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XXIX Cycle - I year presentation

Inductive Charging System For Electric Road Vehicle

MS Degree with honors in Electrical Engineering

Group of Power Converters Electrical Machines and Drives

PhD Jointly ENSEEIHT – “École nationale supérieure d'électrotechnique, d'électronique, d'informatique, d'hydraulique et des télécommunications” Toulouse – France – GEET – “Genie electrique electronique de Toulouse”

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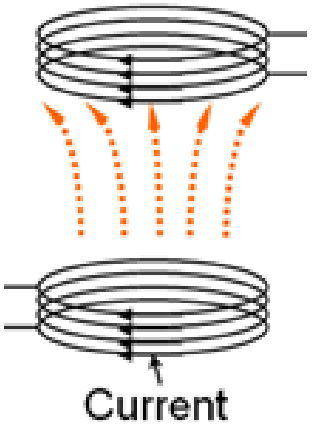
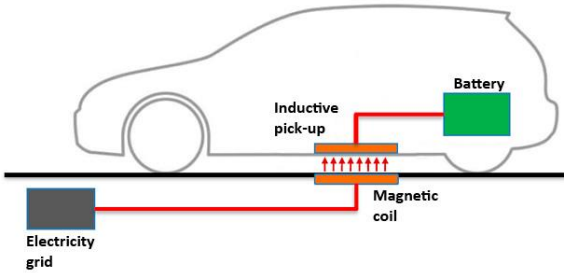
Idea

The main goal is to realize a laboratory prototype suitable for both stationary and dynamic charging. This latter issues can be addressed by using different pads topologies. Several IPT (Induction Power Transfer) systems are proposed in the literature. In particular the single phase double D primary pad, buried under path, coupled with a bipolar (BP) secondary pad installed on vehicle chassis, seems to be promising in order to meet our requirements.

Induction Power Transfer

The *Induction Power Transfer* **IPT** makes possible the power transfer without cables. This solution could be useful to supply an Electric Vehicle (EV). Moreover, the EV charging can occur while the vehicle proceeds on a dedicated path.

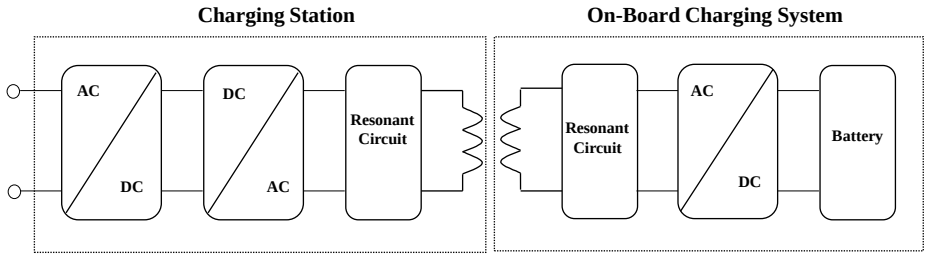




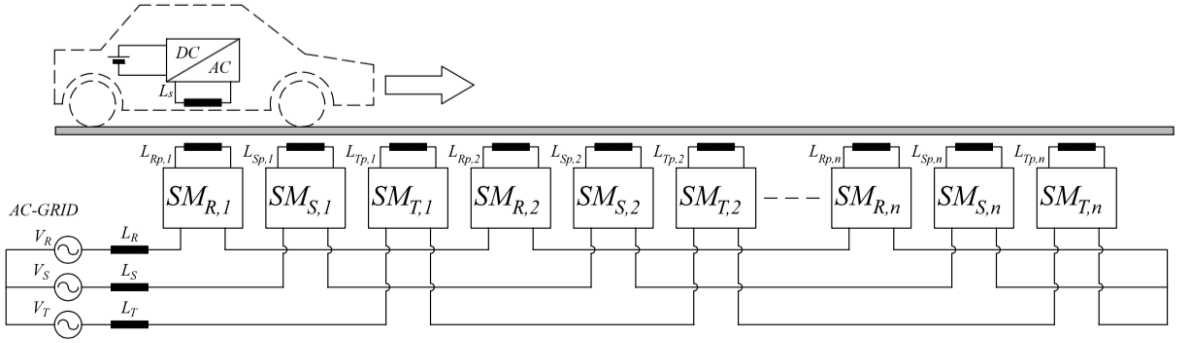
The main advantages are:

