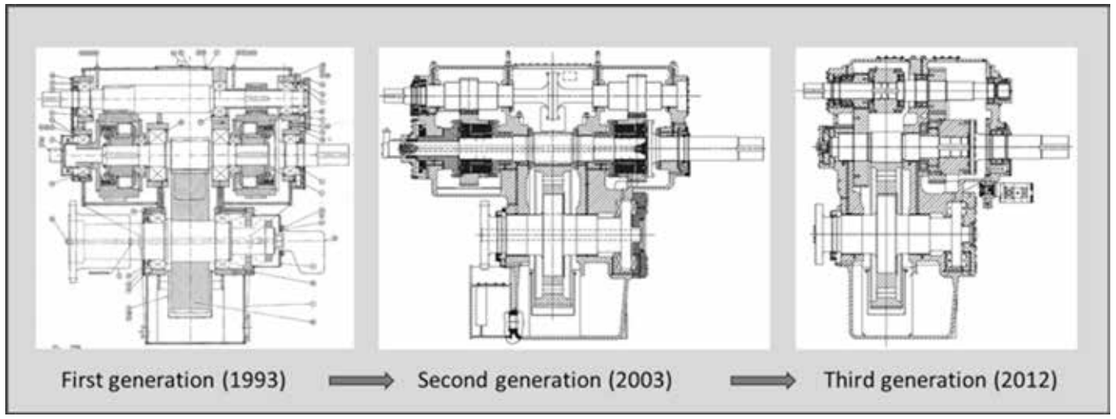
- 35% less installation length (between main engine and generator)
- 20% lower weight
- Robust design for machining and assembly, supporting a high quality standard

The new Wärtsilä 2-speed gearbox family

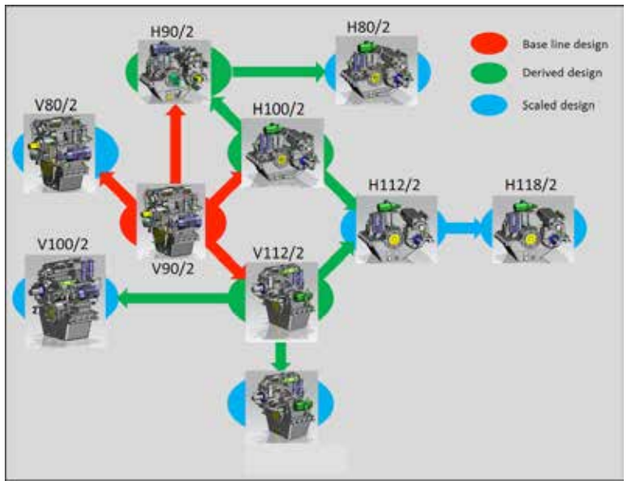
The third generation of Wärtsilä 2-speed gearboxes has now expanded to a large family of gearboxes. It covers a power range from 2 MW up to 13 MW. It is available in five basic sizes 80, 90, 100, 112 and 118 (gearbox size = offset between input- and output shaft in cm) with both vertical (V) and horizontal (H) executions.

The "family tree" for these gearboxes is shown in Figure 4. Due to the large power span for the gearboxes, the different sizes could not be designed by scaling alone. On a more detailed level, there are significant differences in the design. However, the designs have the same basic features:

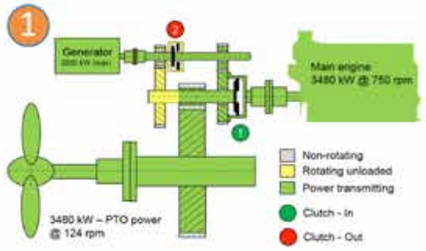
- Two selectable propeller speeds 70-85% (Speed 2) and 100% (Speed 1)
- Uninterrupted electric power generation from the PTO (Power Take Off) during speed change
- PTO line dimensioned for loads up to 100% main engine load



■ Fig. 3 - The Wärtsilä 2-speed gearbox design evolution.

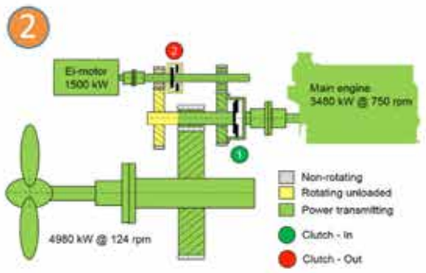


■ Fig. 4 - The Wärtsilä 2-speed gearbox family.



Propeller speed 1
Diesel Mechanic mode

Clutch 1 is engaged and clutch 2 is disengaged. The gearbox is operated as a conventional 1-stage gearbox for propulsion and power generation.

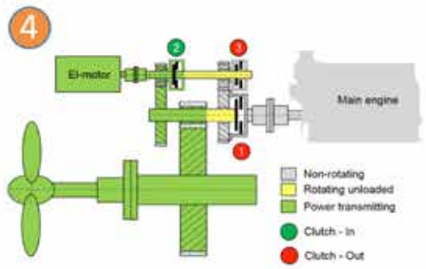


Propeller speed 1
Booster mode

Similar to the Diesel Mechanic Mode, but in this mode the electric machine is used as an electric motor adding additional power for propulsion.

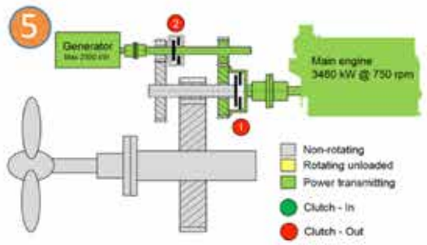
Propeller speed 2
Diesel Mechanic mode

Clutch 1 is disengaged and clutch 2 is engaged. The engine power is transmitted up to the PTO line in front and down to the pinion in aft to a lower speed, depending on the gear ratios for the two gear meshes.



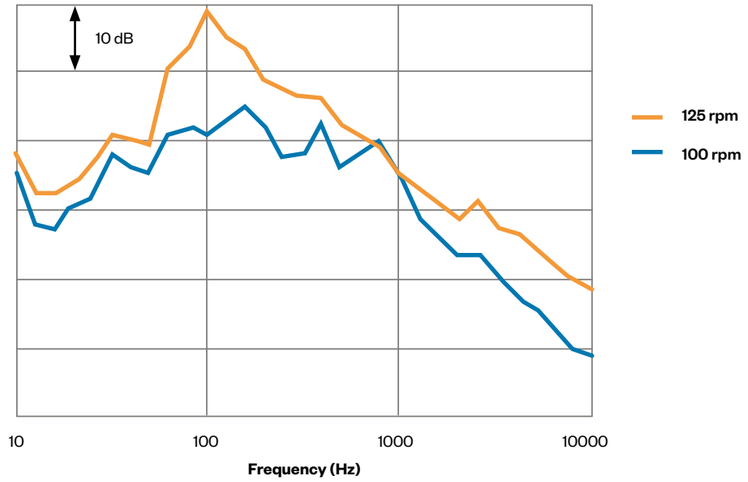
Propeller speed 2
Diesel Electric mode

A third clutch is required to disconnect the gearbox completely from the main engine and the propeller can be electric driven through the PTO line when clutch 2 is engaged. The third clutch is a standard option.



Generator Mode

Both clutch 1 and clutch 2 are disengaged. The engine is directly connected to the generator through the PTO line.



■ Measured underwater radiated propeller noise at propeller speeds 125 rpm and 100 rpm.

The operation principles of the Wärtsilä 2-speed gearbox (page 34)

The operation principle for a 2-Speed gearbox for a ship with five operation modes are shown in Figure 5:

1. Propeller speed 1 – Diesel Mechanic mode
2. Propeller speed 1 – Booster mode
3. Propeller speed 2 – Diesel Mechanic mode
4. Propeller speed 2 – Diesel Electric mode
5. Generator mode

The Wärtsilä 2-speed hybrid gearbox – The enabler

The basic features of the 2-speed gearboxes enable a number of additional features, such as the following:

1. A significant reduction in fuel consumption and CO_2/NOx emissions, as described
2. Optimization of engine power for propulsion and electric power production
3. Power boost functionality – adding electric power to the propeller through the PTO/PTI shaft
4. Reduction in total installed engine power, main and auxiliaries, due to flexibility in combining power from the two sources
5. Electric drive as one of the defined operation modes or as a Take-Me-Home functionality
6. Redundancy due to both Diesel Mechanic and Electric drive – the E-drive can be powered from batteries or from conventional generator sets.
7. Low noise operation: By reducing the propeller speed there is a significant reduction in the underwater radiated noise. This is of great importance for fishing vessels and seismic vessels, but it is also highly appreciated by the crew due to less noise and vibration in the living quarters of the vessel. Measurements show reduction of sound pressure at maximum 20 dB when the propeller speed is decreased from 125 rpm to 100 rpm. Note that 10 dB reduction in the noise level is perceived as 50% reduction in the noise.

[MARINE / IN DETAIL]

Fig. 1 - JS INEOS INSIGHT – member of the world´s first series of ethane-powered marine vessels in Grangemouth, Scotland.

World´s first ethane-powered marine vessels

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Originally designed to run on LNG, MDO and HFO, the Dragon class vessels were meant to use LNG as fuel when trading ethane and other LPG cargoes. However, logistical challenges with LNG and extremely favourable price development of ethane led to the idea to use LEG cargo boil-off as fuel. Wärtsilä worked in close collaboration with Evergas and INEOS to make the world's first ethane-powered marine vessels a reality.

