DALHOUSIE UNIVERSITY
FACULTY OF ENGINEERING

Team Members:
Mazen Ibrahim, Khalid El Yaacoub, Connor Dawe
External (Client) Supervisor: Deepak Jagannathan
Internal Supervisor: Jean-Francois Bousquet

MOOG FOCAL™

Department of Electrical and Computer Engineering

Subsea Contactless Connector

Introduction

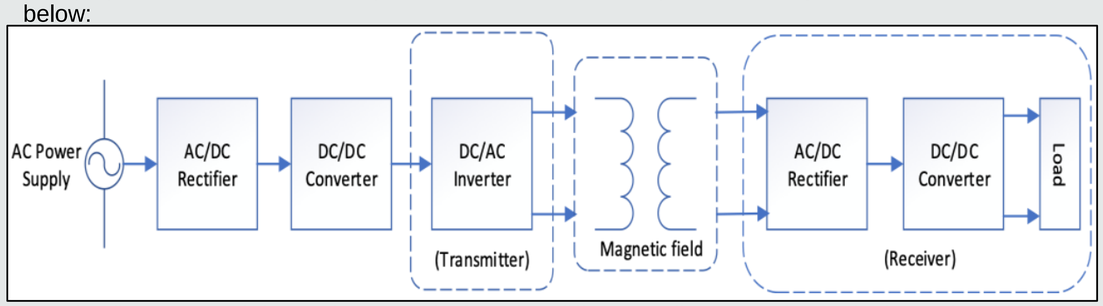
As Autonomous Underwater Vehicles (AUVs) become more technologically innovative, high efficiency and improved reliability are important requirements for Underwater Power Transfer (UWPT) solutions. Under supervision from Dalhousie and Moog Focal, the main objective of the senior year project is to design and prototype a feasible contactless subsea connector for offshore applications. This project was introduced to the 2019/2020 Capstone design team that have completed the preliminary research regarding possible power and communication module design. The goal of the current Capstone team is to optimize and enhance the design by scaling up the power transfer to 1kW while cooperating with the Mechanical Capstone team to reach a feasible connector solution that satisfies our client at Moog Focal.

Design Process

- Subsea Connector design divided into two stages: 1) Transmitter & Receiver coils, 2) Transmitter & Receiver power electronics.
- Matlab utilized to design and simulate the Transmitter and Receiver coils. Simulations include calculating coil inductances, outer diameters, effective distance between the two coils, and testing the power transfer efficiency.
- Final helical coils design simulation finalized and approved by the Mechanical team to meet physical housing constraints.
- Coils designed to support 1.2 kW of power transfer at approximately 76% efficiency.
- LTSpice used to design the power electronics and produce comprehensible circuit schematics.
- Circuit simulations included: an AC to DC Rectifier for the transmitter and receiver side, a Full MOSFET H Bridge connected to the Bridge Driver, and a preliminary DC to DC converter.
- Remaining electronics components such as Bridge Driver, DC/DC converters, transistors, diodes, and capacitors will be ordered externally.
- The final stage of the project's design process is to acquire the client's approval on the completed circuit schematics.

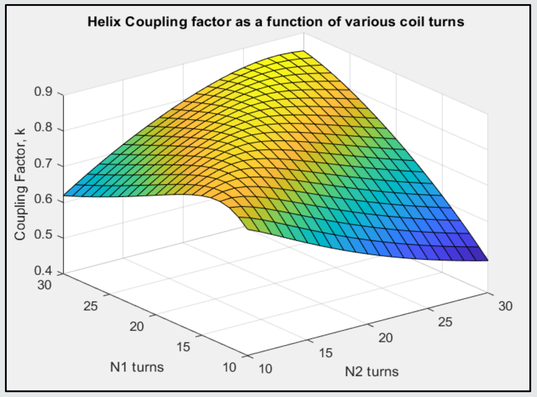
Details of Design

- The project followed the same system architecture as the previous design team; which can be seen below:

