

Evaluation of Losses in a Bidirectional Wireless Power Transfer System for Electric Vehicles

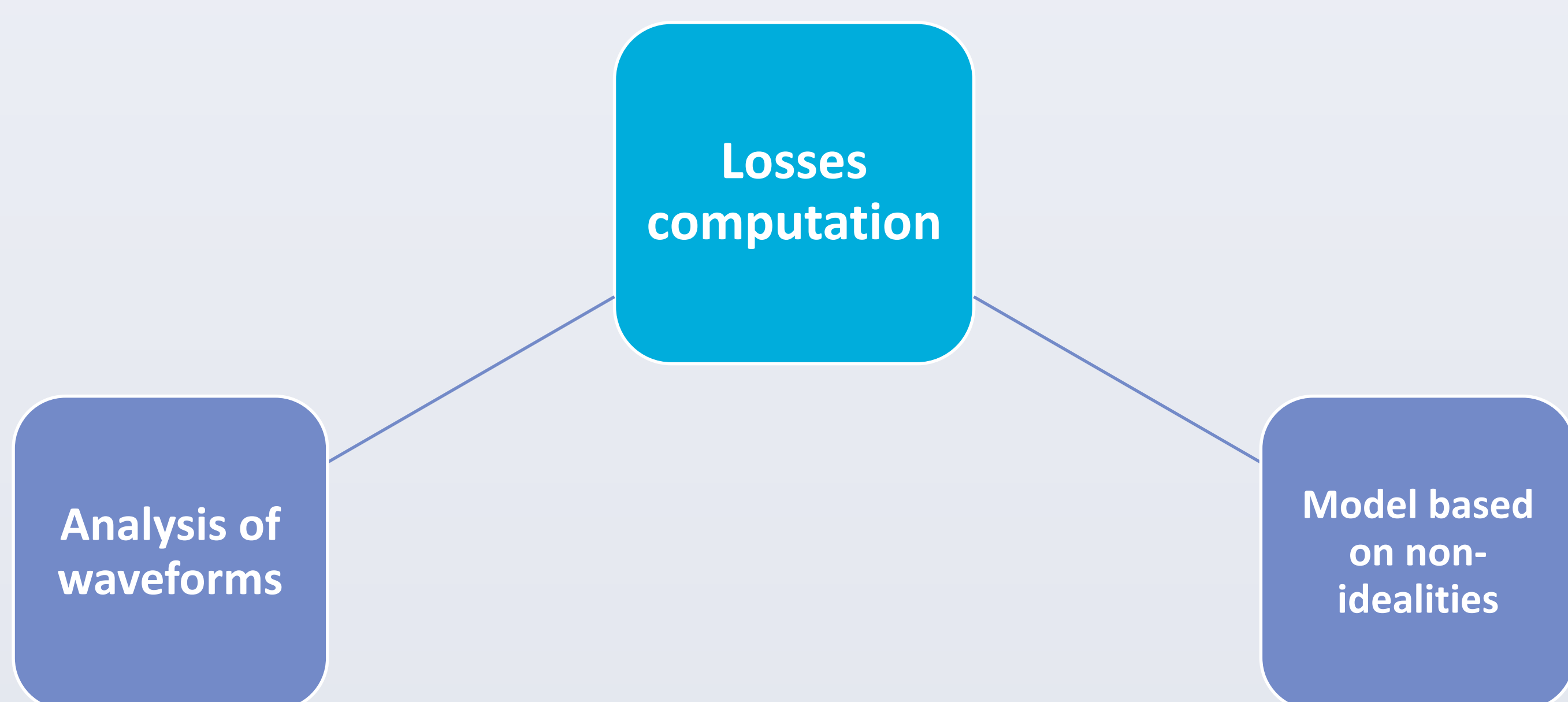
