**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:

<table>
<thead>
<tr>
<th>Charger specifications</th>
<th>T24x parameters (prototype value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output</td>
<td>3.7 kW</td>
</tr>
<tr>
<td>f0 [kHz]</td>
<td>85</td>
</tr>
<tr>
<td>Coils geometry</td>
<td>C1 [nF]</td>
</tr>
<tr>
<td>Primary coil [mH]</td>
<td>0.75 x 0.75</td>
</tr>
<tr>
<td>Secondary coil [mH]</td>
<td>0.5 x 0.5</td>
</tr>
<tr>
<td>C2M0080120D SiC MOSFET</td>
<td>R1 [mΩ]</td>
</tr>
<tr>
<td>R1 [mΩ]</td>
<td>0.98</td>
</tr>
<tr>
<td>C1 [nF]</td>
<td>143</td>
</tr>
<tr>
<td>C2 [nF]</td>
<td>156</td>
</tr>
<tr>
<td>R2 [mΩ]</td>
<td>143</td>
</tr>
<tr>
<td>R3 [mΩ]</td>
<td>52</td>
</tr>
<tr>
<td>M [mH]</td>
<td>54.5</td>
</tr>
<tr>
<td>K [mΩ]</td>
<td>0.23</td>
</tr>
</tbody>
</table>

**THEORETICAL COMPUTATION OF LOSSES**

<table>
<thead>
<tr>
<th>Waveform analysis</th>
<th>Non-idealities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coils</td>
<td>( L_{\text{coil}} = R_{\text{1L}} \cdot I_1^2 + R_{\text{2L}} \cdot I_2^2 )</td>
</tr>
<tr>
<td>Matching</td>
<td>( L_{\text{match}} = R_{\text{c1}} \cdot I_1^2 + R_{\text{c2}} \cdot I_2^2 )</td>
</tr>
<tr>
<td>Inverter</td>
<td>( L_{\text{inv}} = p_{\text{ch}} \cdot I_{\text{inv, input}} - p_{\text{ch}} \cdot I_{\text{inv, output}} )</td>
</tr>
<tr>
<td></td>
<td>( L_{\text{con, inv}} = 2 \cdot R_{\text{ds}} \cdot I_2^2 )</td>
</tr>
<tr>
<td>Rectifier</td>
<td>( L_{\text{rec}} = p_{\text{ch}} \cdot I_{\text{rec, input}} - p_{\text{ch}} \cdot I_{\text{rec, output}} )</td>
</tr>
<tr>
<td></td>
<td>( L_{\text{com, rec}} = 2 \cdot R_{\text{d2}} \cdot I_{\text{rec}}^2 + 2 \cdot V_{\text{th}} \cdot I_{\text{rec}} )</td>
</tr>
</tbody>
</table>

**EXPERIMENTAL VALIDATION**

- Electrical signals measured in the prototype:

<table>
<thead>
<tr>
<th>Electrical signals</th>
<th>Charge mode</th>
<th>Discharge mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_{\text{inv, input}} ) [V]</td>
<td>288</td>
<td>298</td>
</tr>
<tr>
<td>( V_{\text{inv, output}} ) [V]</td>
<td>290</td>
<td>293</td>
</tr>
<tr>
<td>( I_{\text{in, input}} ) [A]</td>
<td>12.56</td>
<td>4.56</td>
</tr>
<tr>
<td>( I_{\text{in, output}} ) [A]</td>
<td>13.78</td>
<td>5.14</td>
</tr>
<tr>
<td>( I_{\text{rec, input}} ) [A]</td>
<td>285</td>
<td>247</td>
</tr>
<tr>
<td>( I_{\text{rec, output}} ) [A]</td>
<td>288</td>
<td>250</td>
</tr>
<tr>
<td>( I_{\text{in, output}} ) [A]</td>
<td>13.74</td>
<td>6.02</td>
</tr>
<tr>
<td>( I_{\text{rec, output}} ) [A]</td>
<td>12.16</td>
<td>5.3</td>
</tr>
</tbody>
</table>

- Losses computation (waveform analysis and model):

<table>
<thead>
<tr>
<th>Electrical signals</th>
<th>Charge mode</th>
<th>Discharge mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>( L_{\text{1L}} ) [W]</td>
<td>20</td>
<td>7</td>
</tr>
<tr>
<td>( L_{\text{2L}} ) [W]</td>
<td>23</td>
<td>27</td>
</tr>
<tr>
<td>( L_{\text{con, inv}} ) [W]</td>
<td>25</td>
<td>3.3</td>
</tr>
<tr>
<td>( L_{\text{con, rec}} ) [W]</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>( L_{\text{match}} ) [W]</td>
<td>34</td>
<td>15</td>
</tr>
<tr>
<td>( L_{\text{match}} ) [W]</td>
<td>64</td>
<td>11</td>
</tr>
<tr>
<td>( L_{\text{match}} ) [W]</td>
<td>23</td>
<td>4</td>
</tr>
</tbody>
</table>

- Comparison between both methods: total losses:

<table>
<thead>
<tr>
<th>Charging</th>
<th>Discharging</th>
</tr>
</thead>
<tbody>
<tr>
<td>130 W</td>
<td>147 W</td>
</tr>
<tr>
<td>49 W</td>
<td>34 W</td>
</tr>
</tbody>
</table>

**CONCLUSIONS**

- This paper presents a model to predict the losses in a bidirectional ICPT wireless charger for EV:
  1. Supported by the non-idealities of the components.
  2. 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.