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Theoretical and Experimental Comparison of Two Interoperable Dynamic Wireless Power Transfer System for Electric Vehicles

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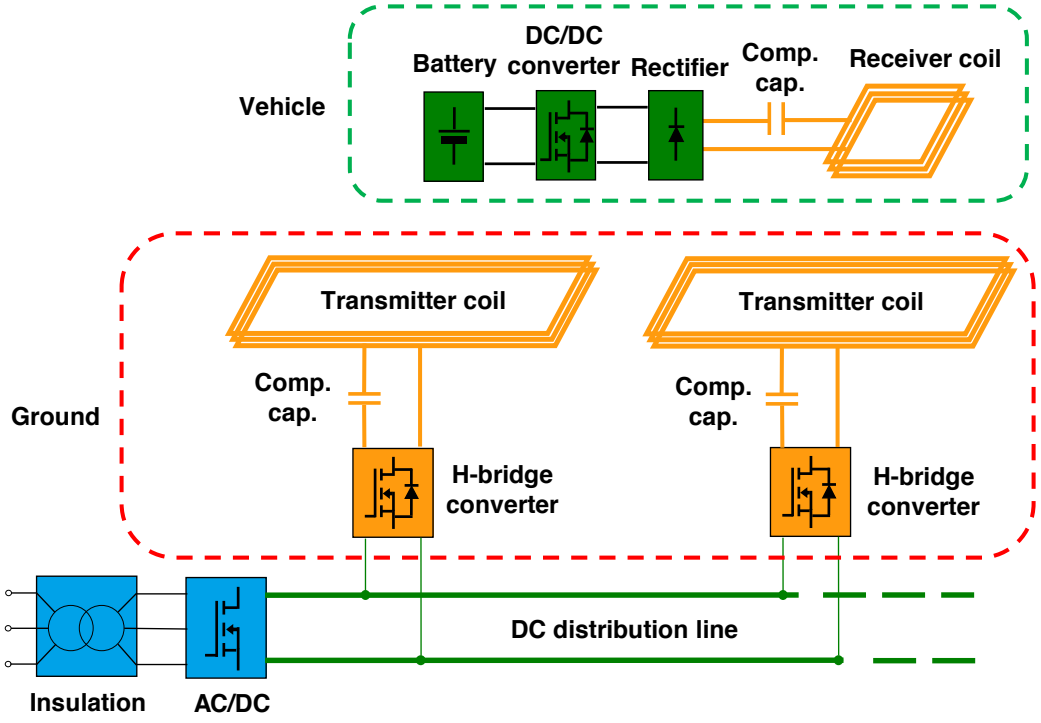
Outline

- Introduction
- SS-Topology theoretical analysis (System A)
- TSS-Topology theoretical analysis (System B)
- Experimental Setup
- Experimental Results
- Conclusions