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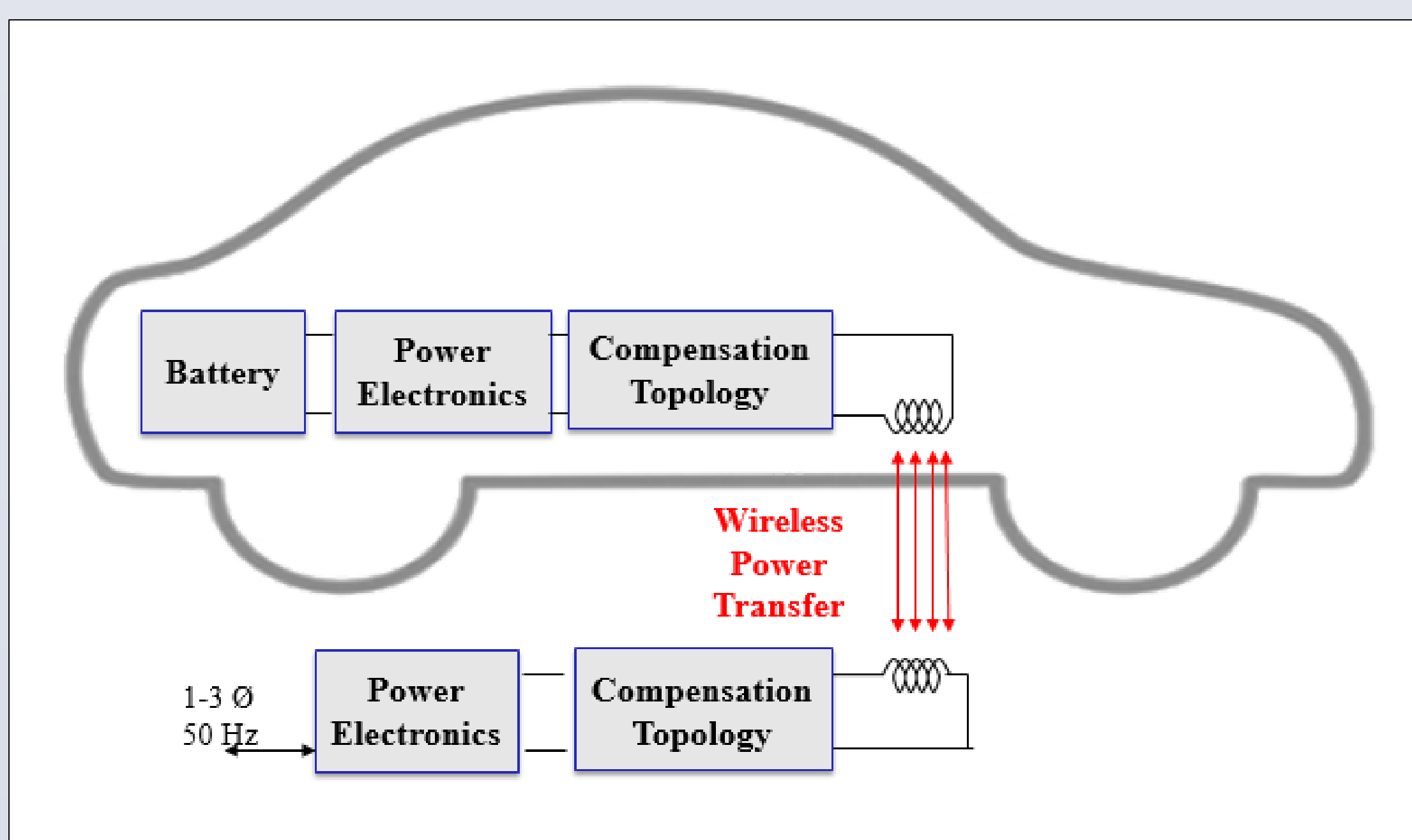
INTRODUCTION

