Engineering for efficiency – the Q4000 thruster drive upgrade

AUTHORS: Dan McCluney, General Manager, Wärtsilä Electrical & Automation Services
Alan W. Bowen, Project Manager, Wärtsilä Electrical & Automation Services

Wärtsilä was contracted to undertake a performance audit on the Q4000, a unique multi-service vessel. This article gives the findings and describes the subsequent benefits to the owner.

Well Ops is a business unit of Helix Energy Solutions Group Inc., and provides a wide range of well operation and decommissioning services using specialist vessels, one of which is the Q4000.

The Q4000 is a unique multi-service vessel capable of operating in water depths down to 10,000 feet (3000 metres), for example in the Gulf of Mexico.

Wärtsilä has been working very closely with Helix ESG to improve the reliability of their Q4000 vessel. Electrical equipment that supplies power to the fixed speed controllable pitch (CPP) thrusters was not operating optimally. In addition, the client began to experience mechanical failures on the thruster gearing systems. These issues resulted in repair-related downtime that could potentially affect vessel availability.

In addition, Helix ESG upgraded the vessel to include a new modular drilling system, thus adding to the vessel's generation network loads.

Last but not least, the vessel was operating at a very low power factor. This required running multiple generators at light loads, causing premature engine wear.

Wärtsilä was contacted to carry out an audit to review the equipment installed, offer solutions to the above-mentioned issues and improve reliability while reducing downtime.

In summary, the major driving factors behind the project were:

- Addressing failures of drive system electrical components.
- Resolving drive system reliability issues.
- Minimizing services-related vessel downtime.
- Reducing fuel consumption and component wear caused by running of excess generators.
- Accommodating increased load on the electrical distribution system concurrent with the vessel's upgraded slimbore drilling system.

Fig. 1 – The Q4000 on station in the Gulf of Mexico.

In this article we will review the options that Wärtsilä considered, discuss the benefits and drawbacks of each, and also determine how and why the proposed solution was adopted.

Issues experienced

The vessel's thrusters were originally driven by a fixed speed squirrel cage induction motor, and variations in thrust output were obtained by varying the pitch angle on the thruster blades. This is a rather common arrangement in the marine industry.

The thruster drive motors were started by means of a reduced voltage start via an auto-transformer and medium voltage contactor switching, again a common arrangement.

The vessel had suffered repeated failures of the mentioned auto-transformers, and various parties had been engaged to review the system and the failures. Transformer manufacturers, the switchgear manufacturer, the original equipment installer and a European design organization carried out investigations; nevertheless, no clear reason for the failures could be given.

Because of mechanical failures to the thruster drive chain, and premature wear on the thruster/motor coupling arrangement, the main drive gearing had worn prematurely.

Several options considered

Option 1: Repair without changes
The first option available to the client was to repair the vessel's thrusters, hire or purchase an additional generation plant to service the drilling loads, and continue to operate. This option was discarded as it was quickly realized that this would not address the downtime issues or the repeated failures.

Option 2: Adding a generating plant to supply the new drilling loads
As the drilling system to be installed had been designed as a modular unit, which could be de-mobilized from the vessel, the addition of one or two new package generator sets was considered. These would be adequately sized to supply the entire drilling package.

This solution was given serious consideration but was not adopted, as it would have increased capital investment. Furthermore, it would have created a loss of usable deck space, additional running costs and emissions, additional maintenance costs, and noise issues.

Option 3: The use of static or rotary power factor correction
Whilst the installation of synchronous condensers, or static power factor correction equipment, would address the low power factor on the vessel's network, it would not solve the equipment failure problems. It would not, therefore, completely address all of the problems. While significant savings in fuel and low engine running hours would be reached with this method of modification, thus providing a return on investment, this return would be achieved only over a protracted period of time, owing to the increase in capital outlay and installation costs.

Another issue associated with applying power factor correction only, was that additional switchgear and cabling would be required to be connected to the network, either locally at the thruster motor starters, or to one of the vessel's 11 kV switchboards. This would increase the overall cost and time impact of the project. It would also require that space dedicated to other equipment or services be re-assigned, and would involve steelwork modifications.

Another important fact considered was that if rotary compensation was employed (synchronous condensers), then the inclusion of these on the network would raise the system's prospective short-circuit fault level. This would have a negative impact on the project. Furthermore, this component of the design would have to be engineered and, dependent upon the subsequent increase in fault level, could have large associated costs.

Option 4: Modification of the vessels thruster systems with variable frequency driven units
The most important load component of the vessel during dynamic positioning, is the one required to drive the position-keeping thrusters. In the existing configuration, the driving thruster motors are normally run on very light loads, thus causing the resultant system power factor to be quite low, as described above.

