Design of a Wireless Ultra-fast Charger for Electric Vehicle

Jacopo Colussi

Supervisor: Prof. Paolo Guglielmi

ScuDo — Scuola di Dottorato ~ Doctoral School — WHAT YOU ARE, TAKES YOU FAR

XXXIV Cycle

Research context and motivation

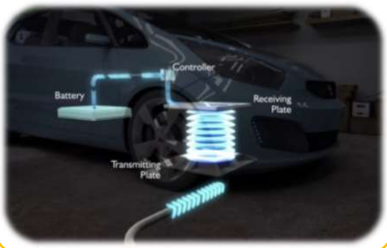
ASSURED

100kW Static Fast Wireless charging system:

- Optimised electric van demonstrator with optimized fast wireless charging system;
- Efficient charging system;
- High Interoperability with different OEM solutions;
- Interoperability with other wireless charging systems.

Static Wireless Power Transfer

- No Battery to Ground Connection needed;
- No active On board converter needed;
- Possible Trasmitter to Receiver auto-alignment;
- High efficiency;



Addressed research questions/problems

Transmitter Side Resonant Capacitors

- Study of the Topology of compensation;
- Design of Power Film Capacitors.

DC-AC High Frequency Converter

- Feasibility Study of different topologies of DC-AC converter;
- Design of the Converter;

DC Supply

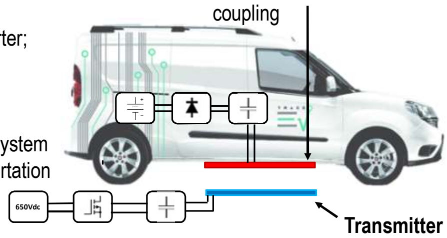
- Possible integration of the system in the urban electric transportation grid;
- No other Active Converters needed

Receiver Side Resonant Capacitors

- Study of Topology for compensation;
- Secondary side impedance matching.

Receiver Coil

- Analysis of different topologies function of transmitter design;
- Study of the Transmitter/Receiver coupling

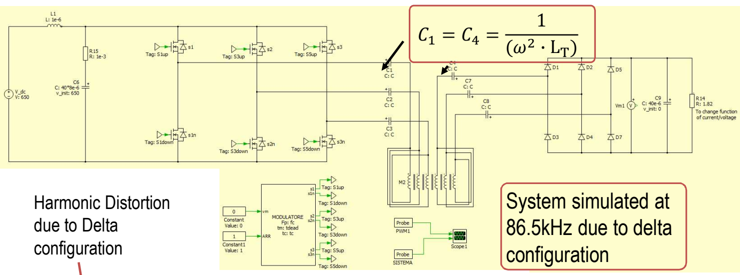


Transmitter Coil

- Study of different Topologies of Coil's geometries;
- Calculate the coupling Parameters;
- Design and optimize the structure

Adopted methodologies

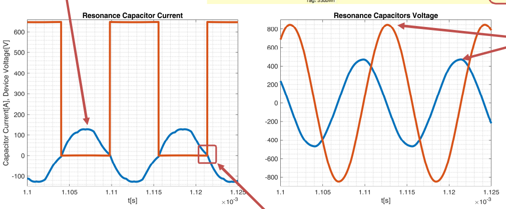
Feasibility study of the Three-Phase system. Delta connection for Electromagnetic system is used to improve the Power and reduced voltage over resonance capacitor.



$$C_1 = C_4 = \frac{1}{(\omega^2 \cdot L_T)}$$

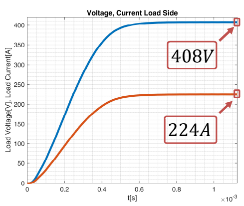
Harmonic Distortion due to Delta configuration

System simulated at 86.5kHz due to delta configuration

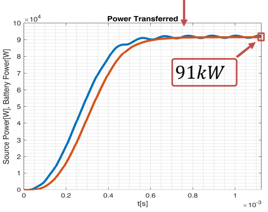


Low peak voltage in resonance capacitors thanks to Delta configuration

Source Power and Load power comparison



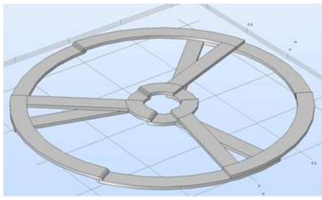
- Zero Current Commutation achieved switching at resonance frequency
- Dead Time: 100ns
- Duty cycle: 0.5



Phase Shift Control Implemented starting with $DutyCycle = 0$ to avoid current overshoot during the start-up.

Novel contributions

Design of a **Three-phase Electromagnetic Structure.** Working Frequency Fixed to 85kHz.

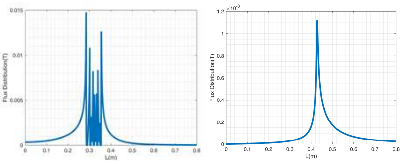


Analytical design of Mutual Inductance

$$M = \frac{(8 \cdot vdc \cdot v_{battery})}{(\pi^2 \cdot \omega \cdot P_{battery})}$$

Design of the Electromagnetic structure starting from desired mutual inductance and the chosen resonance capacitor.

T-self-inductance	L_T	$20.21\mu H$
T-mutual-inductance	M_{TT}	$44nH$
R-self-inductance	L_R	$20.21\mu H$
T-R-mutual-inductance-same-phase	M_{TR11}	$9.61\mu H$
T-R-mutual-inductance-different-phases	M_{TR12}	$87nH$
Air gap	D	$5\ cm$
Resonant Frequency	f_c	$85kHz$
Resonant Capacitors	C	$170nF$



Flux Analysis on the transmitter side and above the shield in the receiver side.

Optimized design to avoid the cross coil mutual coupling to maximize the power transferred.

Future work

- **Testing** of the first prototype. Testing of the electromagnetic system and testing of the power electronic board to meet the conformance test regulations.
- Improve the **Control** to achieve soft commutation during startup of the system to avoid switching Losses.
- Electromagnetic system **Optimization** to achieve stability of the system in all operative conditions.

Submitted and published works

- Michela Diana, Jacopo Colussi, Alessandro La Ganga, Paolo Guglielmi, "*An innovative slot cooling for integrated electric drives*", 2019 IEEE Workshop on Electrical Machines Design, Control and Diagnosis(WEMDCD).
- Vincenzo Cirimele, at all , "*The Fabric ICT platform for managing Wireless Dynamic Charging Road lanes*", IEEE Transactions on Vehicular Technology.

List of attended classes

- 01ROERV – Sensorless control of electric machines (21/01/2019, 5)
- 01QORRV – Writing Scientific Papers in English (28/03/2019, 3)
- 02LWHRV – Communication (13/11/2018, 1)
- 08IXTRV – Project management (21/01/2019, 1)
- 01QAAAA – Public speaking (22/01/2019, 1)
- 01QAAAA – Research integrity (30/01/2019, 1)
- 01QAAAA – Time management (28/01/2019, 1)

External Activities

- European PhD School: Power Electronics, Electrical Machines(23/05/2019, 8)