- It is important to characterize the efficiency of a **COMPLETE BIDIRECTIONAL** wireless charger for Electric Vehicles (EV) operating at **85 kHz**.
- We propose an **ANALYTICAL MODEL** to predict **LOSSES** based on the **NON-IDEALITIES** of the components.



BIDIRECTIONAL WIRELESS CHARGER

Scheme



Prototype

- The switching frequency is **85 kHz** as recommended by SAE TIR J2954.
- Supported by **square coils** separated 20 cm.
- The power converters are composed of CREE C2M0080120D **SiC MOSFETs**.
- Specifications and parameters:

Charger specifications		TX-RX parameters (prototype values)	
Output	3.7 kW 300 V	L_1 [μH]	240.5
f_s [kHz]	85	L_2 [μH]	230.6
Coils geometry		C_1 [nF]	14.3
Primary coil [m ²]	0.75 x 0.75	C_2 [nF]	15.6
Secondary coil [m ²]	0.5 x 0.5	R_{L1} [mΩ]	196
C2M0080120D SiC MOSFET		R_{L2} [mΩ]	143
R_d [mΩ]	40	R_{C1} [mΩ]	67
V_{th} [V]	0.98	R_{C2} [mΩ]	52
C_{oss} [pF]	80	M [μH]	54.5
R_{ds} [mΩ]	80	$K=M(L_1L_2)^{1/2}$	0.231

THEORETICAL COMPUTATION OF LOSSES

	Waveform analysis	Non-idealities
Coils	$L_{coils}^{ch} + L_{match}^{ch} = P_{inv_output}^{ch} - P_{rec_input}^{ch}$	$L_{coils} = R_{L1} \cdot \hat{I}_1^2 + R_{L2} \cdot \hat{I}_2^2$
Matching		$L_{match} = R_{C1} \cdot \hat{I}_1^2 + R_{C2} \cdot \hat{I}_2^2$
Inverter	$L_{inv}^{ch} = P_{inv_input}^{ch} - P_{inv_output}^{ch}$	$L_{con,inv} = 2 \cdot R_{ds} \cdot \hat{I}_1^2$
		$L_{sw,inv} \cong L_{Coss} = \frac{1}{2} f_s C_{oss} V_{ds}^2$
Rectifier	$L_{rec}^{ch} = P_{rec_input}^{ch} - P_{rec_output}^{ch}$	$L_{con,rec} = 2 \cdot R_{drec} \hat{I}_{rec}^2 + 2 \cdot V_{th} \cdot \hat{I}_{rec}$

EXPERIMENTAL VALIDATION

- Electrical signals measured in the prototype:

Electrical signals	Charge mode	Discharge mode
V_{inv_input} [V]	288	298
V_{inv_output} [V]	290	293
I_{inv_input} [A]	12.56	4.56
I_{inv_output} [A]	13.78	5.14
V_{rec_input} [V]	285	247
V_{rec_output} [V]	288	250
I_{rec_input} [A]	13.74	6.02
I_{rec_output} [A]	12.16	5.3

- Losses computation (waveform analysis and model):

Electrical signals			
Charge mode		Discharge mode	
L_{inv}^{ch} [W]	20	L_{inv}^{dis} [W]	7
L_{rec}^{ch} [W]	23	L_{rec}^{dis} [W]	27
$L_{con,inv}$ [W]	25	$L_{con,inv}$ [W]	3.3
$L_{sw,inv}$ [W]	1	$L_{sw,inv}$ [W]	1
$L_{con,rec}$ [W]	34	$L_{con,rec}$ [W]	15
L_{coils} [W]	64	L_{coils} [W]	11
L_{match} [W]	23	L_{match} [W]	4

- Comparison between both methods: total losses

	Waveform analysis	Model based on non-idealities
Charging	130 W	147 W
Discharging	49 W	34 W

CONCLUSIONS

- This paper presents a model to predict the losses in a bidirectional ICPT wireless charger for EV:
 - Supported by the non-idealities of the components.
 - Verified with the analysis of waveforms.
- For the comparison, a prototype according to the SAE TIR J2954 has been built.
- The results present small differences between both approaches, which are assumed to be due to measurement errors.