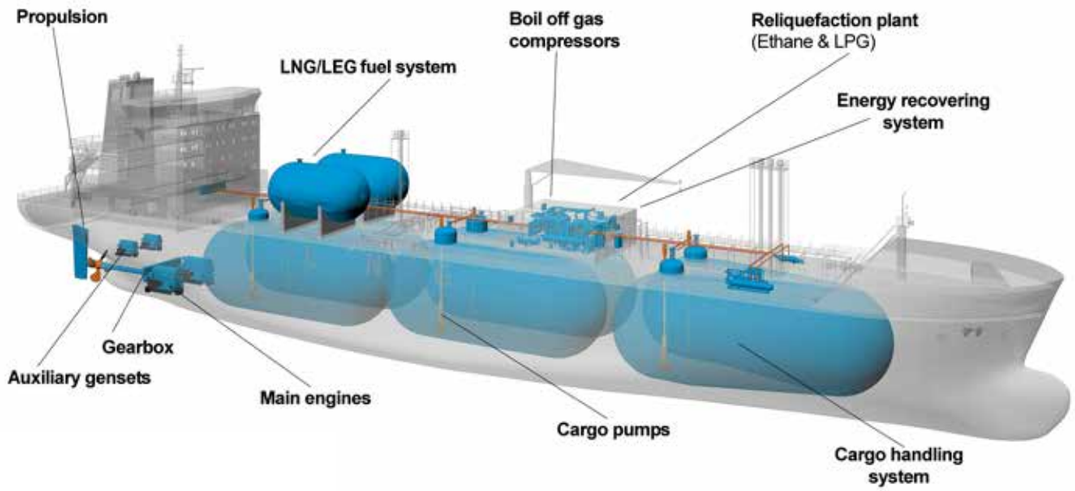


Fig. 2 - Schematic of the Evergas Dragon Series 27,500 cbm multi-gas carrier.

In January 2013, Evergas was awarded a fifteen-year charter contract from INEOS Europe for the transportation of ethane into Europe from the US Mariner East project. Evergas, in turn, announced new-building contracts with Sinopacific Offshore and Engineering, China, for the construction of state-of-the-art, medium-sized, 27,500 cbm LNG multi-gas carriers.

In April 2013, Wärtsilä was rewarded a contract to Evergas to supply an integrated solution consisting of gas handling systems, dual-fuel main and auxiliary engines, and propulsion for three 27,500-cbm, multi-gas carriers. The installed engine power consists of two Wärtsilä 6L50DF main engines plus two Wärtsilä 6L20DF auxiliary engines. The vessels are capable of transporting a range of gases, including liquefied natural gas (LNG), liquefied ethane gas (LEG), ethylene and liquefied petroleum gas (LPG). In 2014, repeat orders were placed for an additional five ships, bringing the total number of vessels to eight.

In summer 2014, approximately one year before delivery of the first vessel, Evergas approached Wärtsilä with a new request: to evaluate the feasibility of burning ethane directly in the engines. The solution would eliminate the need to bunker LNG separately, and one could utilise LEG cargo boil-off directly as a fuel in the engine. Wärtsilä completed an initial feasibility study which indicated that it would be feasible for Evergas to maintain normal operations when utilising LEG as an alternative fuel to LNG. During the second half of 2014, Wärtsilä, in close collaboration with Evergas and INEOS, embarked on a joint engine development project to develop an LEG-optimised performance set-up for the Wärtsilä 50DF engine.

The first two Evergas Dragon Series vessels were delivered in July 2015. The Marcus Hook ethane export terminal, near Philadelphia, PA, USA, went into operation in March 2016, and the JS INEOS INTREPID became the world´s first vessel to carry export US shale ethane on 9 March, 2016. Wärtsilä completed successful LEG gas trials on INEOS INTREPID shortly after her arrival in Rafnes, Norway, and on 23 March, 2016, it became the world´s first ever ethane-powered marine vessel. On 1 September, 2016, the first ethane shipments also commenced from Enterprise's Morgan's Point, Texas terminal and the ethane receiving terminal in Grangemouth, Scotland began taking its first cargo in late September, 2016 upon the arrival of JS INEOS INSIGHT.

This article will highlight the development project for Wärtsilä 50DF-LEG engines and the main customer benefits for INEOS and Evergas with ethane-powered propulsion. Aspects related to the fuel and gas handling scope of supply are also summarised. Finally, the significant emissions reductions with the use of LEG, similar to those with LNG, are elaborated.

Test facility preparation

During early 2015, in a period of four months, Wärtsilä designed, manufactured and installed a pre-fabricated LEG gas vaporizer and mixing unit. The commissioning of the unit took place in March 2015, in Wärtsilä´s gas engine test facility in Bermeo, Spain.

Upon gasification, the LEG enters into a mixing chamber, connected to the local natural gas network, to facilitate controlled mixtures of ethane and methane of any concentration to enter the engine.

Evergas, with the support of INEOS, arranged delivery of 60 metric tons of LEG for engine testing. The fuel was offloaded from a European, short-route LEG carrier in Zeebrugge in February 2015 and loaded into three, 20-metric-ton, cryogenic transportation tanks.

Development of the technical solution

The Wärtsilä 50DF engine is a four-stroke, dual-fuel engine operating on the Otto combustion principle when operating in gas mode. In practice, this means that a pre-mixed blend of air and fuel is

Fig. 3 - LEG gas vaporizer and natural gas mixing station.

Fig. 4 - Offloading of ethane in Zeebrugge, Belgium – February 2015.

compressed inside the combustion chamber until an external source of ignition starts the combustion. The optimal operating window of a lean-burn, dual-fuel engine is summarised in Figure 5.

Due to the fact that the request to utilize LEG came quite late in the project, the first engines for the Evergas Dragon Series already had been manufactured and were delivered to the shipyard as standard LNG-optimised, dual-fuel engines. Consequently, it was of utmost importance to find a technical solution that limited the overall changes to the engines and maintained maximum commonality with the standard, LNG-optimised set-up, in order to have a cost-effective and easy-to-implement, retrofit solution.

During the initial technical feasibility, Wärtsilä concluded that, even though the new combustion set-up would be optimised for LEG, the solution was still capable of using LNG in gas mode and MDO or HFO in diesel mode at the normal maximum continuous rating without any changes to engine hardware or software. Furthermore, the engine would be capable of running on any mixture of LNG/LEG, providing an extremely flexible, quattro-fuel-capable engine that can switch between HFO, LFO, LNG or LEG with uninterrupted power availability.

To better understand the technical actions taken to optimise the Wärtsilä 50DF for LEG, it is first appropriate to examine the actual fuel properties of LNG and LEG and understand their impact on the Otto combustion process. Table 1 summarises the relevant properties of LNG and LEG.

The lower heating value (LHV) of a gas represents the amount of heat released by combusting a specific quantity of the gas.

Wärtsilä´s dual-fuel engines control engine load by managing the gas quantity admitted, through the utilisation of a Solenoid Operated Gas Admission Valve (SOGAV). Due to the higher volumetric LHV of ethane, no modifications were needed to the standard SOGAV on the Wärtsilä 50DF engine.

Special attention was also paid to the fact that the molecular mass of ethane is higher than that of methane and notably that of air. Wärtsilä carried out a complete Approval in Principle, which included special measures addressing safe gas monitoring and ventilation, with relevant classification societies.

The methane number (MN) of a gas indicates the gas´s resistance to self-detonation and subsequent knocking. Pure ethane has a methane number of 43, meaning that using the standard set-up would result in a maximum power output of 63% when using ethane. It was thus necessary to take actions to develop a low-methane-number-optimised combustion set-up that would enable Wärtsilä and Evergas to reach the target output of 73%, which would enable normal operation of the vessel.

To achieve the targeted output, simple but effective measures were taken to optimise the combustion set-up. The compression ratio of the engine was lowered slightly, and the boost pressure was also optimised for LEG through minor modifications to the turbocharger, by increasing turbocharger speed and boosting pressure at lower load. This enabled the requirements to be met with minimal changes to the engine configuration.

The automation system and software of the low-methane-number-optimised engine is unchanged compared to the standard set-up. The only modifications required to the engine control system are made via the user interface, in order to modify the maximum output in gas mode to 73% of the nominal maximum continuous rating.

During May and June 2015, a successful test and certification program was carried out. Upon successful validation, actions were taken to begin modifications to the delivered engines on the Evergas Dragon Series vessels to prepare them for operation on LEG fuel.