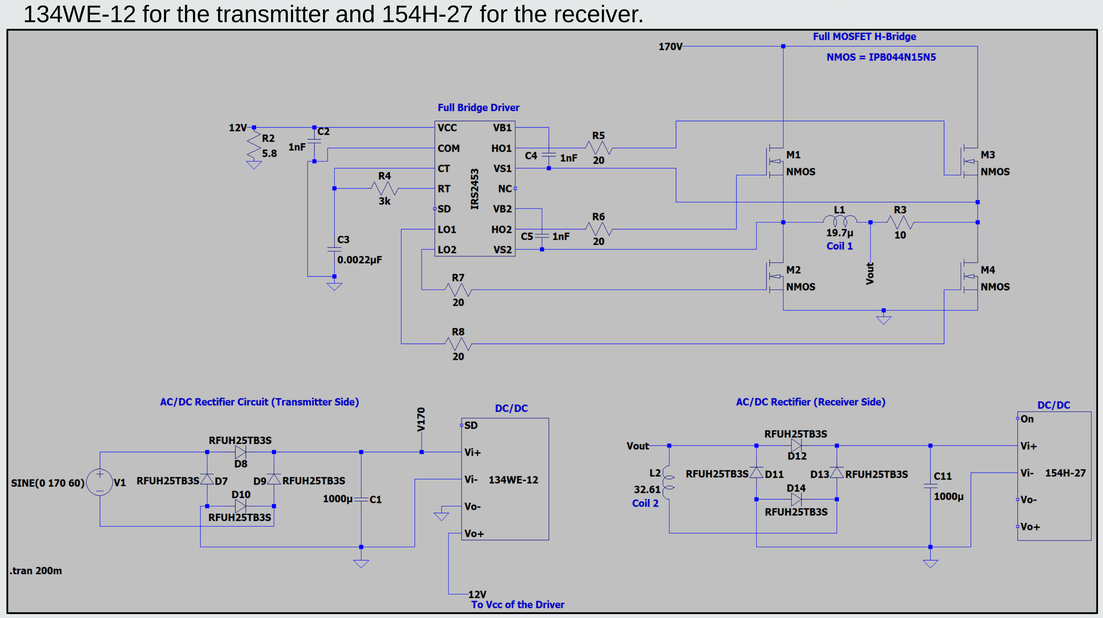


- For the first stage of the project, we designed 3 different coils. From these designs, the third design was chosen to meet the mechanical teams' constraints. The design parameters of the chosen coils are shown here:

Design 3	
Gauge 5 Wire (0.1819 inches diameter)	
Coil 1: Do1 = 3.8 inches	N1 = 25
Wire diameter, W	0.1819 in
Turn Spacing, S	0.207 inches
Wire length	298.451 inches
Coil Height, H	9.722 inches
Inductance, L1	19.74 uH
Coil 2: Do2 = 5 inches	N2 = 25
Wire diameter, W	0.1819 in
Turn Spacing, S	0.2073 inches
Wire length	392.7 inches
Coil Height, H	9.73 inches
Inductance, L2	32.61 uH
Total Power Loss	**33.09 W**
CA1 & CA2 = 2.2	



- For the second stage, we designed and simulated our circuits using the LTSpice software. To achieve high efficiency, we used an IRS2453 for our H-Bridge driver while also using two DC/DC converters; 134WE-12 for the transmitter and 154H-27 for the receiver.



Conclusion and Recommendations

In conclusion, current power delivery systems for Autonomous Underwater Vehicles (AUVs) are expensive and require frequent maintenance. The goal in this project is to remove the need for frequency maintenance by providing a contactless transfer of power, improving the efficiency of the device, while keeping costs low. We were successfully able to design the power coils on the expected time in cooperation with the Mechanical Capstone team. On the other hand, the power electronics designed took longer than expected as we had certain setbacks in some of our initial designs that were not approved and so had to be redesigned. In addition, we spent a lot of time modelling and designing our circuit based on a driver that was later on found to be unavailable for purchase meaning that we spent a lot of time working on something that cannot be bought. Thus, we did not have enough time to be able to purchase physical components and assemble them together for a physical prototype for delivery. Instead, we provided working simulations of individual parts of our design and the full schematic such that they can be bought and assembled in the future.

Our recommendations for this project:

- Always ensure that a physical part component can be bought before spending time designing the circuit around it
- Allocate a lot more time for the power electronics design over the coils design as this was the most difficult aspect of the project
- Always consult with the Mechanical team at every step of the design process to ensure a physically feasible design
- Always contact the client to address any design concerns of the project to resolve the issues as fast as possible

References

- Tantos, A. (2012, April 12). H-Bridge Secrets. *Modular Circuits*. https://www.modularcircuits.com/blog/articles/h-bridge-secrets/
- *Wire Gauge and Current Limits Including Skin Depth and Strength*. American Wire Gauge Chart and AWG Electrical Current Load Limits table with ampacities, wire sizes, skin depth frequencies and wire breaking strength. https://www.powerstream.com/Wire_Size.htm.
- Carvajal, A. J. (2018). *First principles design of coreless power transformers.* (Doctoral dissertation, Massachusetts Institute of Technology).
- Physical coil parameters calculator: http://deepfriedneon.com/tesla_f_calchelix.htm