Advanced AC-DC Power Architectures for Modular Data Center Enclosures

ELECOMP Capstone Design Project 2022-2023

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:

Mike Brawner
Staff Engineer, C5I Systems
mbrawner@gdeb.com
860-867-3665
860-705-1499 (Mobile)

Tyler Balczun
Senior Engineering, Communications Systems
tbalczun@gdeb.com
860-867-3657

Project Motivation:

This Project will investigate, perform technology assessment and develop simulation models of capabilities for next generation enclave level high voltage direct current power systems for mobile data centers.

Mobile, reconfigurable processing enclaves and data centers require stable and reliable high voltage (>400 Volts) dc power. Traditionally, these systems are powered by 3 phase alternating current, and the individual servers/processor convert the ac to dc on a component level vice providing dc directly.

Project will investigate, perform technology assessment and develop simulation models of capabilities for next generation enclave level high voltage direct current power systems for mobile/reconfigurable data centers.

Anticipated Best Outcome:

Goal is to Identify emerging technologies/systems and develop simulation model(s) to provide enclave level stable and reliable high voltage dc power. Goal is to develop a model that can not only provide the required power characteristics but also enable data processing component changes and upgrades while isolating the ac power feed from continual power load re-balancing.

The investigations will include identification and assessment of applicable technologies and components', systems Readiness Level (TRL) and potential risks for maturity of that technology.
The Sponsor will provide the required project information including server types of interest, applicable voltage ranges and desired characteristics and host platform inputs.
The Sponsor will also provide the required documentation and guidance on TRL determination and mapping and trade study approaches.

Students will be expected to deliver the following products as part of this project:

- Project Plan and Weekly Progress Reports
- Technology Assessment Reports
- Simulation Models
- Follow-on Prototype Proposal

Following the system concept model approval, the student(s) will develop a prototype development plan to support a potential proof of concept demonstration.

The Sponsor will provide guidance and operational requirements for student use in the execution of this project. In order to control the transfer of sensitive information, the Sponsor will utilize commercial system based information and publically available oceanographic conditions information.

Project Details:

High speed computer servers and processing enclaves require stable and reliable high voltage (>400 Volts) dc power. Traditionally, these systems are powered by 3 phase alternating current, and the individual servers/processor convert the ac to dc on a component level vice providing dc directly.

As an increasingly number of processing systems are being added to platforms, the capability to provide self-contained, appropriate power is desired. Next generation servers will be even more reliant on stable and reliable DC power. Flexible DC power technology/systems are required to provide the capabilities to enable improved reliability, and hardware arrangement flexibility.

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

- High availability AC-DC and DC-DC Power Supplies and Convertors
- Real time power level and quality monitoring
- Active system management to mitigate quality and outage conditions
- Reconfigurable as modernization upgrades introduces (balancing)

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The following will define the phases of the program:

In Phase I (Fall Semester) of the Project

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

In Phase II (Spring Semester) of the Project

1. Development of detailed models and simulation
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 provide the desired capabilities
    - 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 as long as 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 considered to 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

Electrical Engineering Skills Required:

- AC and DC Power Generation and Management
- Computer Server Architectures
- System Interconnection (cabling/Harnesses and Mounting)
- MatLab and Simulink

Computer Engineering Skills Required:

- None identified

Composition of Team:

2-3 Electrical Engineers

US Citizenship Required

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

Opportunities to reduce platform integration costs and complexities for new payload integration

The leverage of the commercial (COTS) data center developments can enable increased platform system processing capabilities without custom development of the underlying power infrastructure. Current systems result often in inefficient use of ac-dc converters and the need for the systems to integrate power conditioners and UPSs to ensure power is suitable.

Electric Boat will benefit by increasing our system design and concept development capabilities and enabling next generation systems to be integrated into platforms with manageable

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 in order 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.