Electric Ferry Wireless Charging

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Project Number
9

AUT

Overview

To develop a viable concept for a wireless power transfer coupling suitable for use on an electric ferry.

Driven by the need for cleaner and more renewable alternatives to fossil-fuels.

Power Requirements

- Charging times required to be maximum of 4-5 minutes at each stop.
- A large amount of power to be transferred in that duration.

The example shows the power required for a 400KWh battery pack:

$$400KWhx\frac{1}{15}hours = 6MW$$

Benefits

Wireless vs. Wired & Fossil Fuels

Cleaner & Greener
Alternative to current fossil-fuels

Repair & Maintenance
No exposed charging contacts or elaborate coupling

Safety
Personnel remote from charging area. Intrinsic galvanic protection.

Reduced Charging Time
Can start before vessel has berthed and continue until departure.

Cost
Reduced capital outlay on infrastructure and coupling method due to simplicity.

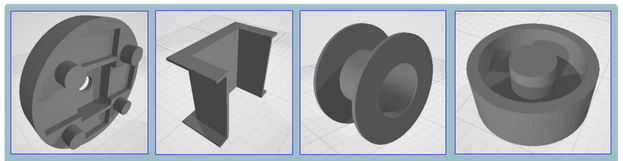
Operational Considerations

- Safety of passengers and crew
- Maximise charge in 4-5 minutes
- Minimal crew interaction
- Charge delivered while docking

GOAL
No impact to current ferry scheduling

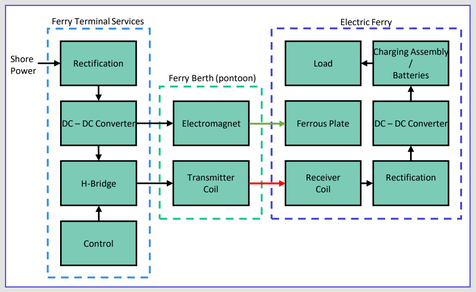
Design

- To develop a viable concept for a wireless power transfer coupling suitable for use on an electric ferry.
- Increase coupling coefficient for efficiency of power transfer.
- Transfer at high frequency to maximise power transfer over short duration.
- Minimise complexity to reduce capital outlay and maintenance costs.
- Minimise footprint required at ferry pontoon/berth.

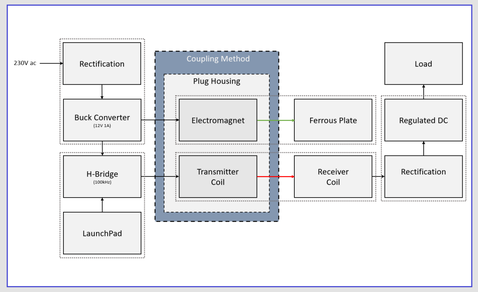


Plug Cap | Transformer Bobbin | Electromagnet Bobbin | Electromagnet Housing

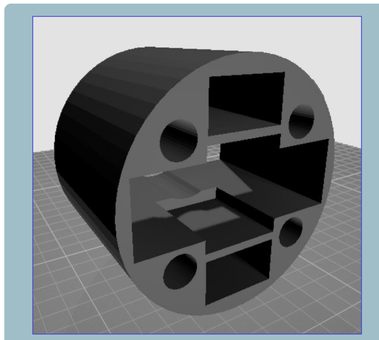
Charging System Block Diagrams



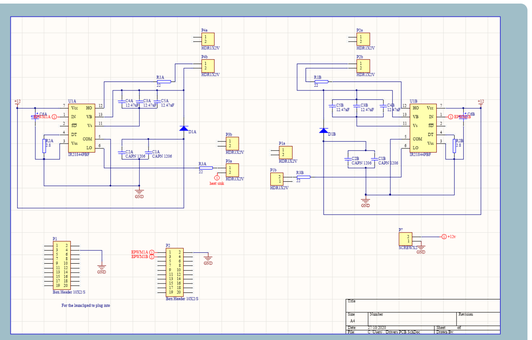
Full Scale Charging system



Scaled Project Charging System



Coupling (Plug) Housing



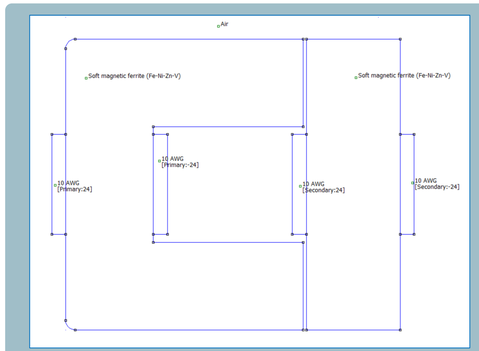
H-Bridge Circuit Schematic

Simulation

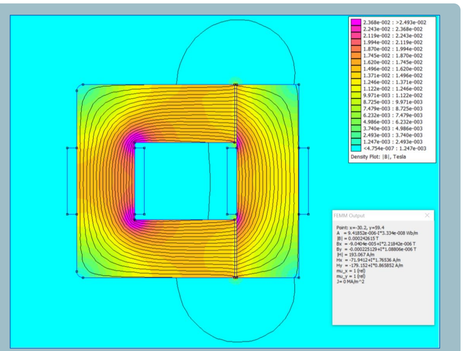
- Various software suites were used for modelling and simulation.
- Different software was used to ratify results and confirm trends.
- Variables were adjusted to trend power transfer efficiencies:
  - Airgap width
  - Number of windings
  - Materials