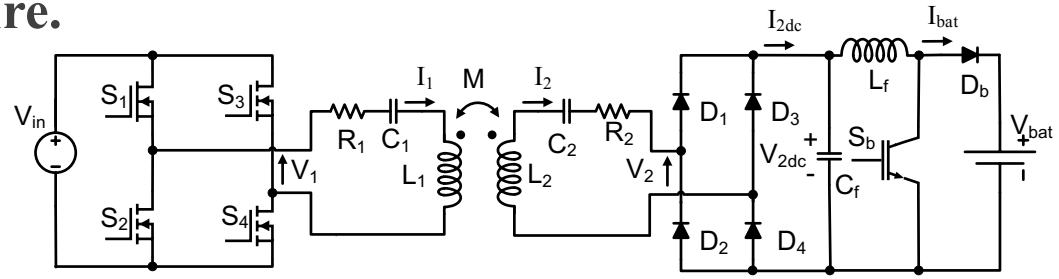
Introduction



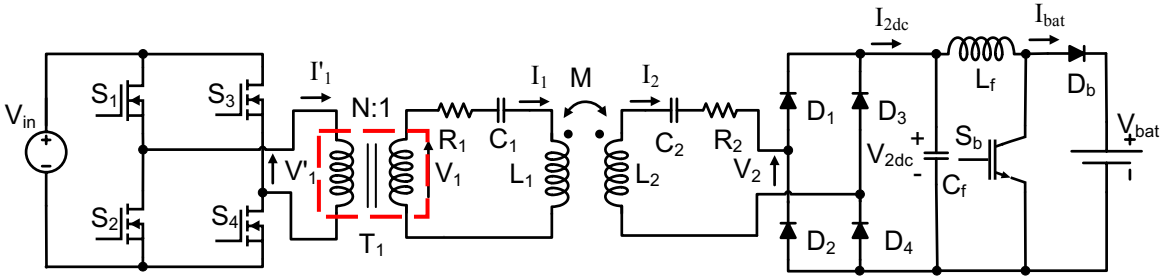
Introduction

- **Series-series compensation have been choosen for two compared systems.**
- **A transformer have been added at the primary side in order to add a degree of freedom in the design.**
- **The comparison between the two systems have been done considering the same receiver structure.**

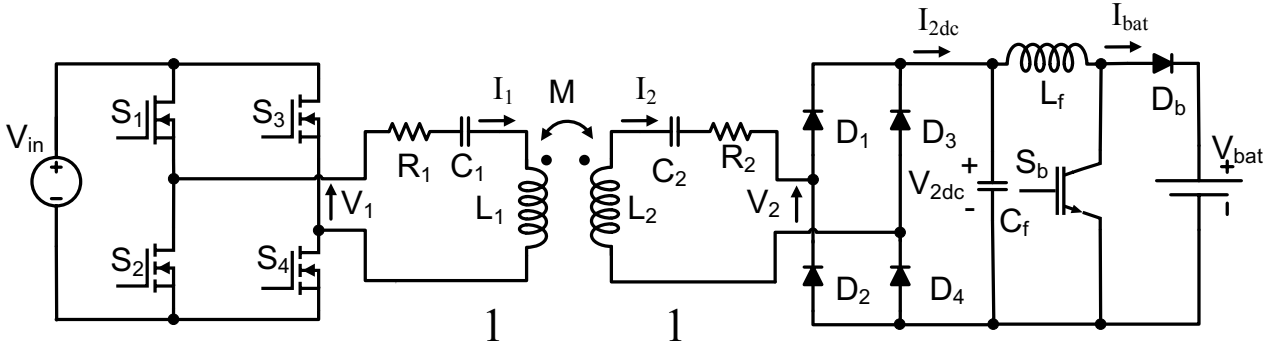
- **SS-topology (System A)**



- **TSS-topology (System B)**



SS-Topology (System A)



$$\omega_0 = \frac{1}{\sqrt{L_1 C_1}} = \frac{1}{\sqrt{L_2 C_2}}$$

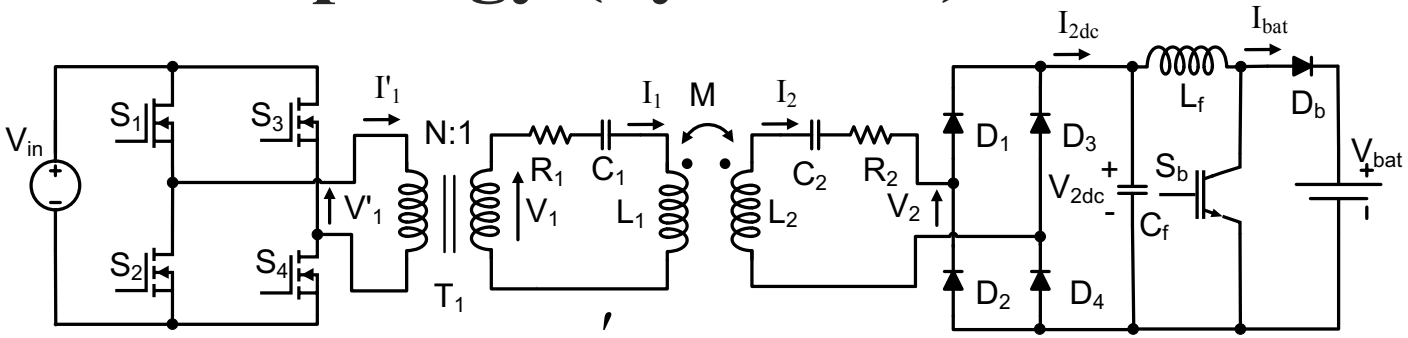
$$\Delta V_{C1} = \frac{I_1}{\omega_0 C_{1sysA}}$$

$$M = \frac{8}{\pi^2} \frac{V_{in} V_{bat}}{\omega_0 P_2}$$

- No losses
- Rectifier at the secondary side
- Maximun battery voltage
- Maximun angle fire at the primary side