Fuel and gas handling systems

The Dragon vessel was originally designed to run on LNG, MDO and HFO, and the design criteria was to use LNG as fuel when trading

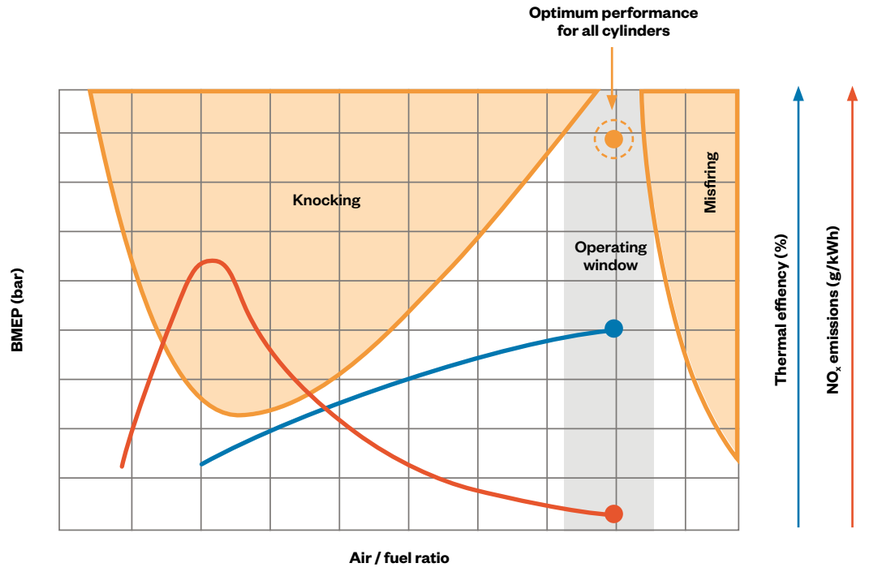


Fig. 5 - Optimal operating window of a lean-burn gas engine utilizing the Otto combustion cycle.

ethane and other LPG cargoes. This was achieved by installing two, 1000-m3 fuel tanks, enabling the vessel to make a US-Europe return trip between every bunkering. Since the vessels also are fully-equipped LNG carriers, the cargo handling system and fuel system were already fully integrated by the team in Wärtsilä Gas Solutions. This integration allowed for an even better utilisation of the opportunity to use ethane as fuel.

When the test run of the engines was successfully completed, and Evergas ordered the conversion on the previously delivered engines, it was time to upgrade the fuel system to enable ethane. Given the quite similar properties between methane and ethane, there were only minor changes needed for the integrated fuel system, mainly because the engine could operate at similar parameters. The main work was in changing setting points on control valves of the system and a software change in the control system. Also important in this work was making sure that, after the modification, the system would also be able to switch seamlessly between the use of LNG and ethane as fuel.

Summary of operating experience

The initial Evergas Dragon Series vessels were delivered in the summer of 2015. The first LEG cargo voyages, however, did not take place until March 2016, due to the fact that the LEG export terminal in Marcus Hook was under completion. During this period, the engines were converted from the LNG-optimised set-up to the LEG-optimised set-up and ran primarily on HFO.

	Comp.	Molar mass	Methane number	LHV (MJ/kg)	LHV (MJ/m³)
Methane	CH_4	16,0 g/m	100	50,1	35,9
Ethane	C_2H_6	30,0 g/m	43,1	47,6	64,4

Table 1 - Gas properties of methane and ethane.

The maiden LEG cargo voyage departed from Marcus Hook to Rafnes, Norway on 9 March, 2016. Upon arrival in Rafnes, Wärtsilä supported Evergas in completing ethane gas trials on the Wärtsilä 50DF main engines. The world´s first ethane-powered marine voyage was carried out on 25 March, 2016 on the JS INEOS INTREPID.

In addition, to prove the fuel flexibility concept, JS INEOS INSIGHT carried out successful sea trials with LNG as well as LEG, confirming the quattro-fuel capability of the Wärtsilä 50DF-LEG engine.

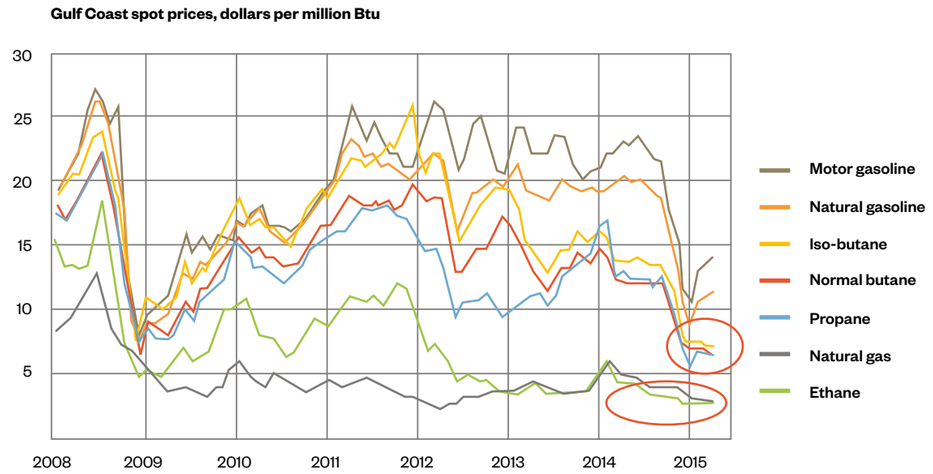
As of 31 August, 2016, four ships were in operation in the Evergas Dragon Series fleet with an additional four vessels to be delivered within the coming months. All four vessels currently in operation have completed their ethane gas trials and are using LEG as their primary source of fuel. The main engines have accumulated over 11,500 hours operating on LEG with positive field experience reported.

Summary of customer benefits

Bunkering convenience & flexibility

The initial intention was that Evergas would transport LEG as cargo but burn LNG in

[MARINE / IN DETAIL]



Note: All prices through 06/01/2015 are monthly average close-of-day spot prices; natural gas is Henry Hub, motor gasoline is Gulf Coast, and NGL components are Mt. Belvieu non-LST.
Source: EIA Bloomberg

Fig. 7 - Spot prices of fuels 2000–2015.

the engines when running in gas mode. The ability to utilise LEG as a fuel in the engine thus eliminates the need to bunker separate liquid gases. The ability to burn ethane in the engines also enables Evergas to fill the deck tanks with LEG and empty them in Europe, leaving only enough LEG to complete the ballast voyage back to the USA. This effectively increases the payload and overall efficiency of the transport operation.

Fuel flexibility

Heavier gases, such as ethane, propane and butane, are commonly referred to as natural gas liquids (NGLs). Recent shale gas developments in the USA contain much higher concentration of NGLs than traditional gas sources, which has created a sharp increase in the production of NGLs in the USA.

The demand for NGLs in recent years, particularly ethane, has not developed at the same rate as production, creating a downward pressure on price. This resulted in an LEG spot price that makes it economically feasible – especially for an LEG vessel operator, who presumably has easy and cost-competitive access to wholesale LEG – to consider LEG as an alternative to LNG.

The excellent fuel flexibility (LFO, HFO, LNG, LEG) provides significant economic benefits and also limits the operator's risk exposure to fluctuations in fuel price and spreads it over the entire lifecycle. It also enables multi-gas carriers to change easily between LNG and LEG charters without modifying the engines, giving better flexibility to the owner to change cargo charters.

Reduced Auxiliary Power Consumption

During the transport of LEG, some quantity of liquid gas will vaporise during the voyage and creates the need to re-cool the gas in order to re-liquefy it and send it back into the cargo tanks. The re-liquefaction process consumes a significant amount of energy.

When using a low-pressure, Wärtsilä dual-fuel engine capable of burning LEG, the operator has the opportunity to divert the vaporised LEG to the engine to be utilised as fuel. This significantly reduces, if not completely eliminates, the need to re-liquefy the cargo´s natural boil-off, thus providing a significant reduction in operating expenses both in the form of reduced auxiliary energy consumption and also reduced maintenance of the re-liquefaction plant, as shown in Figure 8.

An additional auxiliary benefit of Wärtsilä dual-fuel, Otto engines is that they require relatively low gas pressure, in the range of 2-5 bar, to operate. Alternative dual-fuel engines that operate on the gas diesel principle require gas pressures of approximately 300 bar for methane and even higher pressures of up to 600 bar for ethane.

Emissions

When used in a Wärtsilä dual-fuel engine, ethane, similar to LNG, has a very favourable impact on emissions, compared to liquid fuels in a traditional diesel engine.

The overall NOx emissions are reduced 80-85% when using either LNG or LEG compared to liquid fuels. The NOx emissions are summarised in Figure 9.

The Wärtsilä 50DF is certified as IMO Tier III compliant in gas mode, using either LNG or LEG, without the need for secondary exhaust gas treatment systems such as Selective Catalytic Reduction (SCR) and/or Exhaust Gas Recirculation (EGR).

Ethane does not contain sulphur so SOx emissions are all but eliminated when using LEG as a marine fuel, meaning that using

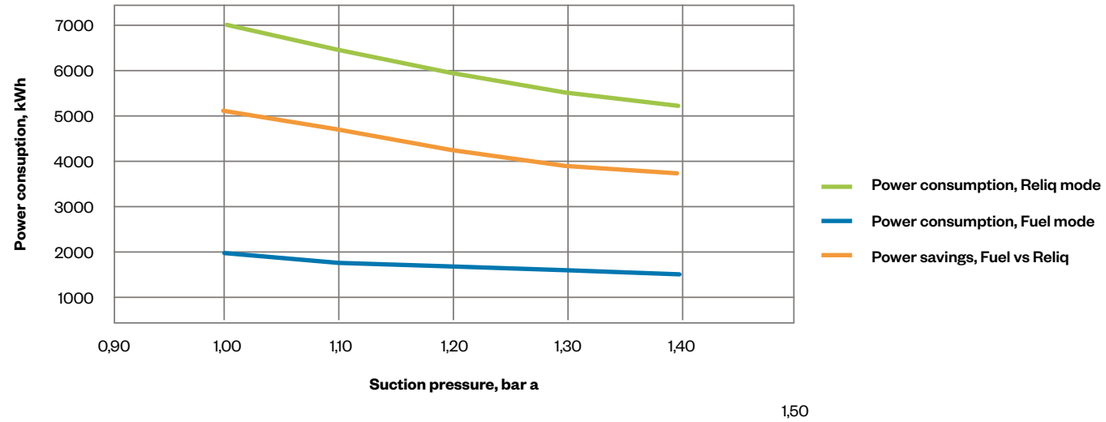


Fig. 8 - Power consumption: re-liquefaction vs fuel mode.

