ELECOMP CAPSTONE
VIRTUAL SUMMIT
TUESDAY, MAY 10, 2022

THE UNIVERSITY OF RHODE ISLAND

THINK BIG WE DO™

Contactless DC Battery Charging

Contactless DC Battery Charging in Underwater Environments

GENERAL DYNAMICS
Electric Boat

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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 untethered. 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. This device also will enable our Navy to defend our freedom and lifestyle from tyranny. By having submarines and other Navy and military assets Russia and other countries are deterred from such hostile actions.

Key Accomplishments

Key Technical Accomplishments, Research and Findings:

- EM Induction: Inductive charging is a type of wireless power transfer that uses electromagnetic induction to provide contactless electrical power transfer to portable devices. The equipment can be placed near a charging station or inductive pad without needing to be precisely aligned or make electrical contact with a dock or plug.
- Resonant Inductive Coupling: Resonant inductive coupling is the near field wireless transmission of electrical energy between magnetically coupled coils, which is part of a resonant circuit tuned to resonate at the same frequency as the driving frequency. Power transmission efficiency is higher when the transmitter coil and the receiver coil are in close proximity to each other, and the fields are aligned.
- Inductive Wireless Power Transfer systems utilizing resonant coils enables an efficient power transfer over a large separation between a primary and a secondary, as well as allows a high degree of misalignment between coils. The high-Q coils are typically made of Litz wire, which exhibits lower skin and proximity effects. Another advantage of resonant systems is that autonomous underwater vehicles of different coil sizes can be charged with a single primary.

Down-selection Using Pugh Matrix Diagram: Our Pugh Matrix Downselection Diagram was used to list all of our technologies and decide which technology we will ultimately use for our project prototype. We had categories for Distance, Efficiency, Alignment, Cost, Environment Compatibility, Operating Lifespan and Feasibility and then weighed each category so we could compare the different technologies.

Project Plan: We made a Project Plan so that we could keep track of what we needed to do and when we needed to do it to get our project finished on time. It acted as a schedule for us so that we could stay on track and not fall behind. Our project plan was broken down by weeks which we put in the "dates column" and then we had our "Items to be Worked on" column with each item's number that would correspond to a list of tasks we needed to complete. Our last column was for "Anticipated Milestone Competition" which was for the biggest tasks we called milestones.

Prototype Design Using Ansys Maxwell Simulations: We used Ansys Maxwell in order to design and simulate multiple coil designs with different ferrite cores. Coils were analyzed at different separation distances and compared based on efficiency and alignment tolerance. The results of a H-field simulation using our chosen coil design are shown **(Fig. 4)**.

Prototype Proposal: The Team developed a template to document all topics required and created a google slides presentation for our Prototype Proposal. This Prototype Proposal was submitted to the Technical Directors for approval. The slides consisted of information on our project's purpose, overview and scope to establish the background information. The team mentioned the different responsibilities and their roles in completing those tasks. For the main part of the proposal, the team addressed the system description and inserted block diagrams **(Fig.1)** for visual reference. Lastly, the team added the list of materials and the building approach and testing strategy.

Produced Required Hardware to Fabricate Project Prototype (Fig. 2 + 3):

- Litz Wire: Litz wire is a type of multistrand wire used for alternating current at high frequencies. The wire is made of many thin wire strands which are insulated and woven together in a specific pattern which equalizes the proportion of the overall length over which each strand is on the outside of the conductor. This patterned winding helps to equally distribute the current throughout the wire and reduce skin effect.
- Ferrite Core: A ferrite core is a magnetic core composed of ferrite. It is used for high magnetic permeability coupled with low electrical conductivity. This will help prevent eddy current loss in our wireless power transmission system.

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.

Project Outcome

We have achieved our Anticipated Best Outcome. As we have fabricated and tested a prototype that was successful in wireless power transfer in an ocean environment.