1. Undersizing of on board vehicle battery;
2. Reduced cost, weight and fuel consumption;
3. Increased autonomy.

Components of an IPT System



An IPT system is essentially constituted of two electric systems magnetically coupled and powered by a high frequency converter. The IPT system can be both stationary and dynamic, but the magnetic structure usually is not the same. Lamped pads are typically used in the *stationary* applications. In *dynamic* applications, two different solutions can be exploited: i) the primary side consists of an extended loop inductor; ii) the primary side consists of lumped pads arranged in sequence between them.



IPT Theory

IPT systems are well-knowed as "*loosely coupled systems* conceptually" because of a lower value of the coupling coefficient. Moreover, the IPT systems manifest a leakage inductance higher than magnetic inductance. As consequents a compensation circuit is needed to reduce the apparent power supply. The magnetizing current is balanced by means of the resonant circuit added on the primary and secondary side so maximizing the active power transfer to the secondary side of the system. This condition occurs only for a frequency value called resonance frequency.

Limitations of Current IPT

High cost

Low effeciency

Sensitive to vehicle alignment

Large size

Limited distance

Need of:

- Novel designs
- Novel topologies
- Novel methods
- New materials
- New control methods

Coil topologies

In order to realize a laboratory prototype suitable for both stationary and dynamic charging, a proper coil topologies must be chosen.