By replacing the original fixed speed motor and the reduced-voltage starting system by variable speed drives with forced-air cooled motors, the power factor of the thruster drive train can be kept to a very high level towards unity (i.e. closer to 1 and hence more efficient). This ensures that the resultant power factor of the vessel network will have a much better value.

By removing the reduced voltage starting system altogether, the overall reliability of the vessel's systems would be increased. The improved power factor would remove the need for too many diesel generators to be run at light load, and thus make more power available for the new drilling loads.

In reducing the number of engines running at the same time, the vessel's operating and maintenance costs are reduced. Also reduced is the environmental impact of the vessel's operations.

As the thrusters would not be running at nominal speed continuously, the reduced running speed and the smoother operation during load changes would lower the wear on the thruster systems, again having a positive impact on maintenance and repair costs.

Having considered all of the above options, it was clear that only option 4 addressed all of the listed issues. Furthermore, by selecting variable speed drives, there was the added benefit of reducing the wear on the vessel's thruster drive chains.

Selection of the variable frequency drive

The market for a 3 MW variable frequency drive, as required for this project, is quite buoyant. There are several different methods or approaches that could be employed to achieve a satisfactory solution.

For instance, the drive options available include different methods of commutation (i.e. 6, 12 or 24 pulses), air or water cooled, and closed or open loop speed control.

Bid packages were sent to a number of major drive manufacturers and integrators, the content of which included the following criteria:

- Motor output rating (3 MW @ 900 rpm).
- Marine class requirements, including maximum harmonics distortion.
- Space for the equipment.
- Capital and operating costs.
- Robust and reliable equipment and means of control.

The amount of total harmonic distortion that would be imposed on the network after the modification to variable frequency drive was a large concern. The most efficient means of controlling this was to adopt a 24-pulse solution. However, the higher costs involved with this (+30%), together with the increased overall dimensions of the equipment (+50%), made this prohibitive.

The solution adopted was to provide the drives as 12-pulse units, but with a twist. The vessel's electrical distribution system is configured as three 11 kV switchboards, each with two generators and two thrusters connected. (Before and after 11 kV network single lines).

The system can be operated with the switchboards in isolation, but typically they are utilized in a ring configuration. Each variable frequency drive unit is supplied via a three winding step-down power transformer. The solution adopted ‡

[MARINE / IN DETAIL]

was to arrange the drives in a "Quasi" 24-pulse arrangement, by phase shifting the two thruster power transformers connected to each bus bar. This resulted in an almost complete cancellation of the harmonics. This solution offered reductions in both capital outlay and installation costs on the vessel.

The reliability of the thrusters is of paramount importance on any vessel, but even more so on a vessel for which maintaining position in varying sea and weather conditions is essential. Therefore, the reliability of the equipment and system design played a major role when selecting the drive package. To this end, an open-loop method of speed control was adopted, thereby removing the need for encoders, or other means of speed feedback, and thus eliminating those components from the package that could cause failure. An algorithm calculates the motor speed in the drive control system, giving deviations less than +/- 0.1% of the desired speed value, which is more than adequate for a thruster drive. The motor control also allows for engaging the motor when the thruster is already rotating (start "on the fly"), a feature which can be important to this vessel's operations.