LEG fuel is a viable means to comply with SECA SOx emissions regulations. Particulate emissions are also reduced by approximately 90% compared to HFO when using either LEG or LNG as an alternative fuel.

Gaseous fuels like LNG and LEG also produce approximately 25% less CO_2 than liquid fuels when combusted, thanks to less carbon content in the fuel.

In general, it can be concluded that utilising ethane as a marine fuel has similar environmental benefits to LNG. Using LEG as a marine fuel enables Evergas to greatly minimise the environmental impact of their operation in comparison to traditional multi-gas carriers that normally have relied on HFO as their primary fuel.

The customer benefits were summarised by Steffen Jacobsen, CEO of Evergas, upon witnessing the successful LEG engine testing:

"We are very pleased that the Wärtsilä engines will be capable of utilising ethane boil-off gas as fuel. It increases our operational efficiency and improves flexibility in the bunkering of fuels. All in all, it results in a significant reduction in operating costs, while also providing a minimal environmental footprint. It also enables us to offer our customers increased flexibility, which has a monetary value to them."

Conclusions

The development of the Wärtsilä 50DF low-methane-number-optimised solution for the Evergas Dragon Series of LEG carriers has been successful.

The overall solution has several competitive advantages for LEG carriers, including the ability to utilise HFO, MDO, LNG and/or LEG with uninterrupted operation; IMO Tier III compliance without the need for secondary exhaust gas treatment; low gas pressure requirements and the ability to effectively utilise boil-off gas from the cargo. Sulphur emissions are eliminated using LEG, resulting in a highly cost-effective means for Evergas to be compliant in SECA zones in both North America and Europe. Particulate emissions are also eliminated, enabling smokeless operation.

The successful result of the project was enabled through strong collaboration between Wärtsilä, INEOS and Evergas. The project is a good example of how positive collaboration across the entire value chain can result in a winning solution and bring economic benefits to all parties and environmental benefits to everyone.

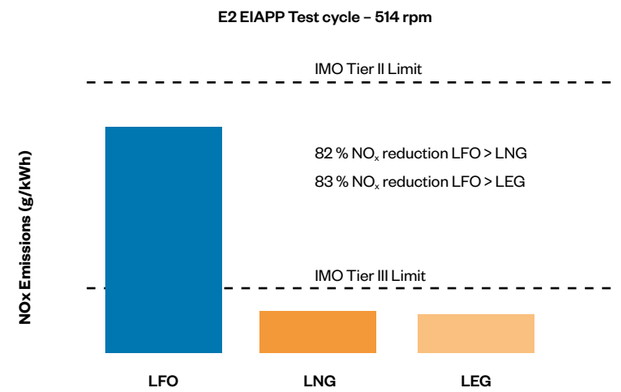


Fig. 9 - NOx Emissions – Wärtsilä 50DF – LFO, LNG, LEG.

Display for the Wärtsilä portable condition measurement system.

Flexible alignment monitoring on the go

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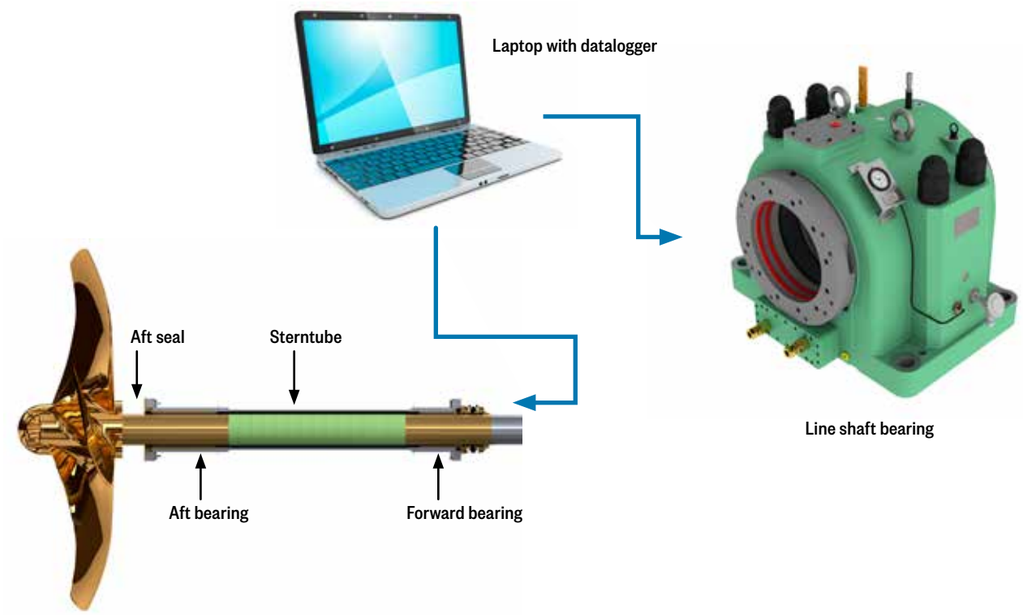
The portable condition measurement system, launched by Wärtsilä in January, is a temporarily installed alignment monitoring solution that allows ship owners and crew to catch, identify, and diagnose shaft positioning and other misalignment issues, while the vessel is operating.

New Alignment health check can save ship owners millions. Wärtsilä is meeting a growing need in the industry for better alignment services, launching a new portable condition measurement system, and expanding into new regions.

The Wärtsilä portable condition measurement system (CMS), launched in January, is a temporarily installed alignment monitoring solution that allows ship owners and crew to catch, identify, and diagnose shaft positioning and other misalignment issues, while the vessel is operating.

Periodic misalignment issues such as whirling, bedplate twist, and vibration problems are difficult to diagnose. Very often, they are only triggered by very specific conditions: a certain RPM, water depth or load. By the time a service engineer reaches the vessel, the fault has often ceased occurring, returning only after he or she has departed.



Wärtsilä portable condition measurement system components.

Wärtsilä's portable condition measurement system avoids this problem by logging data on vibration, positioning and other factors over a period of weeks to catch signs of misalignment issues as and when they occur. The equipment and logged data are then dispatched by courier to Wärtsilä's alignment experts, who analyse the data to diagnose the likely location and nature of the problem.

Ship owners recognise the advantages of the system as a cost-effective way to predict and avoid costly breakdowns and lasting damage. The interest in the market towards this system is already exceeding expectations.

Easy to transport, quick to install

The portable CMS includes a set of vibration, positioning, and proximity sensors, a torque meter, speed pick-ups, temperature sensors, and a strain gauge, all of which are connected by cables to a laptop and data locker.

To prepare for installation, the ship owner first sends over the vessel drawings. Wärtsilä's engineers can examine the shaft line arrangement and decide in advance where to place the sensors. The crew is then requested to clean the areas where the sensors are to be installed. In some instances, they are also instructed to weld on small brackets to which sensors can be attached. However, the sensors, ranging up to about 5 cm2 in size, can often simply be bolted into place.

The entire system fits inside a briefcase, which can be carried onto the vessel by the superintendent engineer. Depending on the vessel's size, the system can be installed within four to six hours.

As the shaft cannot be turning when the installation takes place, the engineer either carries out the installation when the vessel is anchored at sea or when it is in port. Vessels with a constant charter can have the equipment mounted while loading or unloading to avoid downtime.

The equipment remains on the vessel to log data for one or more journeys. When the monitoring is complete, the crew removes the equipment as instructed by Wärtsilä's engineer, packs it into the case and sends it back, usually by courier, to Wärtsilä's alignment excellence centre.

Vibration sensors – accelerometers similar to those found in a typical smartphone – are positioned to compare vibration levels between two shafts on a vessel or, alternatively, with vibration levels of shafts on a sister vessel. The system records events where vibration levels exceed a pre-set maximum, as well as monitoring how vibration levels change with running conditions, such as whether the vessel is running in shallow or deep waters.

The positioning and proximity sensors, which work by sending out and then retrieving a signal, are placed to monitor how the shaft is moving inside the vessel's bearings at various speeds, whether it is moving up to one or another, and detecting any 'whirling'.

The speed pick-up measures rotations per minute (rpm), and the strain gauge measures bend and torque in the shaft itself. The laptop and a specially formatted hard-drive (the data locker), are installed in a cabinet, usually

Alignment measurement of the propeller shaft using Wärtsilä´s patented gyro laser technology.

Laptop, with datalogger, installed.

Image of a line shaft bearing.

in the vessel's shaft tunnel room. The cabinet also can be installed with its own display.

If there is a small peak in vibration, an alarm will immediately sound so that acute alignment problems can be addressed before any damage is caused. Wärtsilä staff can then remotely advise crew on how to operate the vessel safely, for example, by keeping within a certain RPM range. This means the vessel can continue trading until its next dry docking.

