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CASE STUDY

LNG Fuel Tank Digital Twin

This case study describes the development and deployment of a dynamic digital twin for an LNG fuel tank and fuel gas supply system on an LNG-fueled vessel. The system supports pressure control, fuel planning, and boil-off gas (BOG) management during bunkering and extended ocean voyages.

CHALLENGE

LNG fuel tanks onboard vessels are continuously exposed to ambient heat and solar radiation, causing boil-off gas generation and rising tank pressure. Pressure that is too high presents a safety risk, while pressure that is too low creates mechanical and operability issues for the fuel gas supply system. Additionally, LNG consumption varies with engine load and voyage conditions, making it difficult to plan bunkering operations and ensure sufficient fuel availability using static calculations alone.

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- **Industries:** Maritime Engineering / LNG Fuel Gas Supply Systems (FGSS)
- **Project Type:** Dynamic simulation and cloud-based digital twin

SOLUTION

A rigorous dynamic process simulation was developed using the CHEMCAD simulator to create a digital twin of the LNG fuel tank and FGSS. The model explicitly accounts for non-equilibrium vapor-liquid behavior, ambient heat transfer through the tank wall, boil-off gas generation, and cooling via cold LNG spray.

Key thermal and operational parameters were tuned using actual vessel data. Heat transfer coefficients were identified through isolated tank tests with all valves closed, while spray efficiency parameters were calibrated using LNG bunkering operation data. The validated digital twin was deployed in a cloud environment and integrated with the Sea-Navi® 2.0 system to deliver online simulation results and future predictions to the vessel.

RESULTS

The calibrated digital twin accurately reproduced measured tank pressure and temperature trends during both isolated conditions and active bunkering operations. Voyage simulations covering a 65-day route (Singapore → Australia → Japan → Singapore) successfully predicted LNG consumption, tank pressure behavior, liquid inventory, and methane composition throughout changing operating modes.

By running simulations prior to departure and during navigation, operators were able to evaluate pressure margins, spray requirements, and fuel availability, significantly improving operational confidence and voyage planning accuracy.

TANGIBLE BENEFITS

- Maintained LNG tank pressure within safe operating limits during voyage and bunkering
- Reduced boil-off gas losses through optimized spray operation
- Improved LNG fuel consumption forecasting over long voyages
- Lower risk of fuel shortages or excessive onboard LNG inventory
- Operational support for CO_2 reduction through efficient LNG fuel management

FIGURE 1 - P&ID of the engine fuel system

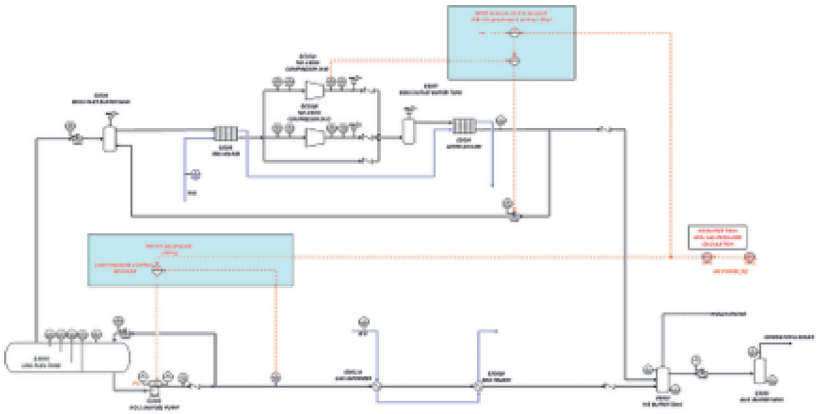

FIGURE 2 - LNG Bunkering operation

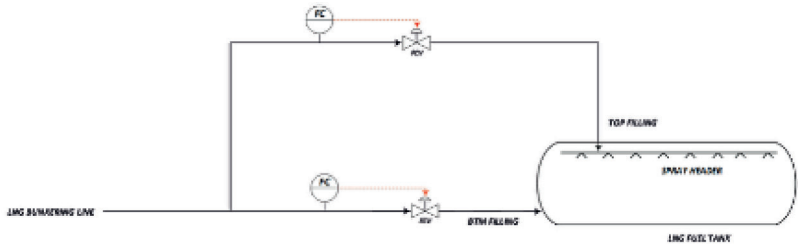

FIGURE 3 - Calculated fuel tank pressure and liquid volume vs. measured data