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## MOTIVATION

- Usually for an EV, all the power units are designed and installed separately. That means they need multiple enclosures and cooling systems, leading to higher costs.
- There's a trend towards using reconfigurable battery packs in EVs, allowing configurations at 400V for charging compatibility and 800V for more driving power. This necessitates OBC capable of charging both 400 & 800V batteries and APM that can accommodate a wide input range of 180V to 900V.



Fig. 1. Standalone Units: APM of Tesla Model 3, & OBC of Model S.

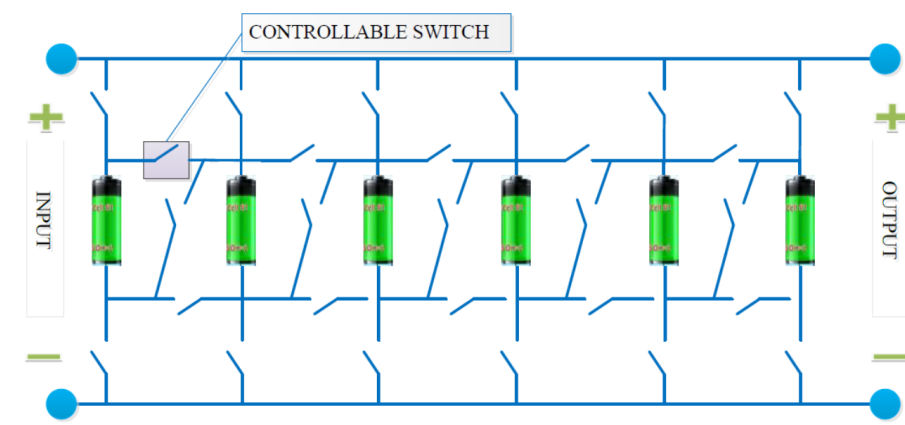


Fig. 2. Reconfigurable battery pack design.

## OBJECTIVES

- To integrate an APM with EV on-board charger thereby saving the size and cost.
- To charge both 400V, and 800V batteries using only 650V GaN HEMTs.

## CHALLENGES

- Developing a multi-stage converters coordination for the Soft Start-up and Shut-down process to avoid potential large inrush current or overvoltage.
- Securing ZVS for both OBC and APM.
- Maintain high performance for different operation scenarios.

## SYSTEM SCHEMATIC AND HARDWARE PROTOTYPE:

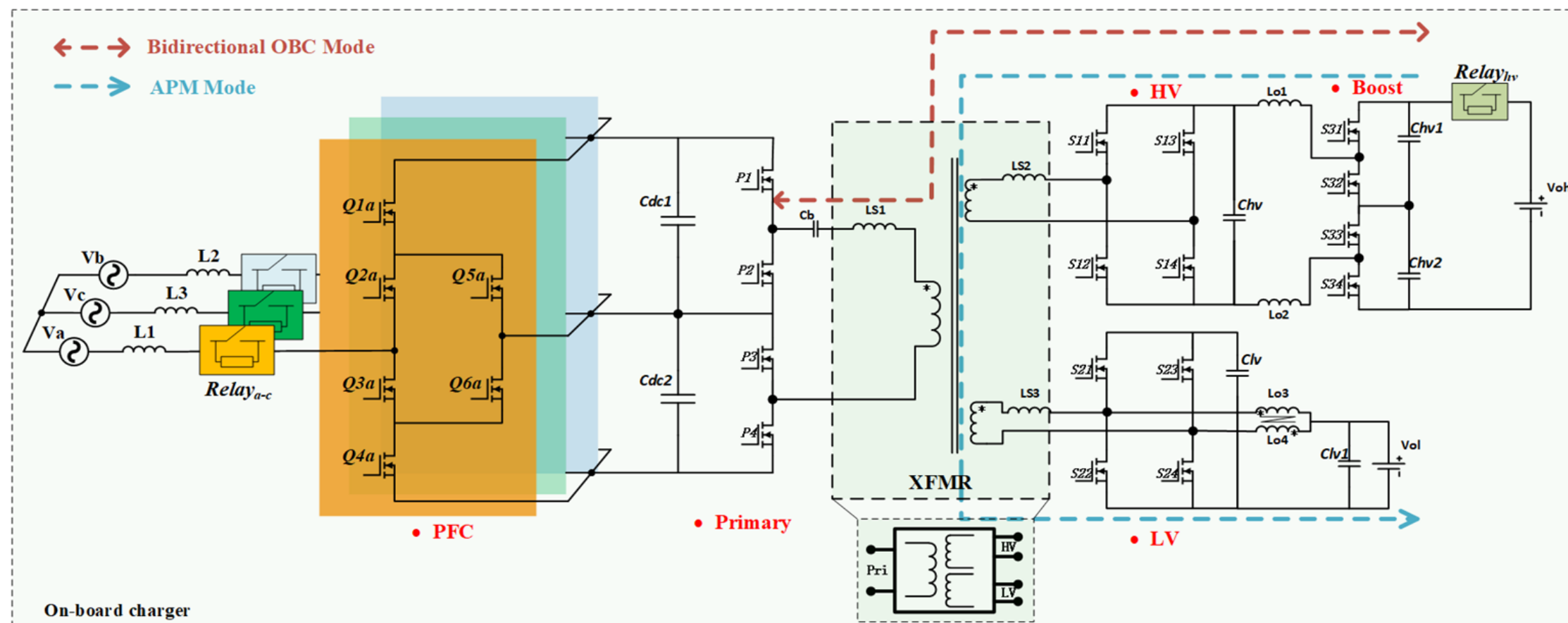


Fig. 3. Proposed integrated charger schematic for 400V and 800V EVs.