Once the equipment is returned to the centre of excellence Wärtsilä's alignment technical support team feeds the collected data into Wärtsilä data management software, generating a status report with recommendations for corrective actions, such as realigning the bearings, engine or gearbox, or even replacing shaft.

Wide range of applications

Although intended initially to diagnose periodic faults, ship owners are fitting the system for a growing number of other purposes: as a precautionary measure to check alignment on new builds immediately after launch; to check for damage when saving fuel by slow steaming with a vessel designed to operate at normal speeds; to collect detailed data on a known fault before going in for repairs; or simply as a routine check-up.

Checking for misalignment issues on new builds is becoming necessary as shipbuilders, rather than manufacturers, increasingly install equipment. As a result, equipment failures on new builds due to misalignment of ship propulsion equipment frequently occur within six months of launch.

Ship owners also nowadays seek to save fuel by slow-steaming their vessels without installing new propeller blades or making other advisable modifications. This can put stress on the shaft and bearings so, before taking the decision, it is sensible for ship owners to first install the portable CMS to check that the cost of damage inflicted is not likely to exceed any savings in fuel.

Collecting data on a known fault can also save valuable time in dry dock by speeding up repairs.

By employing portable CMS, Wärtsilä can provide a detailed status report before the ship is due for dry dock. This allows engineers to plan the repairs, ordering new bearings if there are signs that the bearings have worn out, or make preparations to get a shaft straightened if the problem relates to a bent shaft.

Finally, both the lighter, more efficient equipment on modern vessels and the shift from mineral oil to less forgiving bio-oil demand more precise alignment, making routine check-ups advisable.

Previously, alignment checks were performed by Wärtsilä when the engine was static, using Wärtsilä's patented gyro laser technology to measure the bending line.

The difference between traditional alignment tests and the new portable CMS is similar to that of performing a stationary electrocardiogram on a heart patient versus sending them out with a portable monitor to record heart activity over 48 hours. The equipment can identify faults that a stationary test cannot.

Common issues detected by the portable CMS include: stern tube bearing failures; stern tube misalignment; shaft bearing failures; shaft bearing misalignment; shaft/coupling/engine or shaft/gear/engine misalignment; main engine bearing failures; main engine misalignment; bedplate twist; and vibration problems.

Cost effective

Wärtsilä typically leases the portable CMS equipment out, starting from as little as EUR 200 a day, before including the labour and travel cost for the superintendent engineer.

With the bill for a breakdown on a fully-loaded container vessel nowadays frequently running into millions of euros, the leasing fee is a very small price to pay for an early warning of faults developing. Having realised the potential benefits of the portable CMS after using it temporarily to diagnose a fault, several customers have asked to purchase a system to use permanently on their vessels.

The new system's benefits are also recognised by insurance companies and classification societies. If a ship undergoes repair after a major breakdown, the equipment can be installed for the first few journeys to identify any issues, lowering the risk that they later become liable for post-repair breakdowns.

Traditionally, when a vessel goes out on a sea trial following repairs, engineers have monitored nothing more than the temperature inside the bearings. This often fails to identify continuing issues, such as vibrations, whirling, misplaced load inside the bearing, or stress in the shaft. Installing portable CMS during a sea trial changes this.

A fall in the cost and size of sensors has helped make the new system cost effective, but the primary driver for its introduction has come from the alignment excellence centre technicians who invented it.

Wärtsilä is receiving several enquiries a day for the new system from across the globe, and is responding to this growing demand by hiring dozens of new engineers and training them up to superintendent level.

[MARINE / IN DETAIL]

Wärtsilä 5500 kW transverse thruster for Oasis class cruise vessels of Royal Caribbean International.

New WTT-40 transverse thrusters: more power and efficiency for cruise ships

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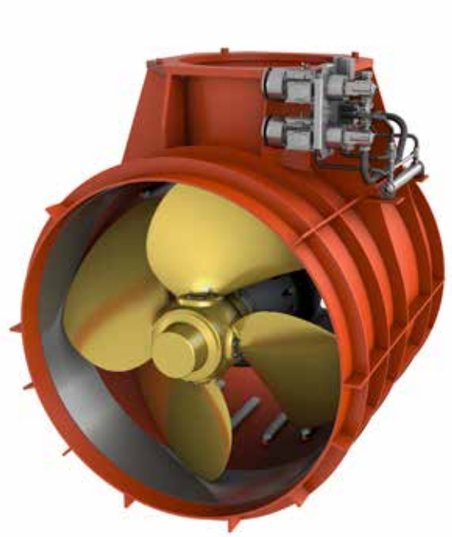


WTT-40 CP: Wärtsilä 4000 kW transverse thruster.

Responding to market demand for next-generation transverse thrusters operating with greater power and efficiency, Wärtsilä launched the new WTT-40 model for cruise ships.

Introduced in the spring at the Seatrade Cruise Global convention in Fort Lauderdale, Florida, the WTT-40 is the first Wärtsilä transverse thruster specifically designed for the 4000 kW power segment, and it is available with a controllable pitch propeller or a fixed pitch propeller. It carries a number of improved features, in the propeller diameter, lubrication system, hydraulics system, manoeuvrability, and noise and vibration reduction, all of which increase the thruster's efficiency while lowering costs for customers.

How thrusters work

Transverse thrusters provide hydrodynamic thrust in a direction perpendicular to the ship's longitudinal axis to counter environmental forces like wind, waves and currents. This kind of thruster propulsion is applied in three primary ways: 1) to manoeuvre a large container, cargo, merchant or cruise vessel in harbour to help it dock; 2) to enable, together with the main propellers, cruise vessels to remain in a fixed location in places where they are not permitted to drop anchor – such as, in the area of a coral reef – while allowing the vessel to lower smaller boats for tourism or diving excursions; and 3) to serve a ship's dynamic positioning (DP) system out on the open ocean, such as on large offshore support vessels and offshore construction vessels working in heavy sea conditions.

Depending on the overall propulsion configuration, cruise vessels can have between two and six transverse thrusters, which are installed in the bow or in both the bow and stern of the ship. The thrusters are located close to the centreline in tunnels running from portside to starboard, operating in both directions. In cruise and merchant ship applications, the transverse thrusters are used up to a few hours per day for harbour manoeuvring purposes. The thruster usage increases for cruise vessels that have station-keeping capability, while maximum use of the thrusters is made in DP systems with a significant number of running hours per day.

New degree of power

Previously, standard transverse thrusters had an available power range of up to 3500 kW. Wärtsilä specially designed a 5500 kW transverse thruster to be used on the world's largest cruise ships, like the Oasis of the Seas. But the WTT-40 is the first Wärtsilä transverse thruster that extends the standard power range upward, mainly intended for the cruise market, but also suitable for application in DP systems. Due to its smart design and more efficient use of components, the WTT-40 is more reliable and also more competitive than previous transverse thruster models.

As cruise vessels become larger, they require larger thrusters in the bow and stern for manoeuvring; the higher and longer the vessel, and the more mass it has, the greater the wind force and other pressures it faces at sea, requiring stronger thrusters to counter with more propulsion. To meet the growing demand for stronger thrusters, ship designers have two options. They can either install more of the same-sized thrusters on their cruise ships, or they can apply larger thruster units. A standard cruise ship can be equipped with four 3000 kW thrusters in the bow, providing 12 MW of manoeuvring power. Now, by producing a 4000 kW thruster, ship designers can install only three larger thrusters that generate the same power as four smaller ones.

In addition, the WTT-40 thruster

Back view in the dusk of Oasis of the Seas.

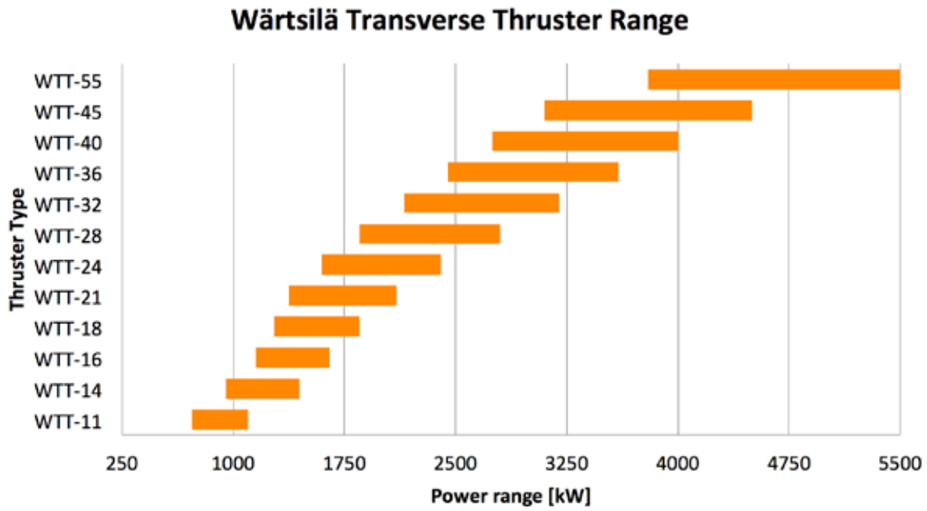
highlights the importance of a controllable pitch propeller in this market. Transverse thrusters in cruise vessels can have two types of propellers: a controllable pitch propeller or a fixed pitch propeller. With a controllable pitch propeller, the angle of the blades, or pitch, can be changed using hydraulic pressure to control propeller power and thrust while the propeller rotates at constant speed. By contrast, the blades of a fixed pitch propeller have a fixed angle relative to the water flow. Therefore, a variable frequency drive is needed to control the speed of the propeller and determine the thrust.

