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Figure 1: Unlike classic aircraft carriers, large-deck assault ships like the Makin Island have no aircraft launch catapult. They serve as bases for helicopters, vertical-takeoff planes and landing craft.

The USS Makin Island is the first large-deck assault ship in the U.S. Navy to be powered by a combination of gas turbines and electric motors. The new propulsion system considerably reduces fuel consumption and maintence costs when compared with the steam turbine-based propulsion otherwise used in this class of ship, yet without compromising performance. To test the control software for the gas turbine propulsion system, manufacturer Northrop Grumman used a dSPACE system on board the ship itself.

The USS Makin Island went into service in 2009 and is the first large-deck assault ship in the U.S. Navy to be powered by gas turbines.

Gas Turbine Saves Fuel

When General Electric brought out the LM2500+ gas turbine with 35,000 HP in the late 1990s, it was a logical step for the U.S. Navy to equip new ships with this propulsion plant due to the clear advantages of gas turbines over the steam turbines previously used: Performance being equal, they are not only more compact, lighter, and easier to maintain, they are also quicker to get running and require less manning. So the latest large-deck assault ship, the Makin Island (named for an atoll in the Pacific), which went into service in 2009, is powered by two LM2500+ gas turbines. At speeds under 12 knots (just over 22 km/h), two 5000-HP

Simulating Gas Turbine Ship Propulsion Plant

Turbine on Board

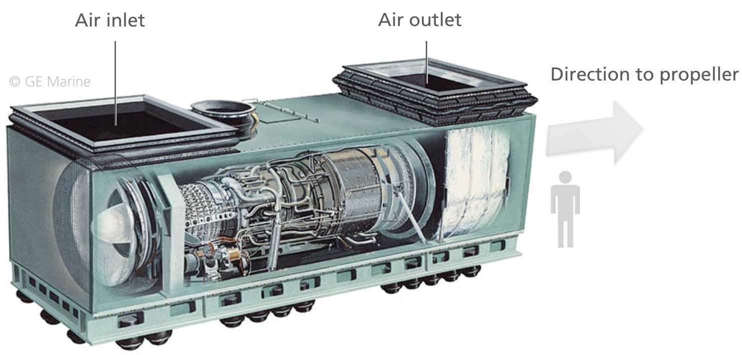


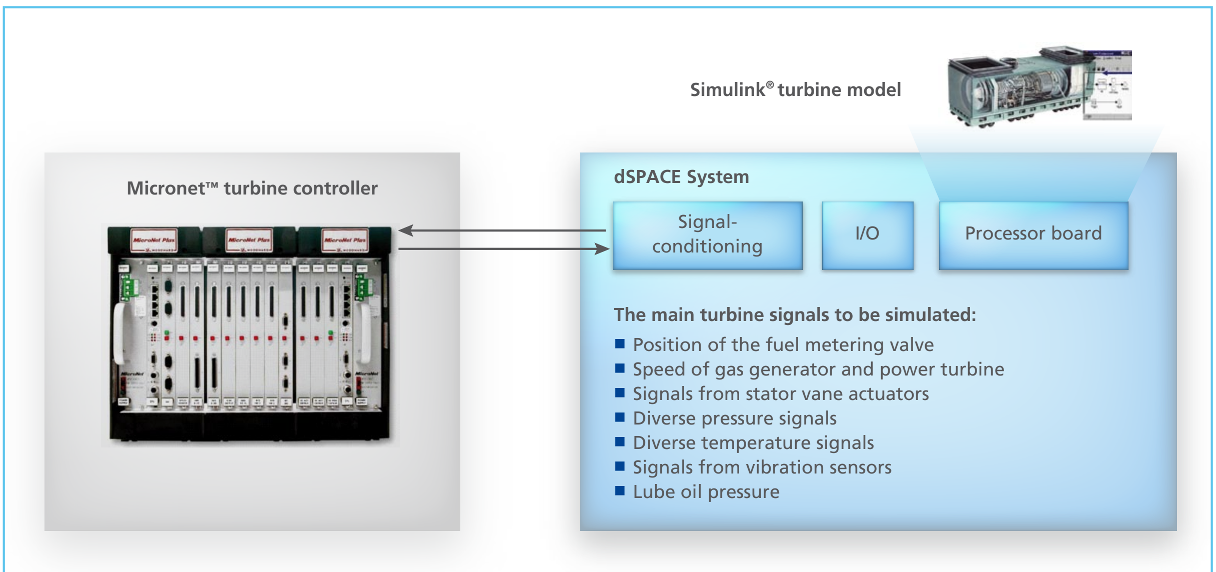
Figure 2: The Makin Island has two LM2500+ type General Electric gas turbines that together generate 70,000 shaft horsepower. A dSPACE system was used to test the Woodward Governor Company MicroNet™ ECU.

electric motors take over propulsion, saving up to 25% of the gas turbines' operating time and approx. 1.5 million liters of fuel every year. Because the Makin Island is the first ship in the U.S. Navy to use the LM2500+ turbine, the associated control software had to be completely readapted and tested. This work required shipboard simulation of all the signal traffic between the electronic control unit (ECU) and the gas turbine, so a powerful, simulation-based, extremely flexible real-time test system was needed.