Findings

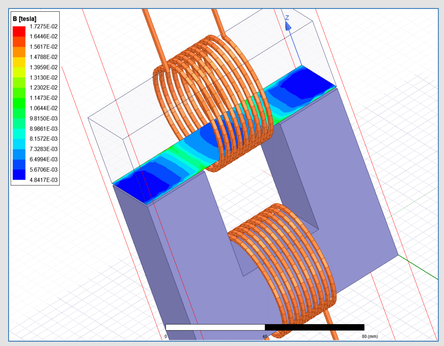
- Ferrite core best due to its high magnetic permeability and low electrical conductivity (prevention of eddy currents)
- Reduction in airgap to reduce reluctance and flux-fringing.
- Reduction in airgap increases coupling coefficient, 'k'.



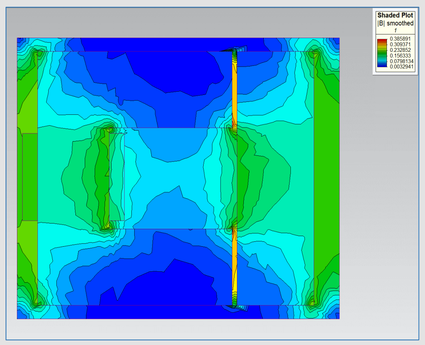
FEMM – 1mm Airgap Model Setup (boundary area not shown)



FEMM – 1mm Airgap Simulated Results



Ansys Maxwell – 1mm Airgap Sheet Effect (magnetic)



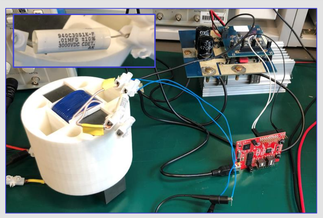
SimCenter MAGNET – 1mm Airgap Simulated Results

Project Build

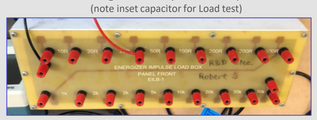
- Litz wire used – reduction of losses from skin and proximity effects.
- 28 turns used – 2 layers of 14 turns each.
- N-87 ferrite used for cores – as frequency at 100kHz.
- LaunchPad used for control – H-Bridge frequency control

Project Testing

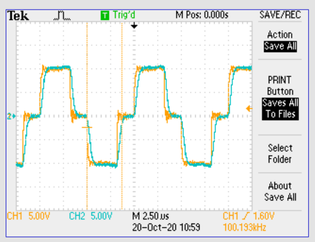
- Coupling coefficient of 0.92
- Capacitance applied to primary when connected to load resulting in excellent power transfer – compensation for leakage inductance.
- Proof of Concept.



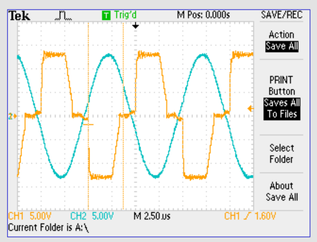
Plug Assembly Test Setup
(note inset capacitor for Load test)



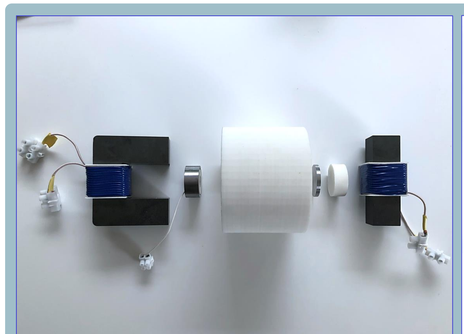
Simulated Load



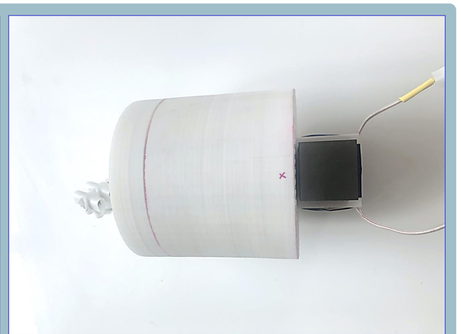
Test at No-Load



Testing under Load



Plug Assembly Constituent Parts



Assembled Plug Assembly