- **High voltage (Voltage Rating), high current (Nominal Current) and high frequency (low ESR) capacitor is needed at the primary side .**
- **Find a capacitor that could satisfy all these requirments is an hard task!**

TSS-Topology (System B)



$$I_1 = I_1^{'} N, V_1 = \frac{V_1^{'}}{N}$$

$$M = \frac{8}{\pi^2} \frac{V_{in} V_{bat}}{\omega_0 P_2} \frac{1}{N}$$

M → Same Power → $\alpha \frac{1}{N}$

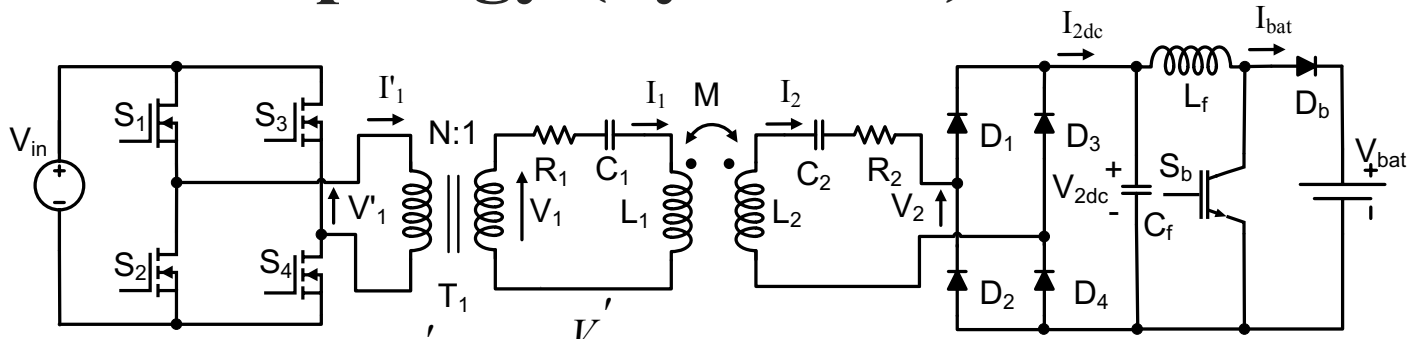
Same receiver => only the trasmitter number of turn could be changed

L_1 → $\alpha \frac{1}{N^2}$

Same resonance frequency

C_1 → αN^2

TSS-Topology (System B)



$$I_1 = I_1' N, V_1 = \frac{V_1'}{N}$$

$$M = \frac{8}{\pi^2}\frac{V_{in}V_{bat}}{\omega_0 P_2}\frac{1}{N}$$

M → Power → $\alpha \frac{1}{N}$

L_1 → Trasmitter → $\alpha \frac{1}{N^2}$

C_1 → Resonance frequency → αN^2

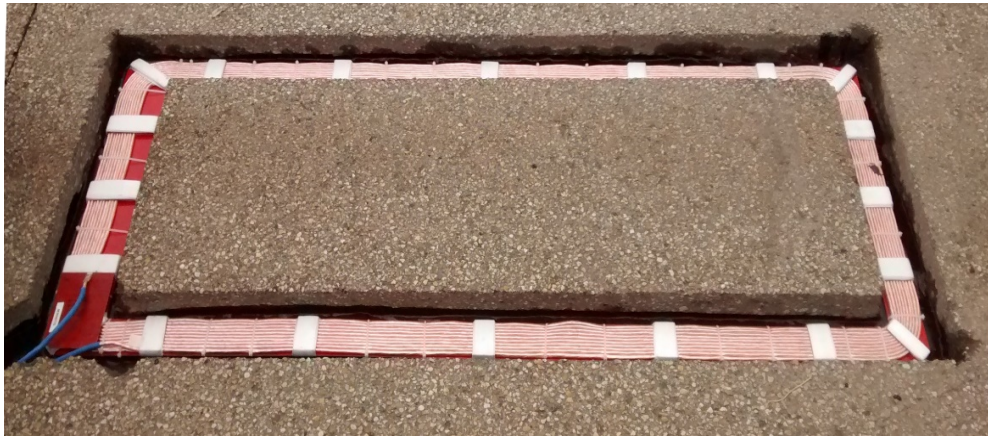
Short-circuit inductance seen at the secondary side