Transverse thrusters that use controllable pitch propellers and fixed speed electric motors are most common in cruise vessels for several reasons. They fulfil the propulsion needs while requiring a low capital investment, consume limited space in the vessel, and have a low number of installed components onboard. Wärtsilä encourages cruise ship designers and owner companies to consider investing in transverse thrusters with fixed pitch propellers, due to their greater efficiency and reliability, and the fact that they produce less noise and vibration. In the long term, these benefits may offset the initial higher investments due to the addition of the variable frequency drive. However, hydrodynamic and mechanical system advances in the WTT-40 thruster series bring the transverse thruster with controllable pitch propeller to a higher level, as explained below.

Innovative features

Next to the higher power level, the first feature that distinguishes the WTT-40 from previous thruster models is its propeller diameter. Whereas standard 3-3.5 MW transverse thrusters employ propellers with a three-meter diameter, the new thruster uses 3.4-meter propellers for the first time. These larger propellers are more efficient and can provide more thrust than a 4000 kW thruster with a smaller propeller. Furthermore, using only three thrusters, rather than four, means that fewer tunnel openings need to be created in the ship, and less installation work is involved. Even with the larger propeller diameter, the layout for the vessel is more efficient because three can be installed closer together than four thrusters. This is an advantage since the closer they are installed to the bow of the vessel, the more effectively they can counter the impacts of wind, currents and waves.

A second key improvement of the WTT-40 involves the integrated lubrication system. Wärtsilä has designed a new hydraulic system that combines the lubrication of the thruster's gears and bearings with the hydraulics for the pitch actuation of the propeller. By combining these two systems, the conventional hydraulic power pack – consisting of a tank, with pumps and valves mounted on top of the tank – needed to operate the propeller pitch is redundant. Thus, the extra space and work to arrange the piping from the tank to the thruster is no longer needed. For the new WTT-40 model, Wärtsilä combined the lubrication systems so that the hydraulic setting for the propeller is built directly on the steel construction of the thruster itself. Now, when the company delivers a part of the ship's tunnel in which the thruster is installed, it also delivers the hydraulic system as part of a compact and integrated system. In addition to saving time and space in the vessel, the integrated lubrication system makes the transverse thrusters easier for shipyards to install. But it is also easier to maintain the system because all of the components are located in one place, meaning that filter changes or inspections happen in one location.



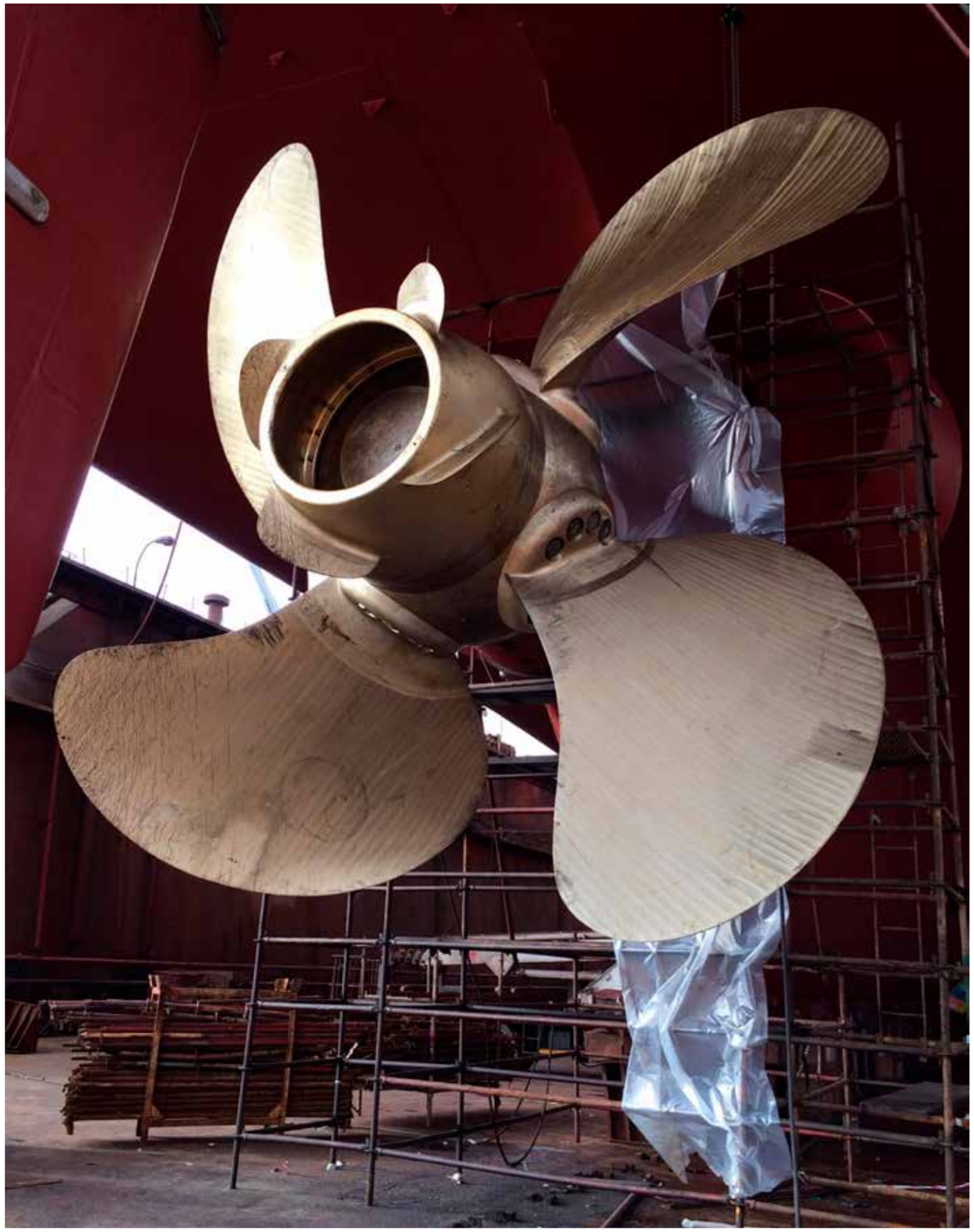
Wärtsilä transverse thruster range.

Wärtsilä initially introduced the integrated hydraulics for lubrication and pitch setting on its smaller thruster models in 2014, starting with 400kW thrusters used for cargo vessels and extending through 3500 kW thrusters used for cruise vessels. Now, because the concept proved successful, it has been extended to larger models like the WTT-40, which is the first thruster of its size to employ the integrated hydraulic system.

Another innovation concerns the thruster's propeller shaft seal. This seal keeps seawater out of the vessel and lubrication oil inside. The function of the propeller shaft seal can be periodically monitored using the small header tank that is connected to the system. Since the propeller shaft seal is subject to wear, it will require replacement after a period of five to 10 years. Now, with the WTT-40 model, the entire seal package can be easily exchanged, as the propeller is designed to be taken off in a simple way. The complex process to replace propeller shaft seals is streamlined, and this results in significant time savings during maintenance of transverse thrusters with controllable pitch or fixed pitch propellers.

Additionally, the WTT-40 thrusters are designed to comply with environmental legislation. In the United States, Environmental Protection Agency regulation rules on sea and inland waterway pollution, issued in 2013, require companies to use Environmentally Acceptable Lubricant (EAL) if there is any interface between lubrication oil and seawater, as is the case with the propeller seal for thrusters. This way, in case of an emergency oil spill or leak, the biodegradable lubricant released into the water is deemed environmentally acceptable. In response to these regulations, Wärtsilä has designed all of its new thrusters, including the WTT-40, in such a way that they can be optionally equipped with EALs, instead of the mineral oil normally used in thrusters.

As a further improvement, the WTT-40 thrusters contribute to the reduction of noise and vibration levels. Constant speed propellers turn in the water at nominal speed, at all times, which can result in noise and vibrations whether the thrusters are being used or not. In a cruise vessel, controlling noise and vibrations is extremely important, and Wärtsilä has several options to support ship designers in addressing the issue. The most effective way to reduce noise and vibrations is by switching to a unit with a fixed pitch propeller with variable speed control. For both controllable pitch and fixed pitch propellers, a larger propeller and a careful design of the shape of the tunnel in the vessel to optimize the flow helps manage noise and vibrations. A good tunnel design not only benefits ship owners but also supports the shipyards building the ships. The tunnel optimizations are done using computational fluid dynamics (CFD) analysis. The same tool and accompanying industry leading knowledge has been used for the design of the thruster gearbox shape and propeller, resulting in the most efficient, best-performing transverse thruster series to date.



EnergoProFin: the only hubcap with fins specially designed for Controllable Pitch Propellers.