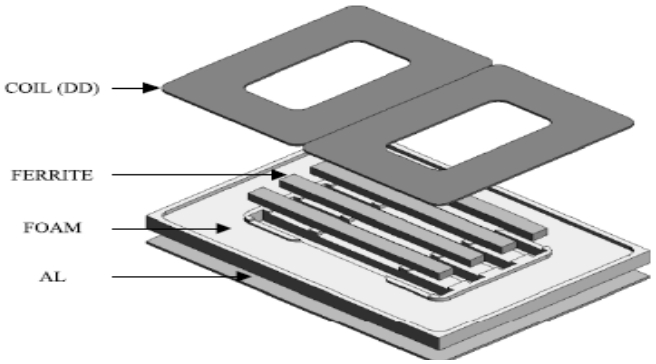
Circular

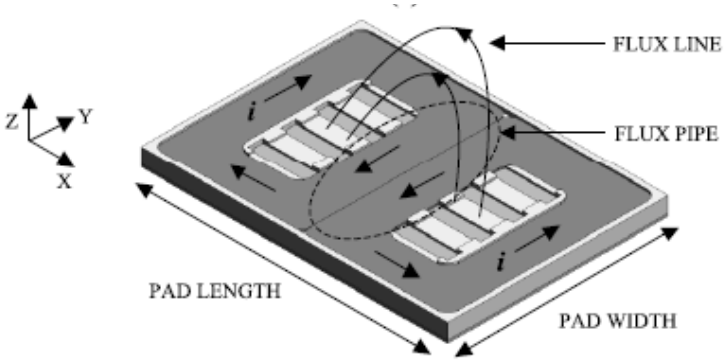
Polarized

- Double D
- Double D Quadrature
- Bipolar

Double-D pad

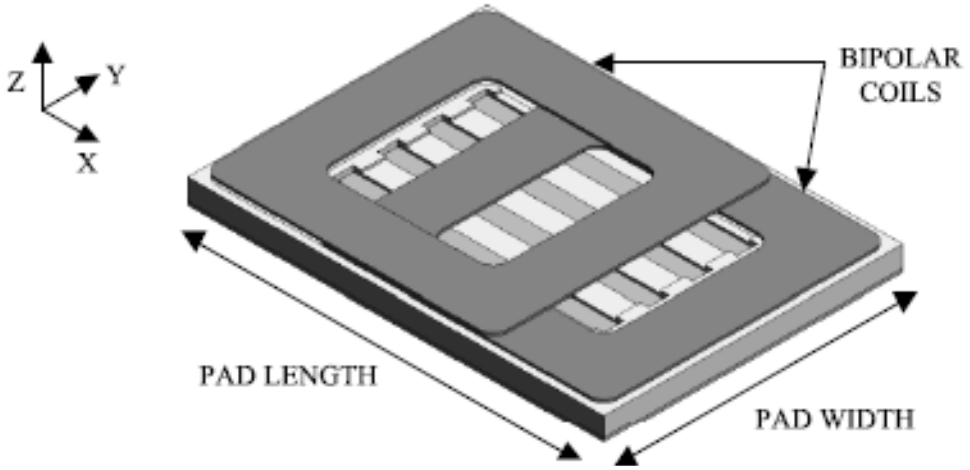
It consists of two complanar coils, some ferrite strips and a sheet of aluminium as support. The two coils are electrically connected in parallel, while they are magnetically connected in series. This arrangement is able to increase the magnetic flux.





Bipolar BP pad

It consists of two identical coils which are partially overlapped and mutually decoupled. In particular the coils are placed on top of ferrrite strips followed by an aluminum back plate. Ferrite must be used in order to channel flux to create a single sided flux pattern and improve coupling. An aluminum back plate is used to block leakage and limit EMI.

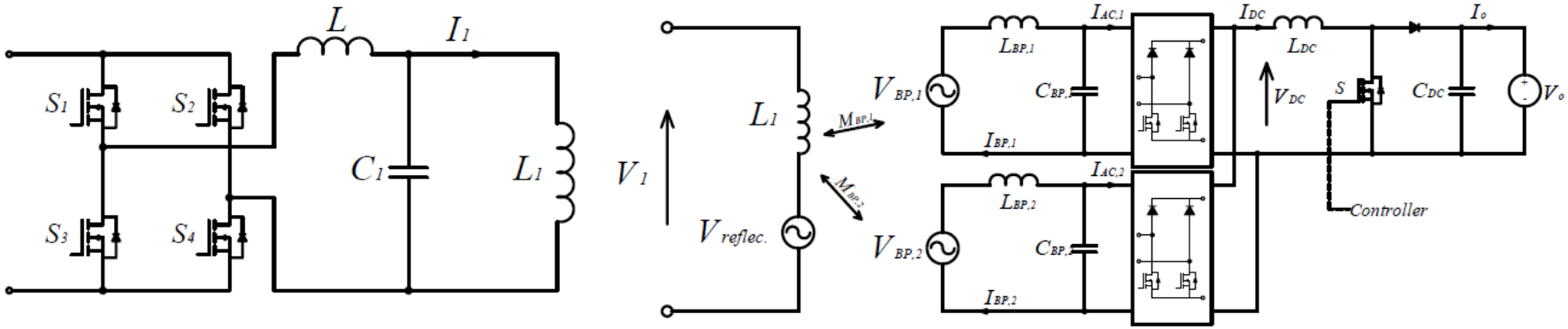


Pad sizing

The mean task is to determine the physical sizes of the primary IPT coupler (buried in the roadway) and of the secondary coupler (mounted on the EV chassis). A noticeable increase of the system performance is can be obtained by a proper choise of the initial physical sizing of the pads. This latter choice allows to reach better performaceswith respect to the use of optimation tecnique.

Power Converter System

The power supply circuit consists of a rectifier and of an H-bridge inverter with an LCL compensation network. The H-bridge inverter could be controlled to generate a high frequency (40 kHz) ac voltage, which is used to supply the primary pad.
Two mutually decoupled secondary coils are used to transfer power from the primary coil. They are parallel compensated thus resulting in two indipendent current sources. The windings are connected in parallel via separate rectifiers to the pickup regulator that can be used to regulate the output voltage V_o and current I_o to the EV battery.



