A Bidirectional MW-Level Electric-Vehicle Extreme Fast Charging Station Enabled by High-Voltage SiC and Intelligent Control

2020 CURENT NSF/DOE Site Visit and Industry Conference
Virtual
Nov. 2020

Ziwei Liang, CURENT, UTK
Daniel A. Merced, CURENT, UTK
Hua “Kevin” Bai, CURENT, UTK
Leon M. Tolbert, CURENT, UTK
Chingchi Chen, Ford
Ke Zou, Ford
Xi Lu, Ford
Deployment of A Bidirectional MW-Level Electric-Vehicle Extreme Fast Charging Station Enabled by High-Voltage SiC and Intelligent Control

Background and motivation:
• Fast charging speed reduces the range anxiety of electric vehicle (EV) drivers thereby expediting the acceptance of EVs;
• High-voltage SiC power modules enable the transformer-less design with HVAC input;
• Input-series output-parallel (ISOP) structure secures the high power density and high efficiency to charge two EVs with 1MW.

Technical approach:
• PFC stage: 1) duty cycle compensation is utilized to achieve output voltage balance; 2) Interleaving control achieves low THD;
• DCX stage: Dynamic switching frequency modulation balances the battery charging current.

Figure 1. Block diagram of proposed EV extreme fast charger

Conclusion:
• The duty cycle compensation could achieve the independent control of PFCs and secure balanced output voltages;
• Dynamic switching frequency modulation achieves output current balance of three DCXs.
A. **Interleaving control:** employing interleaving control for each PFC, i.e., shifting the gate signals by 120° (1/3Ts). This helps further reduce the grid-side current.

B. **Duty cycle compensation:** when two input-series PFC stages have different load, duty cycle compensation control method is utilized to achieve balanced output voltages.

\[ V_{o1}(1-d_1) + V_{o2}(1-d_2) = |V_{in}| \]  

(1)

\[ V_{o1} = |i_{in}| \cdot (1-d_1) \cdot R_1 \]  

(2)

\[ V_{o2} = |i_{in}| \cdot (1-d_2) \cdot R_2 \]  

(3)

**Figure 2.** Simulated grid current (a) with same gate signals and (b) with interleaved gate signals.

**Figure 3.** Simulation results of the DC output voltage for series-connected PFC modules: (a) without the balancing control and (b) with the balancing control.
Paralleled-output DCX stages Control Method

A. **Challenge:** the operation of DCX is sensitive to the resonance condition, i.e., diversity of the resonant parameters could lead to the unbalance output.

B. **Dynamic frequency control:** based on the output current feedback, the algorithm could adjust the frequency of corresponding DCX dynamically to secure all DCXs work under the resonant condition. The algorithm block diagram is shown in Fig.4.

**Figure 5.** Output current balancing control performance with the resonant inductance of (a) $L_{r1} = L_{rd}$, $L_{r2} = 0.9 L_{rd}$, $L_{r3} = 0.95 L_{rd}$ and (b) $L_{r1} = 1.05 L_{rd}$, $L_{r2} = 0.9 L_{rd}$, $L_{r3} = 0.95 L_{rd}$.

**Figure 4.** Output current balancing control of paralleled DCXs
Authors made use of shared facilities sponsored by ERC Program of the National Science Foundation and DOE under NSF Award Number EEC-1041877 and the CURENT Industry Partnership Program

We would gratefully acknowledge the sponsorship of our US government and industry partners as below.

[Logos of sponsors: NSF, DOE, CURENT, arpa.e, Wolfspeed, Ford Motor Company]