Simulating Signal Traffic

Northrop Grumman's engineers faced the paradoxical task of testing the ECU's turbine emergency shutdown and warning functions without actually operating the turbine, since this was a condition of their contract with the U.S. Navy. The ECU was significantly different than its counterparts on other ship classes, and actually had to monitor a normal engine startup prior to engaging the engine's protective features. The only way to do this was to simulate the turbine's signals to make the ECU "think" that the turbine was really running. Simulating turbine startup was a major challenge for the test system, because during the start sequence the ECU expects the turbine to send numerous signals (temperature, pressure, speed and so on) with specific values and rates-of-change at various points in time. If these return signals do not fit the expected reference values, the ECU immediately aborts the start sequence. "Unfortunately, it was not possible to use manual settings to trick the ECU into its Run status," explains James Turso, an engineer at Northrop Grumman. "So we had to simulate the complex start sequence before we could begin testing the ECU's turbine emergency shutdown and warning functions."

Figure 3: To test the MicroNet™ ECU, a dSPACE system simulates all the signal traffic between the turbine and the ECU. The turbine model was developed in MATLAB®/Simulink®.



Choice of Test System

For gas turbine simulation, engineers at Northrop Grumman specified a hardware-in-the-loop (HIL) simulator that had to fulfill a whole series of requirements:

- Real-time capability with a maximum model throughput time of 5 ms (the turbine model was developed in MATLAB®/Simulink®)
- Signal conditioning capability (to exchange signals with the Woodward Governor Company MicroNetTM ECU)
- All sequences software-controllable
- Uncomplicated, flexible connection of test hardware to the ship's electrical system, i.e., without adapting the ECU, the gas turbine or the cabling
- Fail-safe, industry-proven system

To be certain of meeting this requirement profile, Northrop Grumman decided to use modular hardware and software components from the dSPACE tool chain.

dSPACE System Simulates Gas Turbines

To present a realistic operational gas turbine to the ECU, the dSPACE system had to simulate a wide range of different turbine signals (figure 3): signals for pressure, temperature and acceleration, the speeds of the gas generator and power turbine, lubricant pressure, etc. "But the biggest challenge was to simulate the signals of the fuel metering valve position feedback signal, which works on the principle of an LVDT," adds James Turso. An LVDT (linear variable differential transformer) is an inductive sensor that generates a high-frequency AC voltage signal with a variable amplitude. In the Makin Island's gas turbines, the signal shape depends on the current opening of the fuel valve, which changes constantly throughout the start sequence (figure 4).

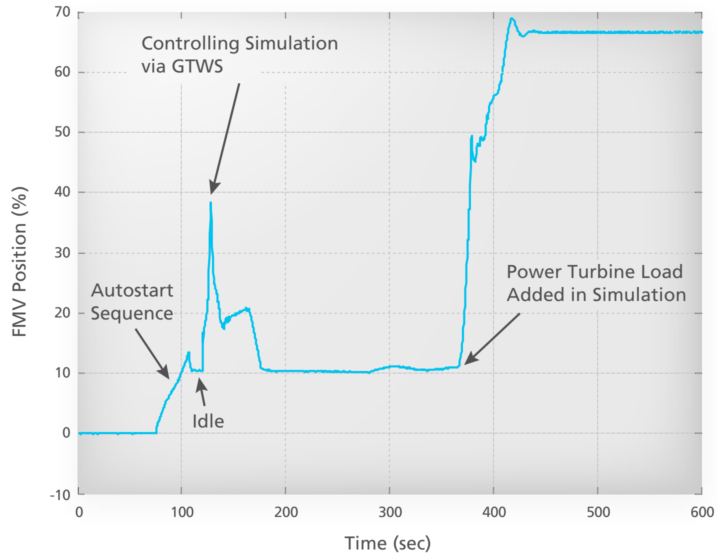


Figure 4: Time behavior of fuel metering valve position (actually the position feedback signal from the dSPACE equipment processed by the ECU) during the propulsion system's startup sequence. Simulating the LVDT for this was the greatest challenge in the tests.

> "Given the tight time constraints on this project, the dSPACE system enabled us to meet the U.S. Navy's tough gas turbine ECU test specifications."
>
> *James A. Turso, Northrop Grumman*

"With the dSPACE HIL system, the simulation of this complex signal works perfectly," concludes James Turso.

All Tests Successful

With the aid of the gas turbine simulation by the dSPACE HIL system, Northrop Grumman engineers brought the various ECU safety and emergency shutdown function tests stipulated by the U.S. Navy to a successful conclusion. The dSPACE HIL system proved its high flexibility in all these tasks and will be used again in any future new-engine startup tests. And as all forms of shipbuilding face increasing complexity, such a HIL system would also be invaluable in testing control systems for other types of components. The days when tests could be performed just by adjusting controls and switches manually are fast coming to an end. ■

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