Contactless DC Battery Charging in Ocean Environments

ELECOMP Capstone Design Project 2021-2022

Sponsoring Company:

General Dynamics – Electric Boat
75 Eastern Point Road
Groton, CT 06340
http://www.gdeb.com

Company Overview:

Electric Boat has a distinguished history, tracing its roots to February 7th, 1899, when the company was established to complete a vessel that would revolutionize naval warfare. Named Holland for its inventor, the visionary Irishman John Phillip Holland, this 54-foot vessel in 1900 became the first commissioned U.S. Navy submarine.

Since then, the Holland's successors have been employed to radically reshape naval warfare and maritime strategy, while contributing to the successful outcome of World War II and play an indispensable role in the country's Cold War victory.

Today, Electric Boat is the design yard and prime contractor for the Virginia-class submarine program. The Virginia class is the first major warship completely designed in a virtual environment, a capability pioneered by the people of Electric Boat. Employing many of the best practices used in the Virginia program, Electric Boat is currently engaged in the development of the Ohio Replacement, the third generation ballistic-missile submarine, which will provide strategic deterrence for the nation well into the remainder of this century. The Ohio Replacement Program represents the future of our company, as we develop new tools and processes to design submarines for the U.S. Navy. Key to our future success will be the new employees who come aboard and learn how to design, build and support nuclear submarines and their undersea systems.

Throughout its distinguished history, Electric Boat has been defined by its people, their skills and the legendary commitment they bring to their jobs. A tangible sense of pride runs through the entire workforce - shipyard trades, designers, engineers and the rest of the disciplines required to produce what is arguably the most complex product built by man.

Technical Directors:

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Project Motivation:

This project will investigate and assess technology options for next generation contactless ("wireless") Direct Current (DC) Battery Charging in ocean environments. Next generation technology/systems are required to provide the platform with the capabilities to recharge external payloads, tethered and non-tethered. The ability to reliably charge/recharge externally hosted payloads without the need for physical mating interfaces will enable changing payloads over time without platform changes, increase platform flexibility and enable new missions. System development to provide a capability that can support a range of voltages and charging component distances in a range of sea water conditions including temperature, salinity and pressure (depth) is required.

Leverage and ruggedization of the emerging technologies being investigated and develop in the commercial industrial base is highly desired. Technologies of interest include:

- EM Induction
- Magnetic Resonance
- Electric Field Coupling
- RF Reception
- Resonant Wireless

Anticipated Best Outcome:

The goal is to develop a contactless DC Charging system concept model for use in ocean environments including applicable components' Technology Readiness Level (TRL) and potential risks for maturity of that technology. The Sponsor will provide the required documentation and guidance on TRL determination and mapping.

Following the system concept model approval, the student(s) will develop a prototype development plan to support a proof-of-concept demonstration. The Sponsor will provide guidance and operational requirements for student use in the execution of this project. To control the transfer of sensitive information, the Sponsor will utilize commercial system-based information and publicly available oceanographic conditions information.

Project Details:

As new unmanned vehicles and platform tethered sensor bodies are being developed and deployed, the ability to maintain DC power systems is becoming more critical. These new and emerging systems will operate at a variety of voltage levels, battery sizes and equipment loads; and will be housed in different host bodies, requiring a flexible, adaptable solution set. The need to be used in ocean environments around the world adds the requirements for compatibility in changing salinity levels, temperature, and pressures (depths).

Research present and emerging methods of high-power contactless DC power transfer to include the following characteristics:

- Sea Water salinity, temperature, and dissimilar material compatibility
- Flexible power transfer levels as required
- Variable contact distances

The goal is to develop a system concept model including applicable components' Technology Readiness Level (TRL) for new technologies and potential risks for maturity of that technology.