New EnergoProFin changes the game in propulsive efficiency

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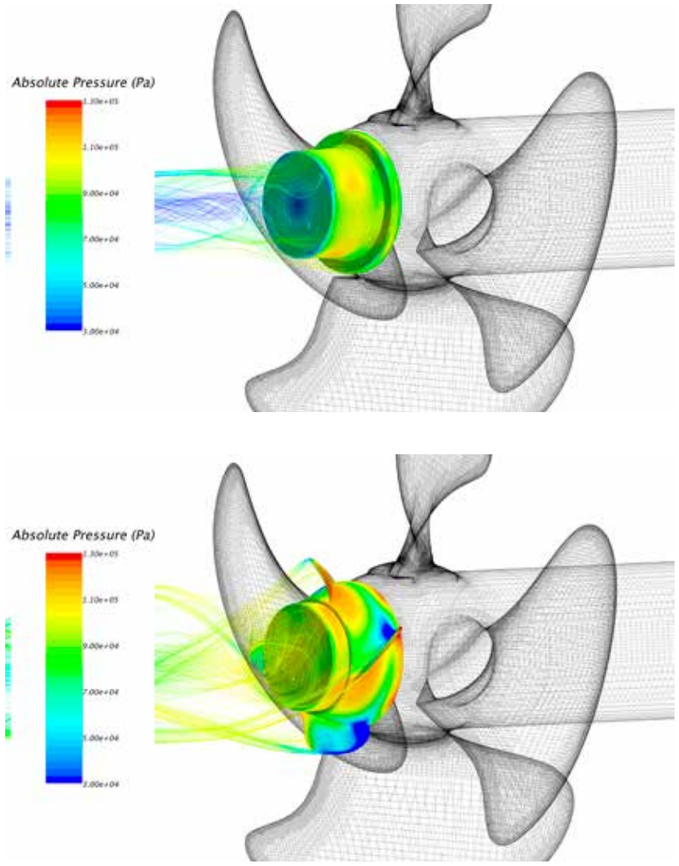


Fig. 1 - Computational Fluid Dynamics images of downstream vortex with a typical hub cap (1a) and with an EPF (1b).

In the fiercely competitive world of shipping, every drop of fuel matters. Naturally, any way to sail farther on less can translate to substantial cost savings for operators, not to mention benefits to the environment. Working toward that goal, Wärtsilä has recently developed an important energy-saving device that is likely to spark a high degree of interest in the business: the industry's first hubcap and fin setup for Controllable Pitch Propellers.

The underlying issue in fuel savings is the efficiency of a ship's propulsion system. In an ideal world, every bit of energy put into the shaft would be used for driving the ship forward. In reality, only about 50-70 percent can be utilised due to various types of kinetic losses. One area of concern is rotational loss, a consequence of the rotating propeller's pushing against the water and thus putting the water into a spin. Rotational loss consumes roughly 5 percent of the energy that goes into the system.

Since its introduction three decades ago, a favored solution to reduce rotational loss has been to place a cap with fins aft of the propeller hub. The cap reduces the swirl, while the fins effectively catch and absorb the force of the rotating water, eliminating the vortex and feeding the energy back into the propulsion drive train. See figure 1.

Wärtsilä's line of such devices, the Wärtsilä EnergoProFin, has proven to be a highly attractive add-on as it boosts propulsive

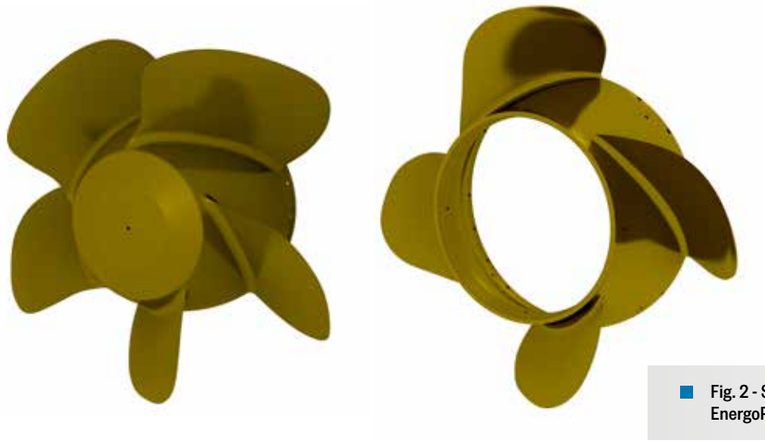


Fig. 2 - Side-by-side images of the EnergoProFin for FPP (left) and for CPP (right).

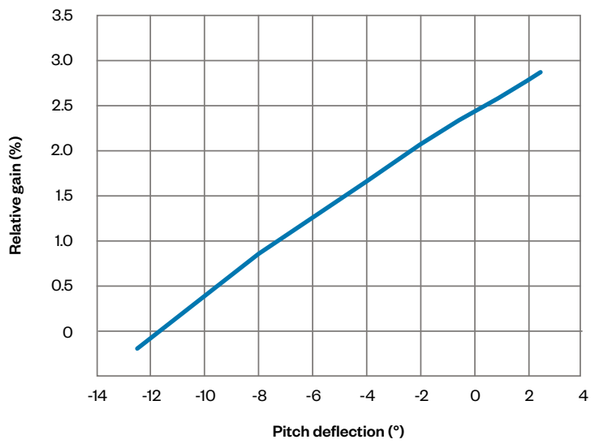


Fig. 3 - EnergoProFin CPP brings also fuel savings in off-design conditions (up to 12 degrees pitch deflection in this case.)

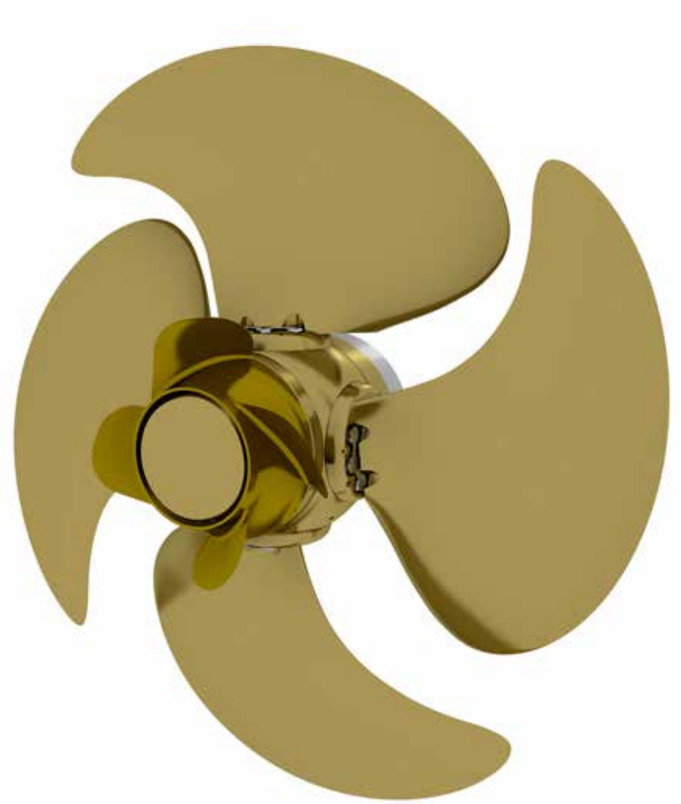


Fig. 4 - EnergoProFin with Controllable Pitch Propeller.

efficiency by a fairly consistent 2 percent at a reasonably low cost. Over 200 units have been sold thus far.

However, this type of solution has historically been limited to use on Fixed Pitch Propellers (FPPs), where the pitch angle of the blades never changes.

The pitch for FPPs is optimized for energy efficiency in only one operating condition – a specific sailing speed in the case of bulk carriers and container ships, or maximum bollard pull in the case of tugs. Other types of ships, notably ferries and fishing vessels, use Controllable Pitch Propellers (CPPs), where an actuating mechanism inside the hub can change the pitch depending on the operating needs, be they sailing, low-speed maneuverability or raw pulling power.

CPPs, with all the mechanics fitted within them, have relatively larger hubs compared to FPPs. The resulting higher hub ratio means that they can produce a more intense swirl. Additionally, when a cap and fin device is used, the angle of the fins is designed to operate with a specific pitch angle. When the pitch is changed on a CPP, the angles of the fins and the blades no longer match. For these reasons, the prevailing view in the industry has been that recapturing the rotational loss in a CPP by using a cap and fin device simply would not work.

That view has now changed – Wärtsilä's Services Hydrodynamic and Mechanical Design Engineering team has developed a new type of Wärtsilä EnergoProFin specifically for CPPs that overcomes the above challenges. It is already being used on two vessels.

Eye-opening research

The catalyst for this breakthrough was an EU-funded research project entitled GRIP (Green Retrofitting through Improved Propulsion), which was carried out from 2011 to 2015. Under its auspices, Wärtsilä and nine other European companies joined forces to overcome some of the fundamental problems in propulsion efficiency. Specifically, they were studying various energy-saving devices in the market to determine which in fact worked and why – questions that were not fully understood in the industry. The approach would lead the participants to take a hard look at the basic principles of the energy-savings equation.

Armed with the deeper knowledge of hydrodynamic principles gleaned from GRIP, along with state-of-the-art CFD, the Wärtsilä team was able to use its experience in producing the Wärtsilä EnergoProFin to develop a solution for CPPs. Figure 4.

Testing the design presented challenges that are all too familiar in the shipbuilding industry. Using a modeling tank comes with a fundamental scaling problem – while it is certainly possible to shrink the ship and its hardware to model size, it is never possible scale down the properties of the water such as density and viscosity. Full-scale tests would therefore be preferable in theory, but ever-changing conditions at sea make comparative tests impossible, even if the high cost of such tests were not a factor. The development team took the best middle-ground approach, using a combination of full-scale and model-scale CFD computations instead. The CFD computations at model scale can be compared to the results that were coming from the relatively accurate modeling tank. Because the CFD calculation methods were correct at the model scale, the engineers could be confident that they would be accurate at full scale as well.

