Propulsion Solutions

Electric ship initiatives offer flexibility, increased warfighting power

By RICHARD R. BURGESS, Managing Editor

Directed Energy

The Navy's electrical ship programs are benefiting from innovative industry participation.

- The concept promises greater ship fuel efficiency and flexible energy for future weapons.
- Superconducting and permanent magnet motors compete for adoption.
- Power transmission and switching technology present challenges.

With the help of industry, the Navy is maturing the solutions proposed for the challenges of electric ship technology, a transition that promises flexible design options, greater fuel efficiency and sufficient power for the mission systems of the future.

With innovative concepts such as hybrid drive, more powerful electric motors and generators, and greater electrical storage capacity and distribution, the Navy is designing and building ships to capitalize on the technology.

"Across the Navy, from basic science to in-service applications, initiatives are being established based on technology gaps and needs," said Capt. Lynn Petersen, deputy program manager of Electric Ships for the Navy's Program Executive Officer for Ships. "New ship designs are taking into account the benefits of all electric and hybrid drive technologies."

Electric drive is a propulsion arrangement in which a ship's engines — typically gas turbines, steam turbines or diesel engines — power an electrical generator. The generator, in turn, powers a large electric motor, which is connected to the propeller shaft. Generators also provide power to the ship's combat systems, lighting, heating, air conditioning, elevators and other missions and "hotel" requirements.

In many warships, a mechanical drive system is used for propulsion. The engines are mechanically connected to reduction gears, which are connected to the propeller shafts. The engines also mechanically power generators or motors that drive generators to provide electrical power throughout the ship. Auxiliary generators are commonly used to produce power.

With conventional mechanical drive, a ship is restricted in design to a layout in which the engines and reduction gears are typically located in the lower aft hull. One advantage of electric drive is that the engines and generators can be located almost anywhere in the ship, connected to the drive motor by the transmission wiring. The flexibility allows a designer more freedom in designing survivability into a ship. The fact that the propeller shaft is rotated by a quiet electric motor rather than a mechanical reduction gear also reduces the acoustic signature of a ship.

A hybrid electric drive is a combination of the two concepts in the same propulsion system, whereby the operator has the option of using electric or mechanical drive, depending on the speed and fuel efficiency desired. The concept is used in modern automobiles, such as the Toyota Prius.

San Diego-based General Atomics and DRS Technologies, Parsippany, N.J., are teamed "to explore technologies to improve fuel efficiency," Petersen said. "The goal of the hybrid electric drive project is to reduce fuel consumption, leading to reduced dependency on fossil fuel.

"Further, the hybrid electric drive system could increase mission effectiveness through longer time on station," he said. "Their project entails developing hardware to be tested at the Philadelphia DDG 51 Land-Based Engineering Site.

The Zumwalt-class DDG 1000 destroyer is being designed as the vanguard of new electric ship technology.

"Though there is no current requirement or program of record for electric drive technologies for the DDG 51 class, hybrid electric drive is a promising technology that deserves careful consideration and is being considered for future budgets," he said.

Roger Sexauer, president of DRS's Power and Environmental Systems Group, said that with hybrid drive, the Arleigh Burke class could operate on electric motors up to 12 knots, saving 12,000 barrels of fuel per ship per year.

The electric drive concept is not new. For example, the Navy's first two large fleet aircraft carriers in the 1920s were powered with electric drive. Today, electric ship technologies are being built into the Lewis and Clark-class dry cargo/ammunition ships, the new amphibious assault ship *Makin Island* and the future Zumwalt-class destroyer.

"The flexibility in an electric ship to make use of existing power-generation assets [such as gas turbine engine-generator sets] would help with reducing fuel consumption," Petersen said. "The enablement of future mission loads through increases in power, if needed, is also realized through adopting electric ship technologies."

The flexibility offered by the electric ship is magnified by improvement in component designs in motors, generators, power transmission, power conversion and electrical storage.

A Tale of Three Motors

The Zumwalt destroyer is being designed as the vanguard of new electric ship technology. Originally, it was designed to be powered by a new electrical motor design, the Permanent Magnet Motor (PMM) designed by DRS.

Advantages of a PMM, Petersen said, include high power and torque density and reduced weight and size compared with a conventional induction motor. A disadvantage "is the inability to turn off the magnetic field in the event of a fault, which could lead to a shipboard safety hazard."

The PMM encountered developmental setbacks, so the Navy decided to fall back to the Advanced Induction Motor (AIM) built by Converteam's U.K.-based naval technology sector for at least the first two of the three planned Zumwalts. The Navy is reconfiguring its Philadelphia facility to test the AIM.

"As a means to manage program and technical risk, the decision was made at that time based on technical maturity of the advanced induction motor versus other candidate technologies," Petersen said. "Induction motors have a more robust, mature design compared to other technologies. Additionally, the motor has a proven record over decades of operational use in the commercial industry and in the British Ministry of Defence."

Induction motors have lower power and torque density compared with newer types of motors. The Converteam AIM also is twice the size of the PMM.