H-Bridge ***Compensation*** ***DD-Pad*** ***BP-Pad*** ***Pickup regulator***

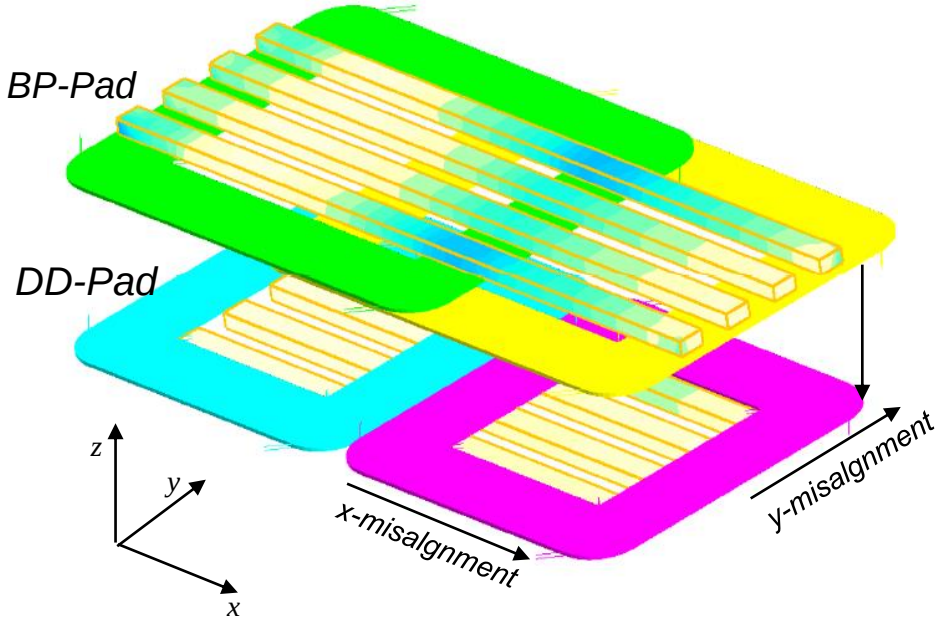
FEM Simulation Tool

The different pad design can be modelled and tested by means of a FEM simulations tool. Thanks a 3D finite element analysis, it is possible to determine the numerical value of the mean system parameters.

Primary self-inductance L_1	Secondary self-inductance L_{BP1}	Secondary self-inductance L_{BP2}	Primary-Secondary Mutual-inductance M_{BP1}	Primary-Secondary Mutual-inductance M_{BP2}
0,168 *mH*	0,365 *mH*	0,339 *mH*	0,112 *mH*	0,108 *mH*

Particular condition:

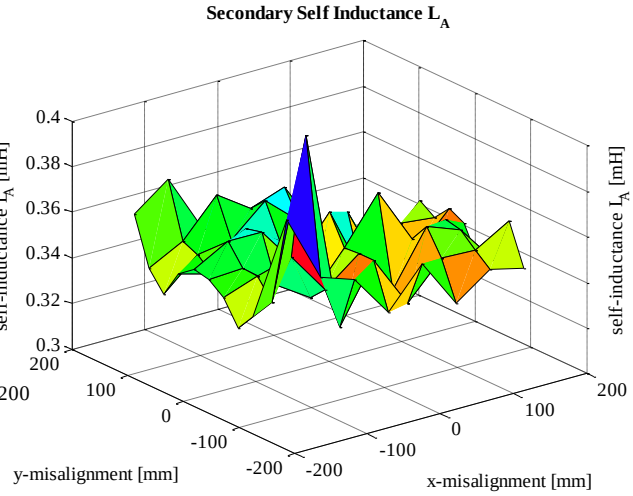
- Air-gap 200 *mm*;
- y misalgnment 0 *mm*;
- x misalgnment 0 *mm*.