Computer modeling was also employed during the design phase to optimize castability, thus minimising the chance of flaws forming in the structure of the finished product.

The hard work resulted in a new type of Wärtsilä EnergoProFin that is compatible with a CPP. It produces roughly equivalent efficiency gains as the FPP version, though there is more variation depending on the specifics of the individual propeller. The upper end of the range exceeds even 4 percent.

A distinctive feature compared to the design for the FPP is that the hubcap is open at the aft end. The hub aft is already seawater resistant and the open end does not influence performance. The angle of the fins, meanwhile, is optimized for the pitch setting that the ship will be using most. Efficiency gains will be highest at that pitch, though it is important to note that there are gains at other pitch settings as well. In other words, in off-design conditions (up to 12 degrees difference in pitch), there is still a positive effect. See figures 2 and 3.

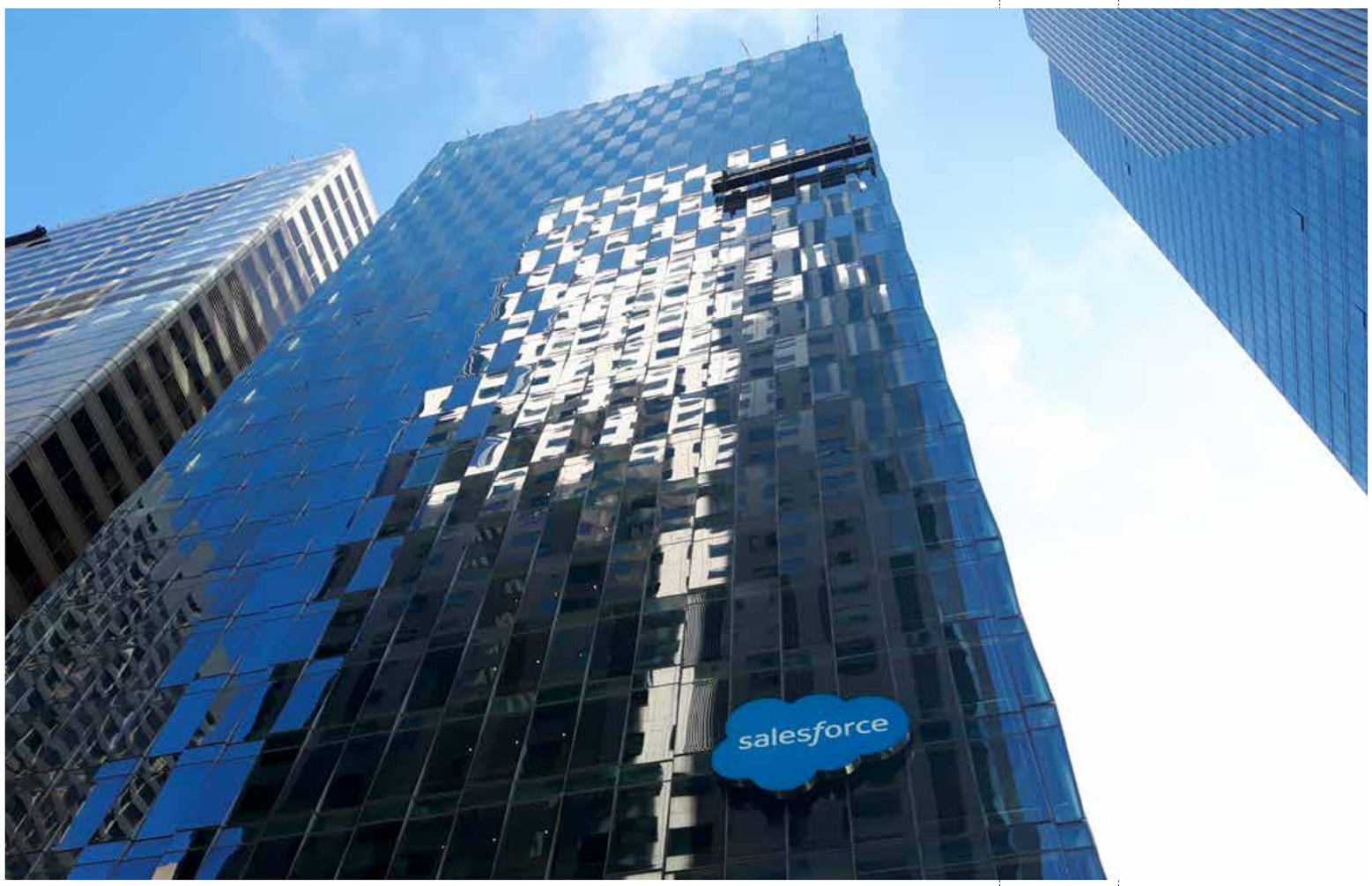
The device can be mounted on both new build and retrofit propellers, though integrating it requires specialized expertise from Wärtsilä engineers. It should be noted that, while the Wärtsilä EnergoProFin for FPPs can be used with competitors' propellers, the current EPF-CPP model can be fitted only onto Wärtsilä propellers with a 4C-3A(O), 4D or 4E hub. Installation on other (including third party) hubs is under investigation.

Assessing the benefits

Development of the Wärtsilä EnergoProFin certainly marks a real achievement for the teams involved. It also serves a testament to the efficacy of joint industry research projects like GRIP and to the power of recent advances in Computational Fluid Dynamics.

The more fundamental significance of this device, however, will be in the sizable energy savings that it can bring to the shipping industry as a whole, and in the benefits to individual operators looking for practical ways to minimise costs and emissions. As information about the new energy-savings option spreads among ship operators, more of them are likely to be taking a close look at their fleets' energy profiles to assess ways to incorporate this new technology into their propulsion systems.

In the meantime, Wärtsilä's engineers will continue to work to make these important energy-saving devices compatible with a wider array of ship and propulsion designs, bringing the benefits of lower fuel costs and lower emissions to more customers.



A pilgrimage to hacking heaven

AUTHOR: Anna Aistrich **PHOTO:** Kimmo Laasonen

Where do hacking aficionados go to learn how to take their digital solutions to the next level? Wärtsilä's Digisauna hackathon winners travelled to San Francisco to soak in all they could.

There is a reason that California's San Francisco Bay Area is the mecca for companies in search of the next big thing in digital solutions. It is home to platform super-disruptors like Uber, AirBnB, Netflix and Apple TV. The success of all these new, cloud-based operational models is stirring up debate over whether they could replace more traditional business models.

Digital tools from Salesforce, another San Francisco-based, cloud-computing giant, support several of Wärtsilä's functions. Salesforce representatives in Finland, applying their experience from previous hackathons, helped generate the idea of using a hackathon to help Wärtsilä speed up its digitalisation efforts.

So, naturally, when Wärtsilä hosted its Digisauna hackathon in April, the prize for the team with the most innovative, productive and applicable idea was a trip to the Salesforce headquarters in San Francisco in June.

The Digisauna event, held in Vaasa, Finland, challenged seven teams to develop new, creative ideas and digital solutions to help improve the company's competitiveness and create added value for customers. After tough deliberation, the jury selected the winning team, the Lead Winners.

The team travelling to San Francisco included the five Lead Winners' members from Wärtsilä –Ilkka Rytkölä, Cristina Urot, Anna Murtoniemi-Laine, Fabio Tamaro and Jaime López Gutiérrez –plus Kimmo Laasonen from Salesforce Finland. After the long flight from Helsinki, the group headed off to stretch their legs on a biking tour through scenic Sonoma Valley.

At the Salesforce office the next day, the Lead Winners gained insight into how Salesforce does digital marketing and the lessons they have learned through the years. Ilkka Rytkölä, Portfolio Manager with Wärtsilä Services and Team Leader for the Lead Winners, explained, "They've been doing it for a long time and know what works and what doesn't. So the team got a lot of good advice on capturing leads and using them for digital marketing. It was impressive to see how professional they are on these topics."

The team also paid a visit to Stanford University and to the Silicon Valley offices of Google, Apple and Accenture. At Accenture, the team got to test different gadgets, such as the HoloLens from Microsoft and some virtual reality glasses. Rytkölä said he was "interested to notice that they have such an academic approach to these gadgets, which I would like to see applied in real life." For him, the missing link was connections to companies that may have applications where the technology could be tested in an actual business case. The intrigue of these gadgets would be greater if they were co-developed to address real needs.

This experience led Rytkölä to what was, for him, the trip's biggest take-home message: to bring their app development back to basics. Because their idea will cause a radical change in the way people work, Rytkölä explained that they cannot just say, "Here is an app. Please use it." He acknowledged that it is easy to jump right to the solution and skip the steps that include user input. So he believes that the key to their solution's success is to discuss with the sales team what the bottleneck issues are and engage them in the process of developing the app from the beginning.

Aside from the technology-related insights he gained, Rytkölä was fascinated by all the diverse microclimates they experienced during their trip. American author Fitz Hugh Ludlow described this phenomenon perfectly, "To a traveller paying his first visit, [San Francisco] has the interest of a new planet. It ignores the meteorological laws which govern the rest of the world."

So maybe it's the area's disregard for the forces of nature that inspires people there to generate such ground-breaking ideas.

A team member tests virtual reality glasses at Accenture Lab.