$$\Delta V_{C1} = \frac{I_1}{\omega_0 C_{1sysB}} = \frac{N I_1'}{\omega_0 C_{1sysA} N^2}$$

$$\omega_0 = \frac{1}{\sqrt{(L_{lk} + L_1)C_1}}$$

Experimental Setup

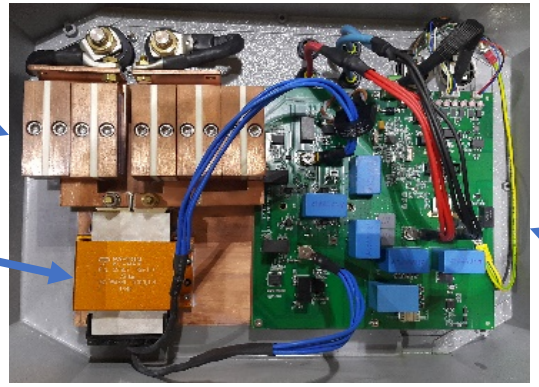
Transmitter (System A)



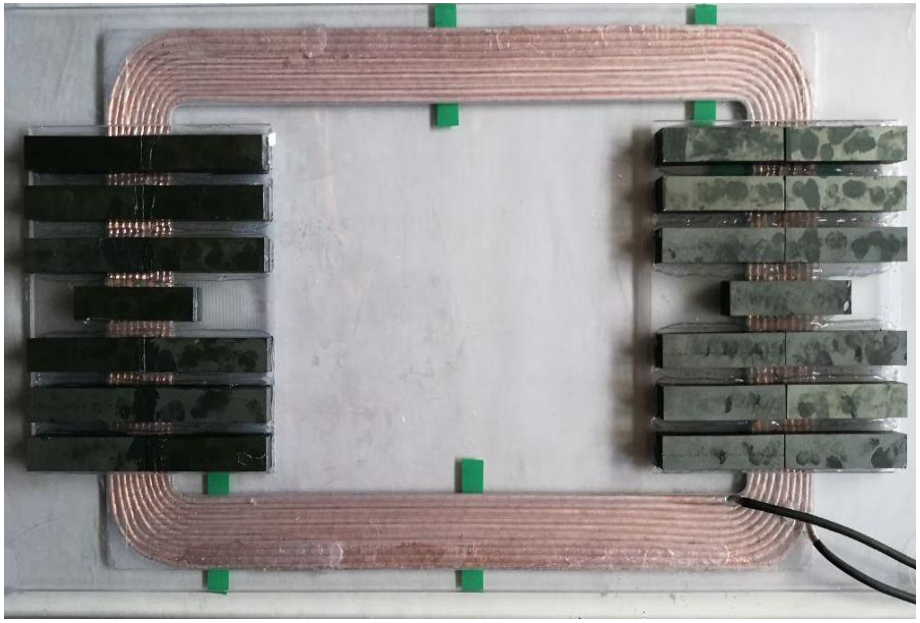
Parameter	Value	Unit
Transmitter resistance, R_1	0.5	Ω
Transmitter inductance, L_1	280	µH
Transmitter capacitor, C_1	12.5	nF
Mutual inductance, M	14.3	µH
Transmitter coil length	150	cm
Transmitter coil width	50	cm
Transmitter coil number of turns	10	-
Wire diameter	5	mm

Experimental Setup
Transmitter (System B)

Parameter	Value	Unit
Transmitter resistance, R_1	8.6	mΩ
Transmitter inductance, L_1	5.2	µH
Transmitter capacitor, C_1	600	nF
Transmitter coil length	200	cm
Transmitter coil width	58	cm
Mutual inductance, M	1.7	µH
Transmitter coil number of turns	1	-
Wire diameter	10	mm
Transformer turn ratio, N	10	-
Transformer leakage inductance referred to low voltage side, L_{lk}	0.55	µH
Transformer magnetizing inductance	2.85	mH