Figures

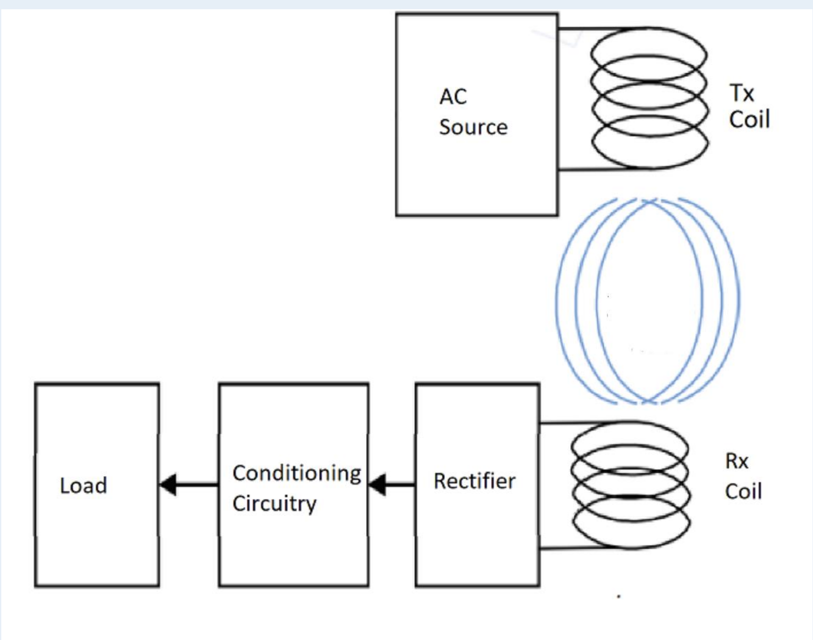

Fig. 1: System Block Diagram

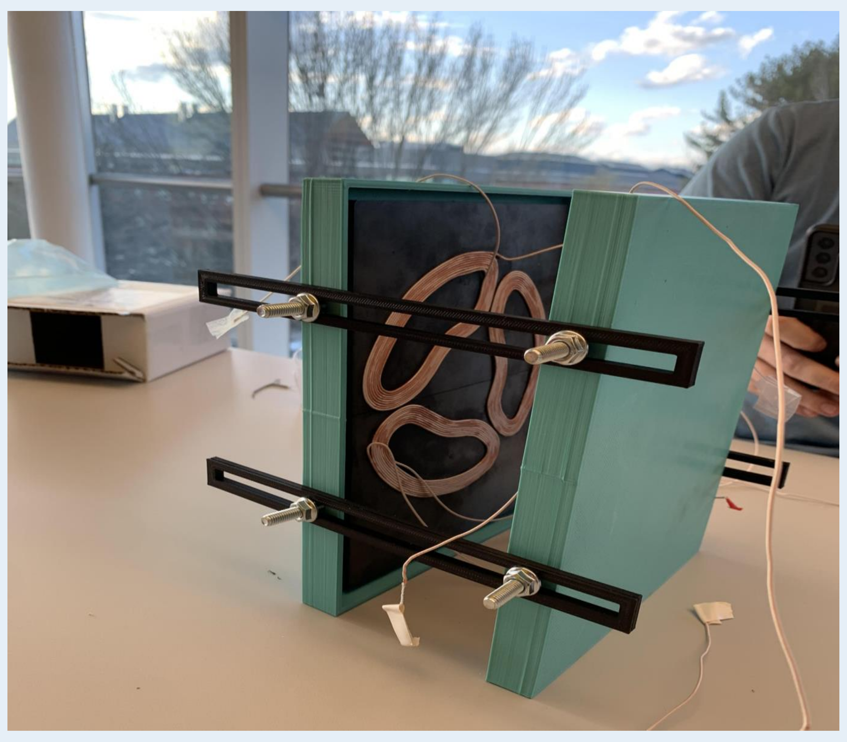

Fig. 2: Primary & Secondary Coils in Test Mount

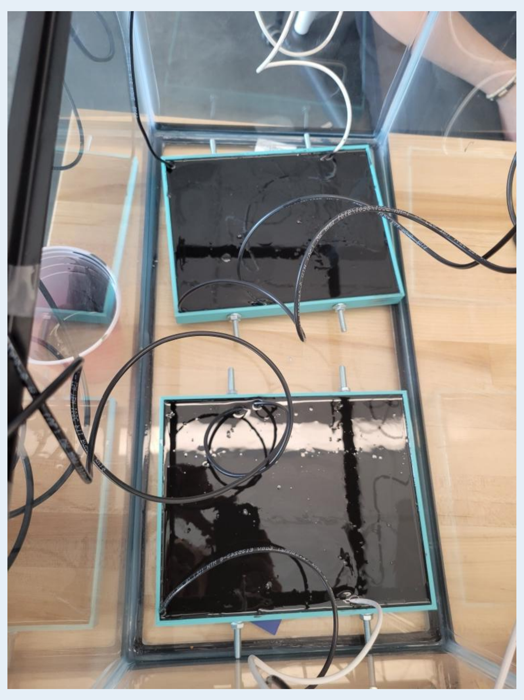

Fig. 3: Primary and secondary coils potted

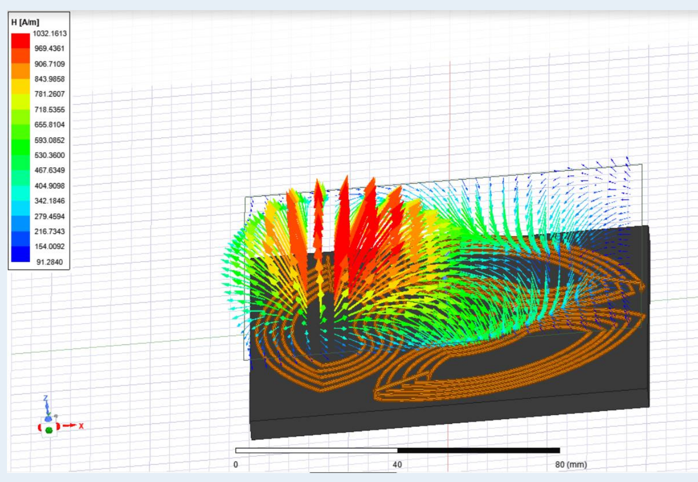

Fig. 4: H-field simulation of chosen coil design