Information that will be provided includes:

- Maximum operational depth
- Operational temp range(s)
- Duration of exposure
- Minimum and maximum separation distance
- Maintenance/Accessibility requirements
- TRL definitions and application guidance
- Range of seawater chemistry to be encountered including salinity, PH and clarity
- Metals that may be in use in the platform vicinity to the system (to support dissimilar metals analysis)
- Primary power source type, power levels and wattage
- Charging system notional size
- Payload(s) generic geometries and DC power types and requirements

The following will define the phases of the program:

Phase I (Fall Semester)

1. Student(s) shall present a Project Plan within the first 30 days of Project start, for approval by the Sponsor's Project POCs, that includes the following:
    a. Interpreted goals
    b. Additional Information required from the Sponsor
    c. Project Schedule
    d. Project Milestones to Track Progress
2. Student(s) shall develop a presentation that will be used to document the following:
    a. Research and findings of contactless charging technologies and devices including commercially available systems
    b. The system concept model including applicable components' TRL for new technologies and potential risks for maturity of that technology
    c. Show the engineering and analysis work used in developing the system concept model including recommended further investigations and analysis
    d. Proposed prototype and test approach
    e. Recommended hardware required to fabricate a prototype (breadboard) system for demonstration

Phase II (Spring Semester)

1. If approved, student(s) shall procure required hardware and fabricate their contactless charging prototype and perform laboratory testing
2. Student(s) shall continue to develop their presentation with the following:
    a. Additional engineering analysis results
    b. As possible, document the concept build progress and test results
3. Final Deliverable to the Sponsor shall include the following:
    - Student(s) shall present the final presentation, for approval by the Sponsor in electronic format in its native software (i.e., Microsoft Power Point)
    - Analysis models of the concept including projected heat generated
    - Any ancillary hardware/components that the system may require to interface between the platform and the charging system itself
    - Any laboratory test results and demonstration concept hardware
    - Recommendation for next steps and further work

The project team shall have weekly correspondence (i.e., email, phone calls) with the Sponsor's Project POCs at a time that is mutually agreed upon. In addition to the weekly correspondence, a monthly virtual, or if possible, in person meeting will be held to discuss project status.

Publication of Work:

Student participants will have the right to publish and present information concerning the Project within URI College of Engineering as required by faculty if it is within compliance with all ITAR requirements. Publications or presentations for audiences outside the URI community will be submitted for review and approval to the Sponsor's Project POCs at least 21 days in advance of publication submittal or presentation date. The Sponsor will have this time frame to respond with any clarifications regarding information that might be Sensitive Information or might otherwise jeopardize Sponsor's ability to obtain IP protection for Foreground IP. Student and faculty participants will not disclose information that Sponsor identifies as Sensitive Information or which the Sponsor has identified as that which would jeopardize its ability to obtain IP protection for the Foreground IP.

Hardware/Electrical Tasks:

- Develop system concept model
- Determine electrical components and system interconnection features required to support concept
- Develop proposed prototype and test approach
- Recommended hardware required to fabricate a prototype (breadboard) system for demonstration
- Fabricate prototype system and conduct system testing and demonstration

Composition of Team:

2-3 Electrical Engineers, **US Citizenship Required**

Skills Required:

Electrical Engineering Skills Required:

- DC Power System Design
- DC Power Component Engineering
- System Interconnection (cabling/Harnesses and Mounting)

Anticipated Best Outcome's Impact on Company's Business, and Economic Impact

Opportunities to reduce platform integration costs and complexities for new payload integration. Additionally, the ability to reliably charge/recharge externally hosted payloads without the need for mating interfaces will increase platform flexibility and enable new missions. Understanding the options and limitations of this capability and platform integration dependencies will enable Electric Boat to help guide its development and concept of operation.

Broader Implications of the Best Outcome on the Company's Industry:

In today's shipbuilding environment, shipbuilders must deliver more innovative products and services, reduce costs, improve quality, and shorten time to market, while achieving their targeted return on investment (ROI). To reach these goals, shipbuilders must continually improve how they integrate payloads and systems to become more efficient and productive. Innovation must occur in all dimensions—product, process, and collaboration. The broader implication is for the Navy to save dollars on new system integration.