ENGINEERING TOMORROW

Case story | VACON® generator and grid converters

Energy-efficient Ro-Pax vessels

Ro-Pax, i.e. roll on/roll off passenger vessels, typically sail short distances from island to island in an archipelago. The operating profiles* for the vessels are constantly changing, which sets challenges for energy efficiency and fuel consumption. C&A Electric and Vacon Korea have designed an efficient energy production solution to improve shaft generator usability. This is used on two Ro-Pax vessels built for the Attica Group1, the parent company of Blue Star Ferries.

In June 2009, Attica Group and Blue Star Ferries ordered two new Ro-Pax vessels from a Korea-based shipyard. Attica Group places particular importance on environmental issues and is continuously investing in new technologies, so they requested the ship builder to develop a sophisticated and energy-efficient solution for energy production on their Ro-Pax vessels. On a tight schedule, Vacon Korea and its system integrator partner C&A Electric were able together to provide what the ship builder needed – a design based on a shaft generator converter package.

Vacon's scope of delivery to C&A Electric included four 1,500 kVA liquid-cooled shaft generator converter packages, based on a modified standard VACON® NX Compact Cube. The main incoming breaker was removed, since the main switchboard was already equipped with this. The rated current is high, with a low rated voltage (400 V 50 Hz), which is typical for Ro-Pax vessels. This posed some challenges for the design of the required filters.

> ***"Although the decision to create a sophisticated solution was made just before finalizing the energy production concept, we managed to find a successful solution that also took into account the challenges of demanding conditions and limited physical space,"***
> *says Jussi-Pekka Sampola, Managing Director, Vacon Korea Ltd.*

C&A Electric is also pleased with the project. "The electric power supplied by the diesel generators was expected to be insufficient when the large thruster motors were running, so the ship builder was trying to find a way to increase the power of the ship network. We suggested using VACON® frequency converters to transfer power from the shaft generators installed onboard the vessel. This was a very demanding solution because the frequency converter used with the shaft generator should be capable of operating in parallel with the diesel generator supplying the network. Thanks to our in-depth discussions and cooperation with Vacon Korea, we were able to find a successful solution," says one of the project team members from C&A Electric. "I expect that this reference will generate further business opportunities for C&A Electric and Vacon in vessel building projects, where redundancy and energy saving capabilities are of the essence for the electric power system," he concludes. Blue Star Delos, the first of the two Ro-Pax vessels, has now been in operation on Greek island routes since mid-November 2011. The second vessel, named the Blue Star Patmos, has been handed over to the owner and has been operating in the North Aegean islands since 12 July 2012.

Energy production onboard a vessel

A conventional way of producing electrical energy onboard a vessel is based on diesel generators, shaft generators and emergency generators. During normal operation the shaft generators are used for on-board electricity production; diesel generators are used as an extra source of electrical energy or when it is not possible to use the shaft generators. Typically this happens when the vessel is berthed or is slowly approaching the quay.

When vessels are berthed, the restrictions on exhaust emissions are strict. One option is to use high-quality, high-octane fuel, which creates less exhaust emissions. However, this is costly. Other options include purifying sulphur oxide (SOx) and nitrogen oxide (NOx) exhaust emissions or using a shore supply system. Both options offer opportunities for AC drive/frequency converter technology.

Conventional shaft generator

The shaft generator is coupled to the main diesel engine through clutches or similar transmission components. The main engines drive the controllable pitch propellers (CPP) of the vessel's main propulsion system. Thrust can be controlled by adjusting the CPP blade angles in a so-called 'combinatory mode', so that the speed of the main engine varies only slightly, typically in the range 400-500 rpm. If the speed of the shaft generator varies, its electrical frequency will change, and this will be considered as an electrical supply failure. In combinatory mode, the diesel and propeller speed are kept constant in order to keep the electrical frequency constant, and the thrust and vessel speed are adjusted by changing the pitch of the CPPs. At speeds lower than nominal the efficiency of a CPP decreases rapidly, which means that the diesel still has to run at almost full load, increasing fuel consumption. In other words, thrust per speed and cost-efficiency of energy production cannot be optimized simultaneously.

The fuel consumption of the main engine does not change significantly over a load range of 40-100%, so at typical CPP loads at very low pitch (30-40% load) the fuel consumption is high, but very little thrust is generated.

VACON® generator and grid converters

A VACON® generator converter (INU) generates DC energy to its DC bus by controlling the shaft generator, and the VACON® grid tied converter (GTC) uses this energy to supply the main switchboard grid at constant frequency and voltage.

The generator loadability depends on the generator speed/cooling characteristics and on the nominal voltage behaviour as a function of speed (rpm). The voltage depends on the automatic voltage regulator (AVR) and generator characteristics. The VACON® grid tied converter is controlled and synchronized with the vessel's electrical grid with exactly the same signals that are used to control and synchronize conventional shaft generators or diesel generators. The vessel's energy production and

Photos courtesy of Attica Group

consumption are supervised and controlled by the Power Management System (PMS).

Engineering criteria for grid tied shaft converters

Several aspects have to be considered when designing and engineering a grid tied shaft generator system. The system designer has to focus particularly on demanding operating modes, such as how to prevent a blackout in case of a failure in any of the consumer segments. After all, the worst case scenario for a vessel at sea is an electrical black-out.

Aspects to consider:

- Load balance between energy sources; 1- and 3-phase load share
- The shaft generator withstands all start-up/failure currents (magnetizing inrush currents) of the motor/transformer load at any operating point
- Margin between nominal load and maximum short time overload
- Load minimum power factor and possible compensation requirement
- Grid synchronization, load sharing, load giving/taking modes
- Protection system selectivity, fuse burning mode to isolate failed segment outside the distribution system
- Possible energy production failure modes, power management system response time and supporting grid stability
- Possible grid code

This case story was originally released before the merger of Vacon and Danfoss Power Electronics was fully completed on 15 May 2015. As a result, Vacon as a company brand no longer exists and contact persons mentioned in the story may have changed. Future case stories on VACON® products will be released on behalf of the new organization – Danfoss Drives – which is part of the Danfoss Group.

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Danfoss Drives

Danfoss Drives is a world leader in variable speed control of electric motors. We aim to prove to you that a better tomorrow is driven by drives. It is as simple and as ambitious as that.

We offer you unparalleled competitive edge through quality, application-optimized products targeting your needs – and a comprehensive range of product lifecycle services.

You can rely on us to share your goals. Striving for the best possible performance in your applications is our focus. We achieve this by providing the innovative products and application know-how required to optimize efficiency, enhance usability, and reduce complexity.

From supplying individual drive components to planning and delivering complete drive systems; our experts are ready to support you all the way.

We draw on decades of experience within industries that include:

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- Mining and Minerals
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- Packaging
- Pulp and Paper
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Since 1968, we have been pioneers in the drives business. In 2014, Vacon and Danfoss merged, forming one of the largest companies in the industry. Our AC drives can adapt to any motor technology and we supply products in a power range from 0.18 kW to 5.3 MW.

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