High-Pressure Gas Supply for Two-Stroke Dual Fuel Engines

a new challenge using LNG as a marine fuel

Driven by economic and environmental factors, LNG propulsion is a quickly developing technology for the shipping industry. Starting with medium speed four-stroke engines using natural gas as propulsion fuel, a number of new technologies have been developed in recent years including those for two-stroke engines. One of the major innovations was the introduction of slow speed, two-stroke diesel engines using dual fuel (natural gas & diesel mixture) technology by MAN Diesel & Turbo (MAN) in 2011.

The gas supply to MAN's dual fuel ME-GI engine is quite different from other fuel supply processes including those run on gas carriers. New challenges are:

- High pressure (up to 350 barg) natural gas supply to the engine
- Converting low pressure LNG to high pressure gas during the ship's voyage
- Designing a Fuel Gas System (FGS) to meet load ramps / shut down scenarios

TGE Marine Gas Engineering GmbH, in a joint effort with ACD llc, engineered a FGS utilizing integrated system controls and a combination of low pressure centrifugal (booster) and high pressure reciprocating cryogenic pumps. Using the combination of pumps ensures the FGS achieves 100% reliability and meets the challenges of this new application. The required FGS is a compact, skidded design and easily installed on seagoing vessels. The FGS can be installed in an open shelter within the cargo area of a gas carrier or below deck of other cargo vessels.

Pumps are a key component of the Fuel Gas System. The submerged vertical centrifugal pumps (see figure 1) are mounted inside the cargo tank and supply LNG at needed pressures and flow rates. The submerged pumps are often referred to as "boost" pumps which simply transfer LNG to the suction end of the high pressure (HP) pumps. Boosting of the LNG pressure eliminates issues associated with cavitation. Cavitation reduces HP pump life and must be avoided to achieve required operational life of the HP pumps. Using a "boost" pump

FIGURE 1 - Submerged vertical MSP-34 "boost" pump

guarantees sub-cooled liquid is properly fed to the high pressure pumps and gives operators assurance the FGS meets all challenges operating at sea.

TGE and ACD have transferred the submerged pump technology to the shipping industry. ACD recently delivered the first MSP-34 (Marine Supply Pump-Submerged) pumps to be installed in an Anthony Veder 15,600 m3 LNGC ship also using LNG as the propulsion fuel. *(See Figure 2)*

FIGURE 2: Anthony Veder, 15,600 M3 LNG cargo vessel.

The reciprocating pumps (see figure 3) increase low pressure (minimum 2.5 - 4.0 barg) LNG supplied from the boost pumps to high pressure (350 barg) LNG. High pressure LNG is then discharged to a heat exchange system which vaporizes the liquid to gas. The high pressure natural gas is then fed to the engine's high pressure fuel control valves through a manifold system designed by MAN.

FIGURE 3: High pressure MSP-SL reciprocating dual pump skid. Single MSP-SL skids also available

TGE and ACD have put much effort into developing the Fuel Gas System and validating system design using simulation based on actual operation of a typical voyage. Given the size and complexity of the ship's engines, and the fact that duplicating 'real-world' operations in multi-engine applications is difficult, the dynamic simulation model is a practical and reliable solution that investigates various aspects of the system's design through multiple operational processes.

TGE uses UNISIM™ modeling for steady state and dynamic process simulation. Very detailed modeling of the components including all piping sections, control elements and ACD's cryogenic pumps form the basis for thorough investigation of liquid (LNG) composition from the cargo/fuel tank to the engine. The simulation program shows how pressure and temperature changes of LNG impact FGS reliability and why a boost pump is required. The boost pump simply ensures a positive means to counter potential problems due to normal voyage situations that threaten sub-cooled liquid conditions to the high pressure pumps.

The critical aspect during operation is to avoid cavitation of the high pressure pump. Marine applications introduce new factors that impact cavitation scenarios compared to on-shore processes. These variables have been investigated in detail using the UNISIM™ model. Simulation has shown that cavitation does not occur using a booster pump, which always supplies sufficiently sub-cooled liquid to the high pressure pump.