Experimental Setup
Receiver



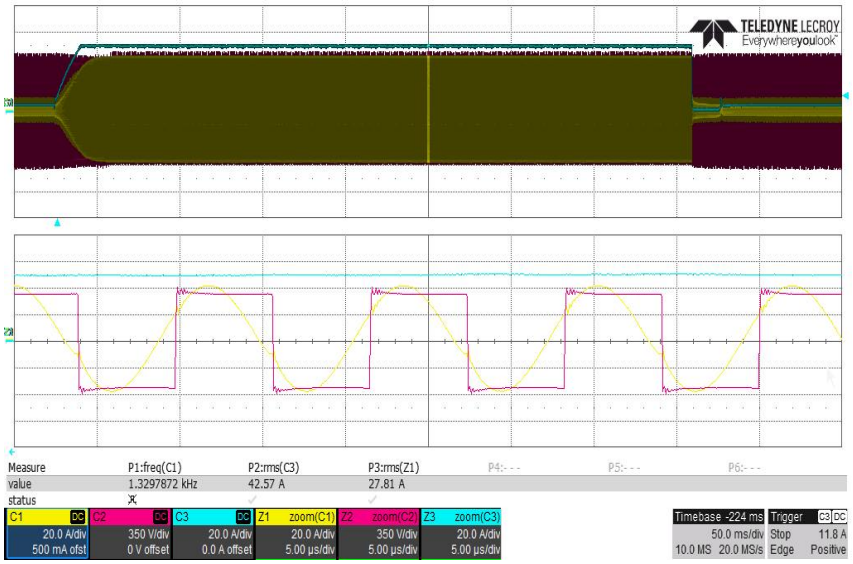
Parameter	Value	Unit
Receiver resistance, R_2	0.3	Ω
Receiver inductance, L_2	120	µH
Receiver capacitor, C_2	29.2	nF
Receiver coil external length	60	cm
Receiver coil external width	40	cm
Receiver coil number of turns	10	-

Experimental Result

- SS-topology (System A)

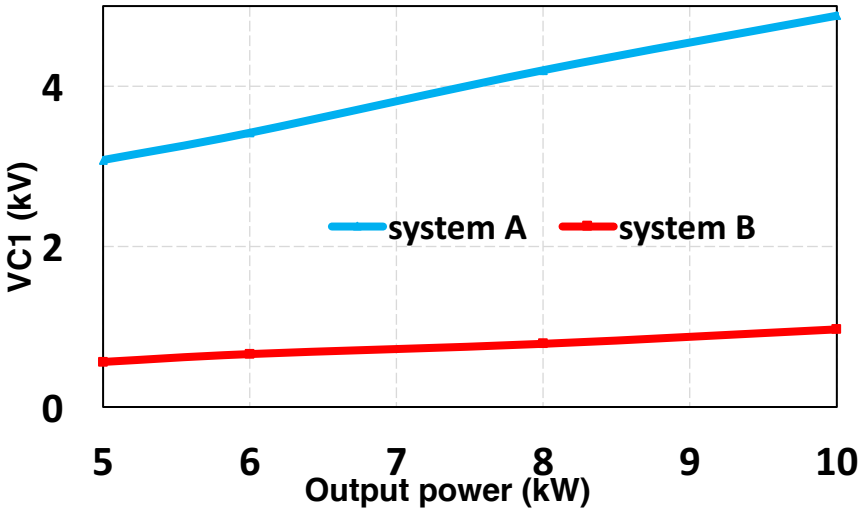
10 kW

- TSS-topology (System B)

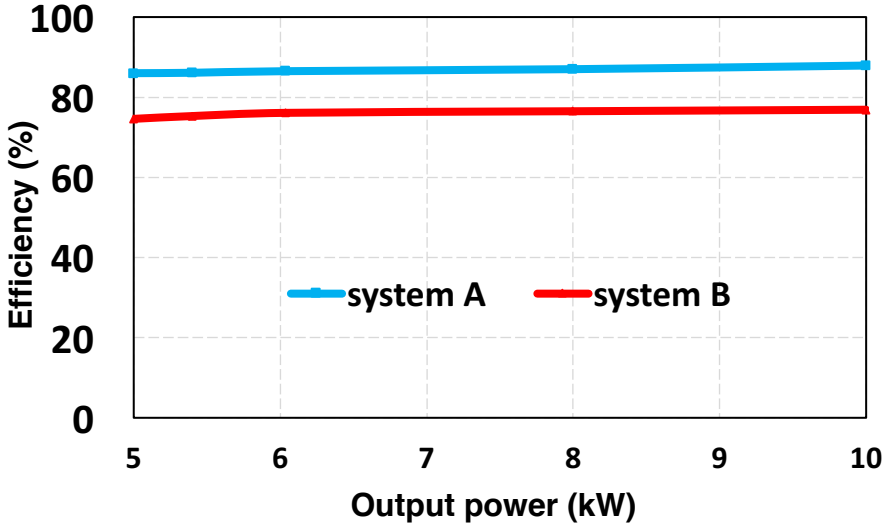


- Voltage at the H-Bridge converter (Magenta)
- Primary current (Yellow)
- Rectify current at the secondary side (Cyan)