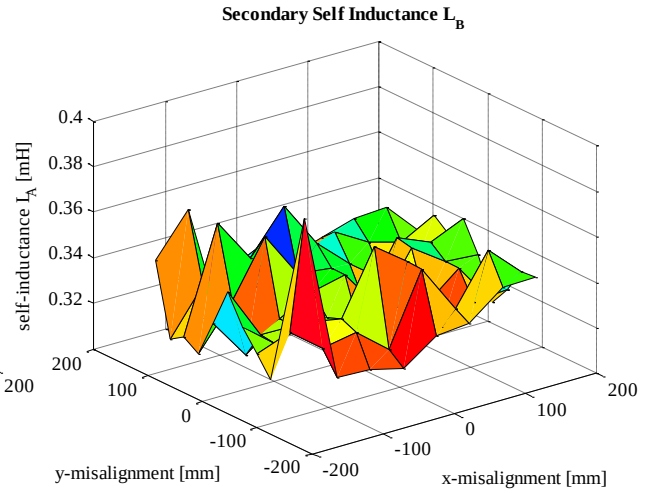


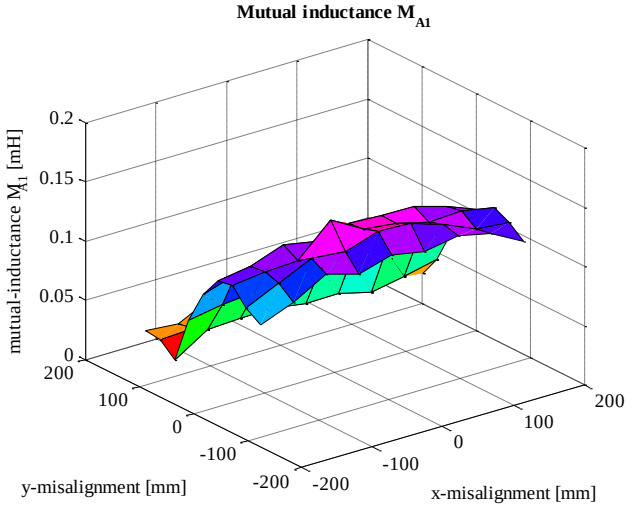
Case Of Study

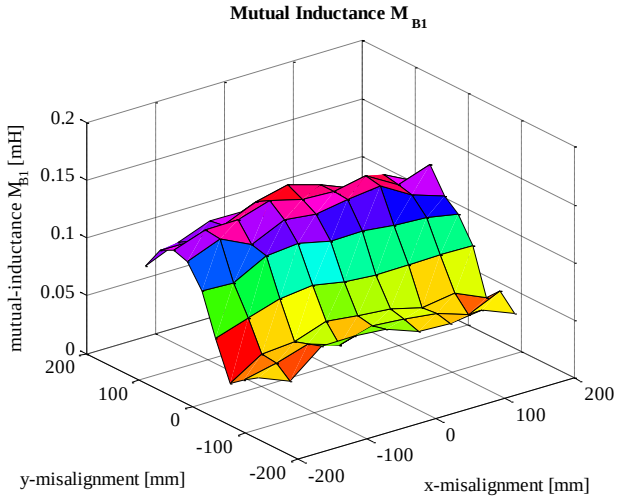
z air-gap [*mm*]	x misalgnment [*mm*]	y misalgnment [*mm*]
150	-186	-106
200	-139,5	-79,5
250	-46,5	-26,5
	0	0
	46,5	26,5
	139,5	79,5
	186	106

Numerical results









First Year and Expected Credits

	Credits year 1								Credits year 2								Credits year 3									
		1	2	3	4	5	6			1	2	3	4	5	6			1	2	3	4	5	6			
	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Total	Check
Modules	21	0	7	9	6	3	0	25	15							0	0							0	25	30-70
Seminars	3,3	0	0	0	2	0	0,4	2,4	3							0	0							0	2,4	10-30
Research	36	3	3	3	3	3	10	25	42							0	60							0	25	80-140
	60	3	10	12	11	6	10	52	60	0	0	0	0	0	0	0	60	0	0	0	0	0	0	0	52	180

Year	Lecture/Activity	Type	Credits	Certification
1	Europrogettazione	Ad hoc module	3	x
1	Misure per l'Ingegneria dei Materiali	MS Module	9	x
1	Modellistica di macchine e convertitori elettrici	MS Module	6	x
1	15th Edition of European PhD School	External Course	3	x
1	Electrodynamic properties of novel materials and devices	MS Module	4	x
1	State of the art in Power Converters for High Voltage DC Transmission Systems	Seminar	0,4	
1	Nano-carbon based components and materials for high frequency electronics	Seminar		