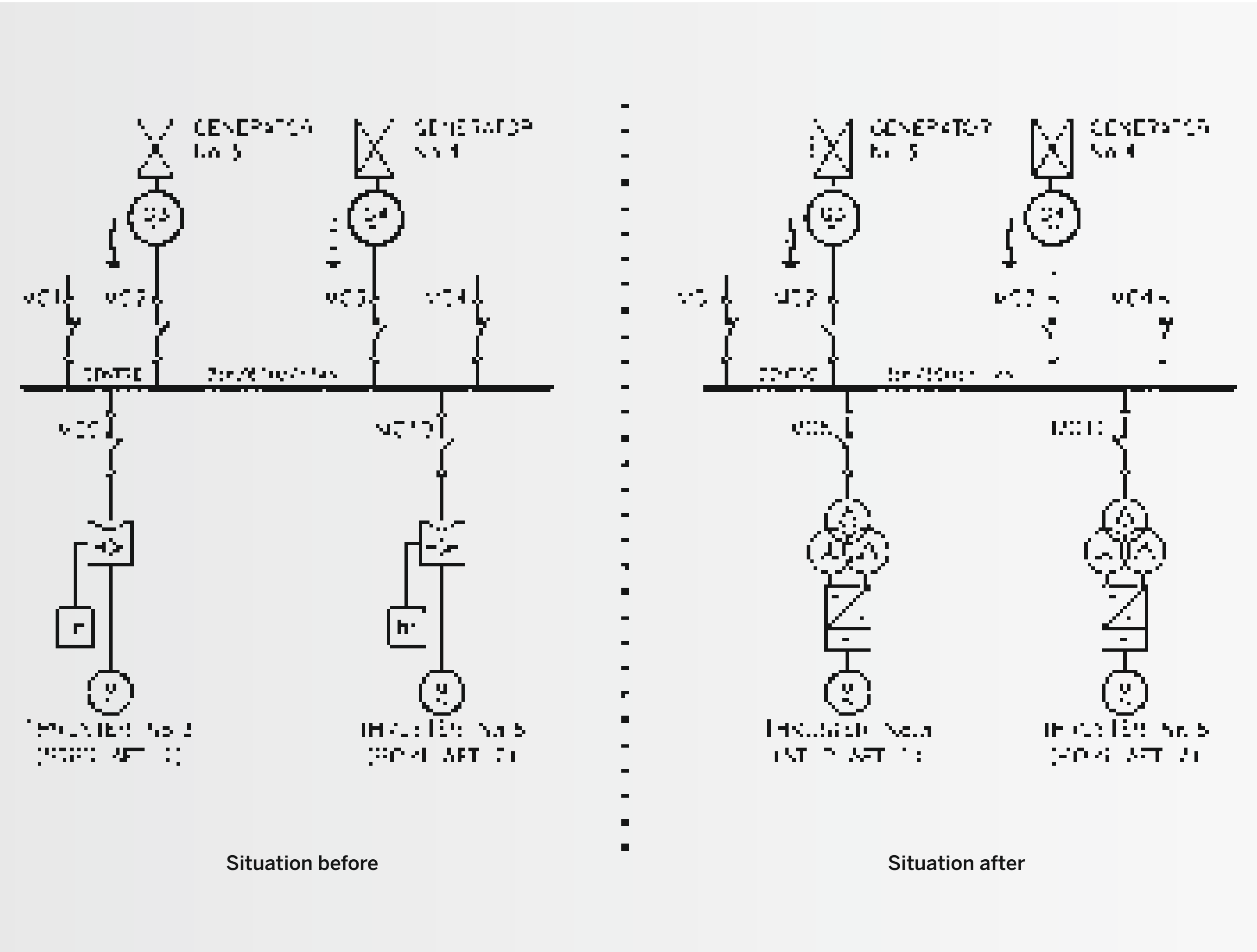
Interface engineering, installation and commissioning

Wärtsilä was engaged to provide all of the required interface engineering, the installation planning, and materials procurement prior to the vessel's arrival at the dockyard facility. Wärtsilä also completed all the installation and commissioning works, making this a true "turnkey" solution. The work was undertaken simultaneously with the installation of the integrated drilling package. Wärtsilä also completed the design of the electrical distribution system as well as the procurement of the drilling package.

In parallel to installing the variable frequency drive, all installation and commissioning of the package's electrics were completed by Wärtsilä Electrical and Automation Services in Galveston, Texas. This served to demonstrate once more Wärtsilä's capability of executing and managing projects for very large marine and offshore installations.

Commissioning of the thruster systems was straightforward and went well with a minimum of surprises, owing to the correct interface engineering, pre-planning and good preparation. A defective batch of diodes in the main rectifiers of the variable frequency drives of the thruster caused a

Fig. 2 – Extract from a power network single line diagram showing the old and new thruster motor drive.



few problems, but this was identified and replacement components were dispatched to the vessel immediately from Europe.

Ultimate results

Prior to the thruster modification, the vessel was consuming over 40 metric tonnes of marine diesel oil per day. After this variable speed modification, the measured fuel consumption has been approximately 20 metric tonnes of fuel per day, a significant 50% saving. Instead of running four generator sets to maintain position, the vessel normally runs two, adding to the savings via reduced running and maintenance costs. The reduction in the number of generator sets required for positioning has allowed the vessel's generators to be used to provide power to the drilling package, or other deck consumers – representing further savings in capital outlay and operational costs.

The environmental impact of the vessel's operations has been reduced in the same proportion, since a 50% reduction in fuel consumption is a direct reduction of 50% in CO_2 and NO_X emissions.

The reduced number of revolutions of the vessel's thrusters has reduced wear and operational costs over the past year.

The above illustrates that the project has been a success; for the vessel's owners, for Wärtsilä's partners, and, subsequently for Wärtsilä.

Future works – a drive for continuous improvement

The commissioning of the thruster systems revealed that some control systems for power generation on the vessel are not allowing the generation/distribution/thruster systems to operate at their maximum capability. Wärtsilä has been engaged by the client to engineer the replacement of these in the very near future.

This drive for continuous improvement, through the innovative application of technology, allows Wärtsilä to reach its goal of being the most valued business partner of its clients.

Fig. 3 – The Q4000 vessel in dock during the drilling package upgrade in 2008.