A full-scale engineering development model (EDM) of the PMM was successfully tested to full power at the Philadelphia facility in June 2008. The Navy currently has no full-scale acquisition plans for the PMM. However, "PMM technologies at a smaller scale have been investigated for potential application to hybrid propulsion and as auxiliary propulsion motors," Petersen said.

Too late for initial consideration for the first two Zumwalts is the High-Temperature Superconducting (HTS) motor designed by American Superconductor (AMSC), Devens, Mass. A preproduction HTS was successfully demonstrated at full power earlier this year at Philadelphia.

The HTS motor uses virtually resistance-free ceramics for electrical transmission.

"Without stressing other parts of the motor design, this superconductor wire basically takes a synchronous motor that's been around for a hundred years and allows us to miniaturize this thing by two-thirds," said John Ulliman, AMSC's president of business development and government relations. "Standard motor technology and design with superconductor wire allows a significant decrease in size and weight. And we can apply it to generators and cables as well as motors."

Advantages of the HTS include "high power and torque density, reduced weight and size compared to other motors and generators," Petersen said.

Disadvantages of the HTS include the relatively high cost of superconducting magnet wire, lack of shipboard experience with handling and operating with cryogenics, he said. A cryogenic system is required to cool the motor coils.

AMSC spent $150 million over 17 years to develop HTS, said Dan McGahn, the company's senior vice president and general manager.

"This is the first motor to really pass all of the Navy's requirements that have been set forth for electric drive technology," he said.

The HTS is 30 percent to 40 percent smaller than the PMM.

"Currently there are no acquisition programs targeted to transition this motor, but it may be considered in future ship designs," Petersen said. "There are opportunities and applications for superconducting technologies that the Navy is considering. One application is superconducting degaussing."

AMSC has installed a degaussing system, which nullifies a ship's magnetism to reduce the threat of magnetic mines, on the Arleigh Burke-class destroyer USS *Higgins* for testing and evaluation. Ulliman said the superconducting wiring was 35 tons lighter than conventional degaussing wiring.

AMSC is hopeful that the HTS motor will be a contender for the third Zumwalt and future ships, such as the CG(X), Ulliman said. He said the open architecture of the HTS design and relatively light weight allows it to be a candidate for installation in a variety of platforms.

DRS hopes its successful tests will keep the PMM in the Navy's scan for incorporation in future ships. The company is working under an $8 million program with the Navy "to incorporate the lessons learned from the PMM motor EDM to improve the design [and] make it even smaller and more power dense than the EDM," said Sexauer.

DRS is looking to the CG(X) as a candidate for the PMM and is working with General Dynamics Electric Boat to assess the motor requirements for the follow-on to the Ohio-class ballistic-missile submarine.

Power Distribution

DRS is building the electrical conversion and distribution system for General Dynamics' Bath Iron Works, Bath, Maine, the design agent for the Zumwalt, under a contract worth approximately $15 million. Known as Integrated Fight Through Power (IFTP), the system converts the high-voltage power produced by the ship's generators and converts it to the proper voltages for all of the ship's electrical systems.

IFTP "provides redundant power and isolates electrical disturbances, thereby improving the quantity, quality and reliability of electrical power," Petersen said.

It "allows you to do all of power conversion and redundancies so that you can take that power and move it anywhere in the ship at anytime," Sexauer said.

DRS is scheduled to deliver the first IFTP components to Bath Iron Works in October.

Ellen Kotzbauer, segment manager for federal programs at Schneider Electric's North American Operating Division in Palatine, Ill., said variable-frequency drive motors could improve energy efficiency and reduce maintenance personnel requirements.

Scott Gordon, Schneider Electric's national account manager for federal programs, noted that because ships are ungrounded electrically, a build up of harmonics from components such as variable-frequency drives can wreak havoc with a ship's electric system if not filtered for harmonics.

"To date, no variable-frequency drives manufacturer has been able to meet those standards," he said. "We are pretty close to qualifying our drives with a filter to be with the power quality requirements of any Navy shipboard application."

Directed Energy

Ulliman, speaking of future shipboard weapons such as the electromagnetic rail gun and directed energy weapons, said future warships need an integrated power plant that takes the massive power essential to drive the ship and "instantly redirect that power to your weapons."

Future shipboard radars in the S and X bands also require high amounts of electrical power.

The issue is "switching some absolutely massive power levels in real time with some pretty dynamic switches and very short timelines," said Larry Charette, manager for Navy and Marine Corps programs for Schneider Electric, which makes electrical components for the Zumwalt. "Some of those technologies and components just don't exist today, so it's a question of how are we going to handle those loads moving forward?

"If you fire the rail gun — that's 64 megajoules for 10 milliseconds — that is an enormous amount of energy for an extremely short amount of time," he said. "You're basically borrowing power from the entire vessel to fire a weapon and trying to make that loss of power for that short time element transparent to the vessel.

"The Navy is really in the forefront on this particular engineering area," Charette said. "No one has ever done this before." ■