Experimental Result



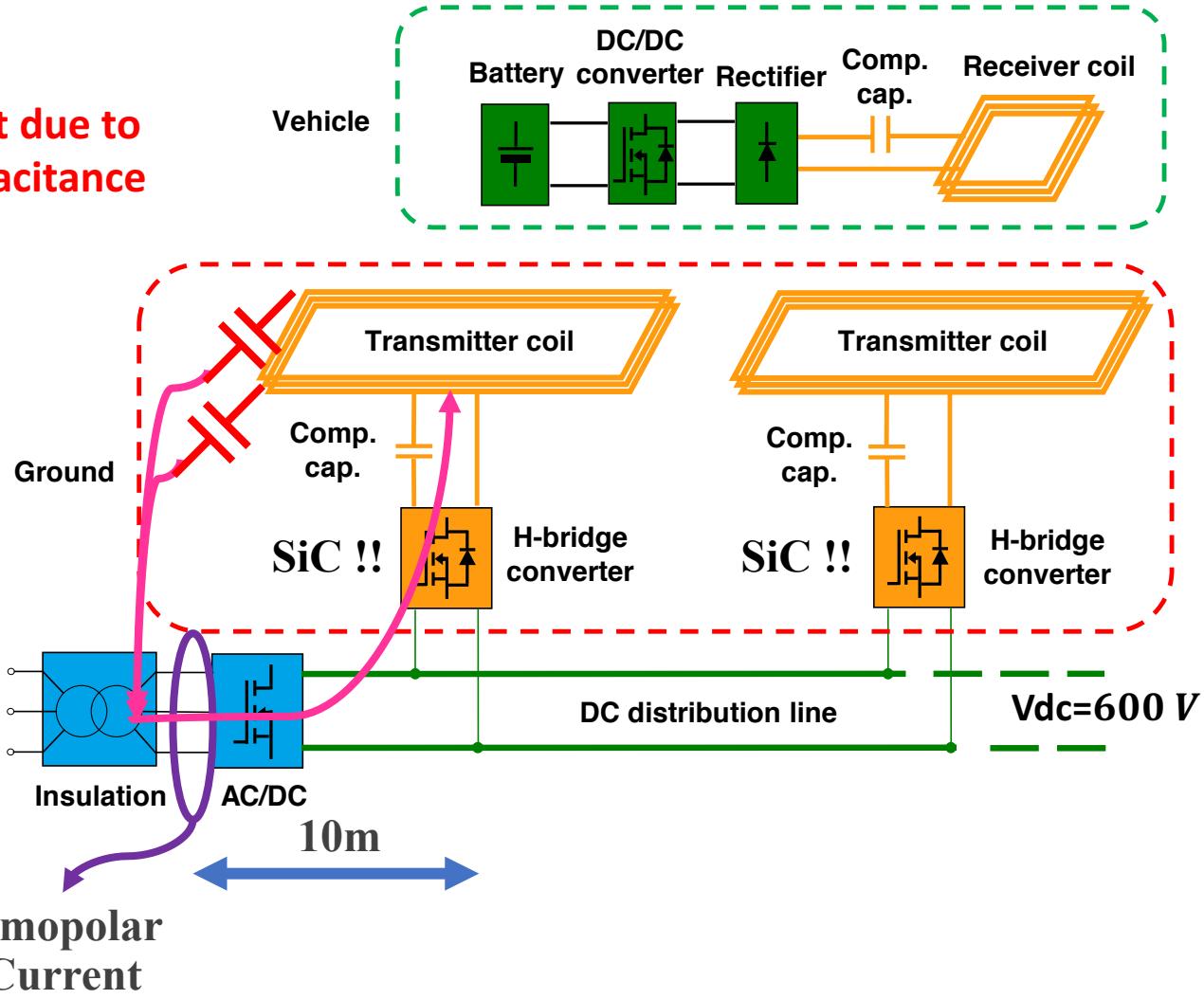
- Thanks to the introduction of the transformer the voltage at the capacitor side is lower for the system B.