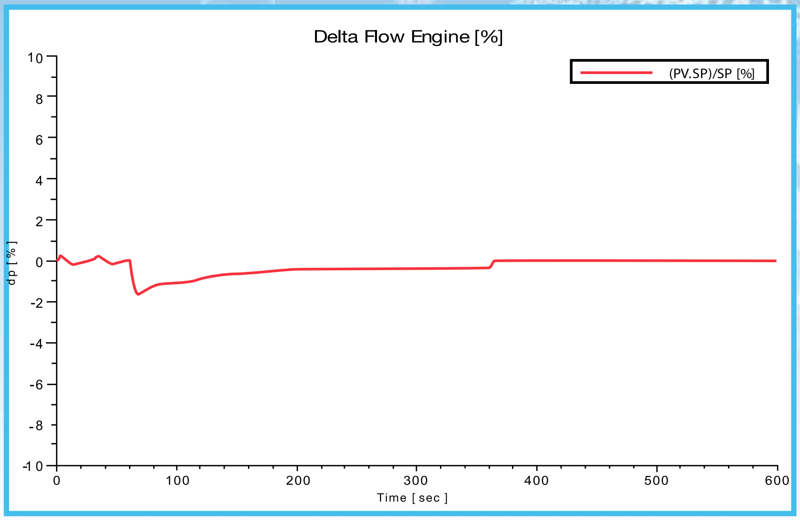

FIGURE 4: Flow deviation in quick switchover scenario.

Figure 4 shows how TGE's FGS maintains fuel pressure requirements to the engine during a quick switchover scenario. The simulation proves the FGS is designed to achieve optimal performance should a switchover (from natural gas back to diesel or vice versa) be required during the voyage.

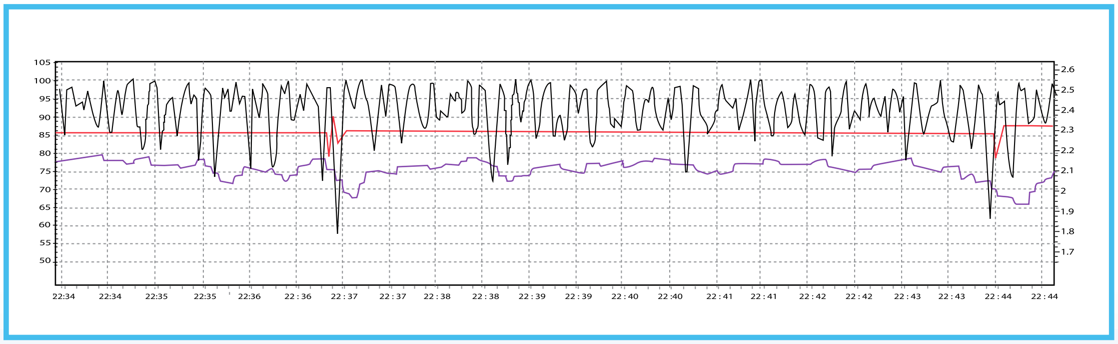

FIGURE 5: Heavy weather load scenario for engine

Figure 5 shows one aspect of demanding requirements in a heavy weather scenario. The black line shows the very dynamic behavior of the engine fuel index. The FGS must follow this fuel index to ensure proper engine operation. Dynamic simulation has clearly shown that TGE/ACD system fulfills such requirements.

Process simulation has been used extensively to verify the control strategies are adequate to meet various operational requirements. The simulation also proves the FGS's behavior throughout the voyage will meet basic system requirements for the ME-GI engine using low and high pressure pumps.

In summary, the UNISIM™ model has shown that advanced controls and the use of dynamic process simulation has proven useful to develop a FGS that meets ALL marine requirements: safe and reliable operation, engine demands and special challenges due to the marine environment. TGE's system, using ACD pumps, meets all marine conditions and proves the system design meets operational requirements for MAN's ME-GI engine and ensures reliable performance throughout the ships voyage.

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