- Efficiency between the ouput and input DC power.
- The efficiency of the system B is lower respect the system A. This is due to the transformer introduction.

Experimental Result

Ground current due to parassitics capacitance



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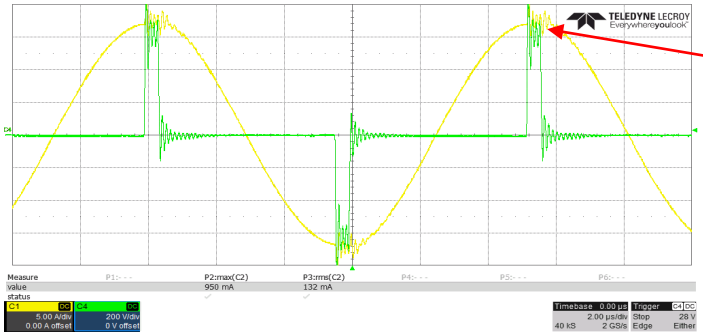
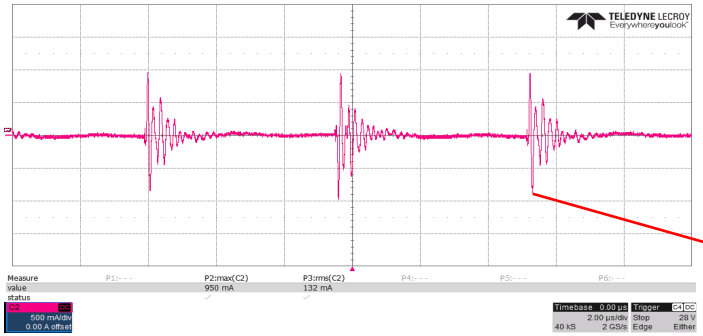
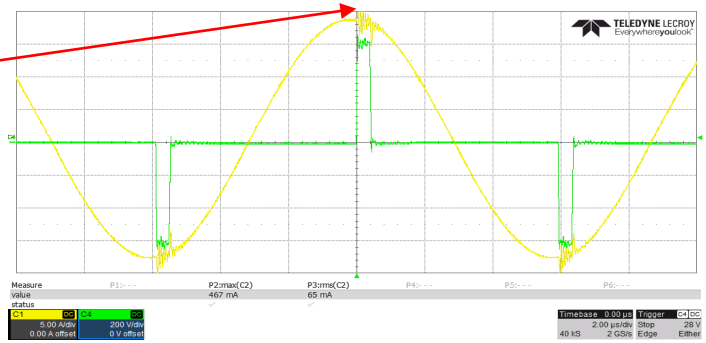
Experimental Result

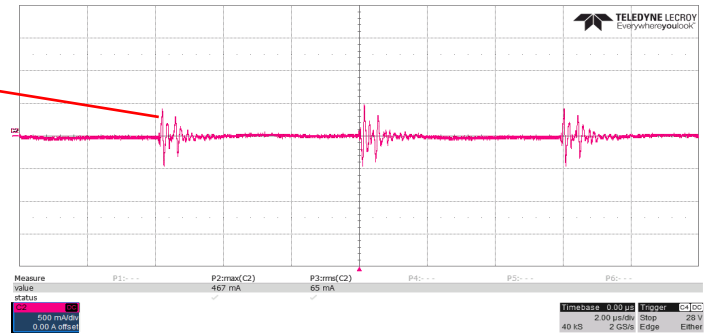
System A





System B





$18\ A_{peak}$

$0,46\ A_{peak}$
$0,065\ A_{rms}$

$1\ A_{peak}$
$0,12\ A_{rms}$

- Voltage at the H-Bridge converter (Green)
- Primary current (Yellow)
- Omopolar current (Cyan)

Conclusion

- A transformer in the SS system have introduced in order to add a degree of freedom.
- Different benefits (Capacitor research simplyfied ,EMC and EMI Reduction)
- Different drawbacks(Cost, Efficiency reduction)

Thank you for your attention

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