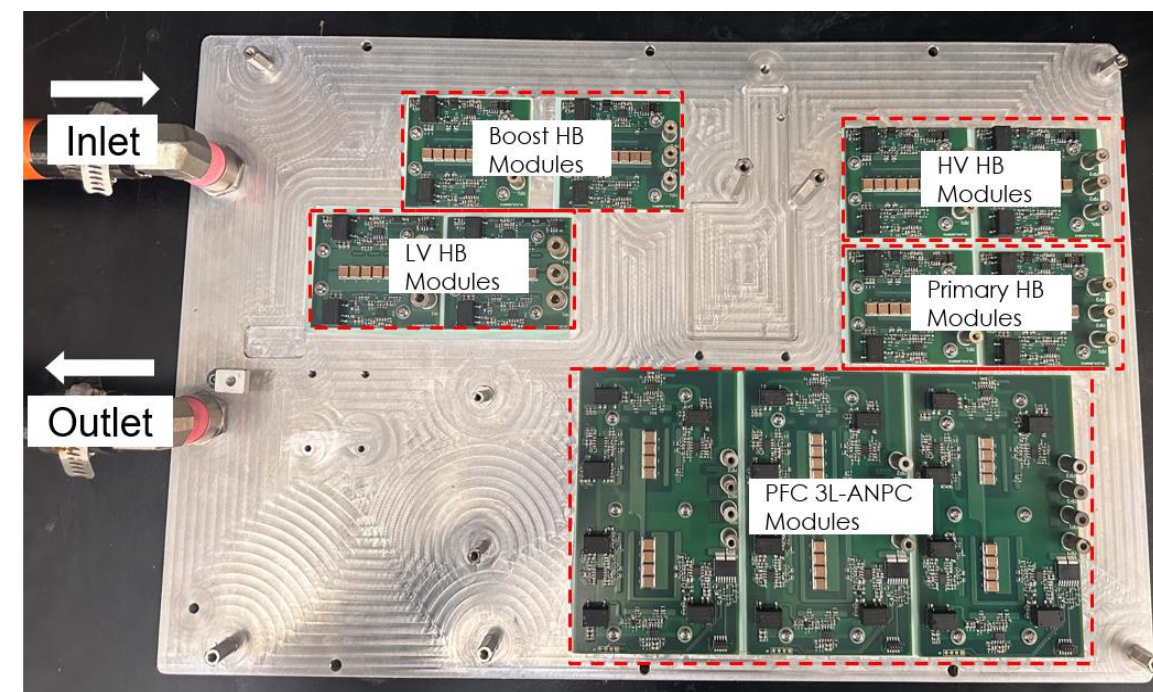


Fig. 4. Liquid Cooled Hardware prototype of the proposed integrated EV charger.

## EXPERIMENTAL TEST VERIFICATION:

### OBC Mode:

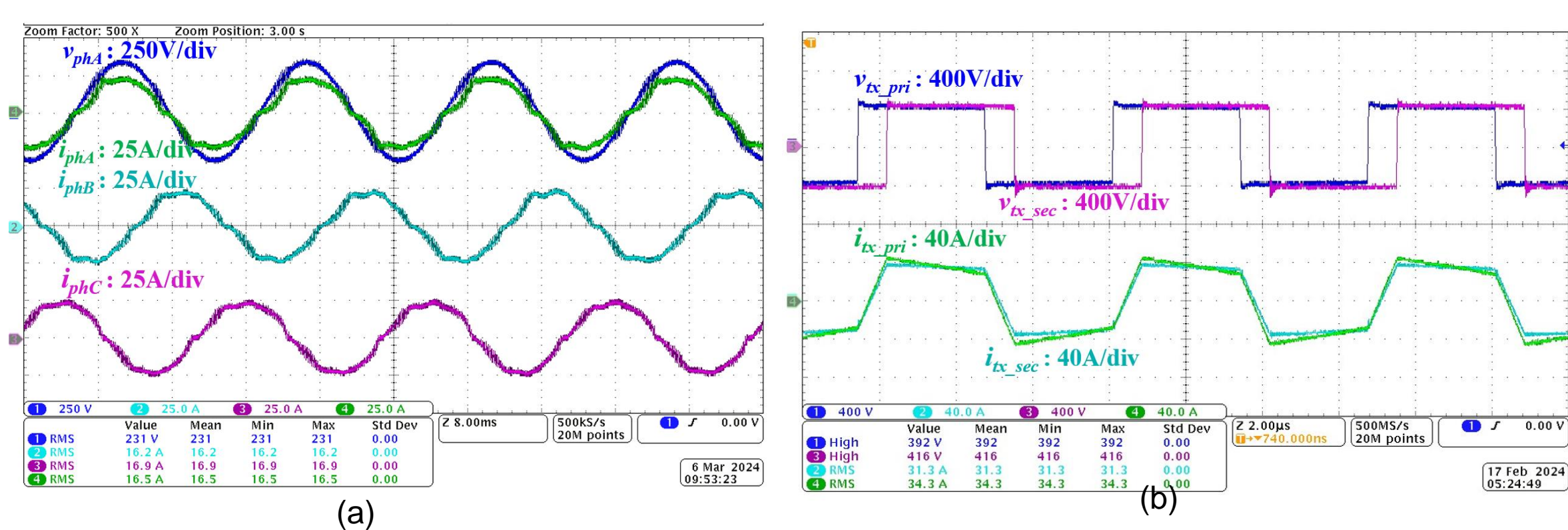


Fig. 5. 11kW OBC test waveforms at 230VAC input and 370VDC output..  
 (a) PFC stage, (b) DAB stage

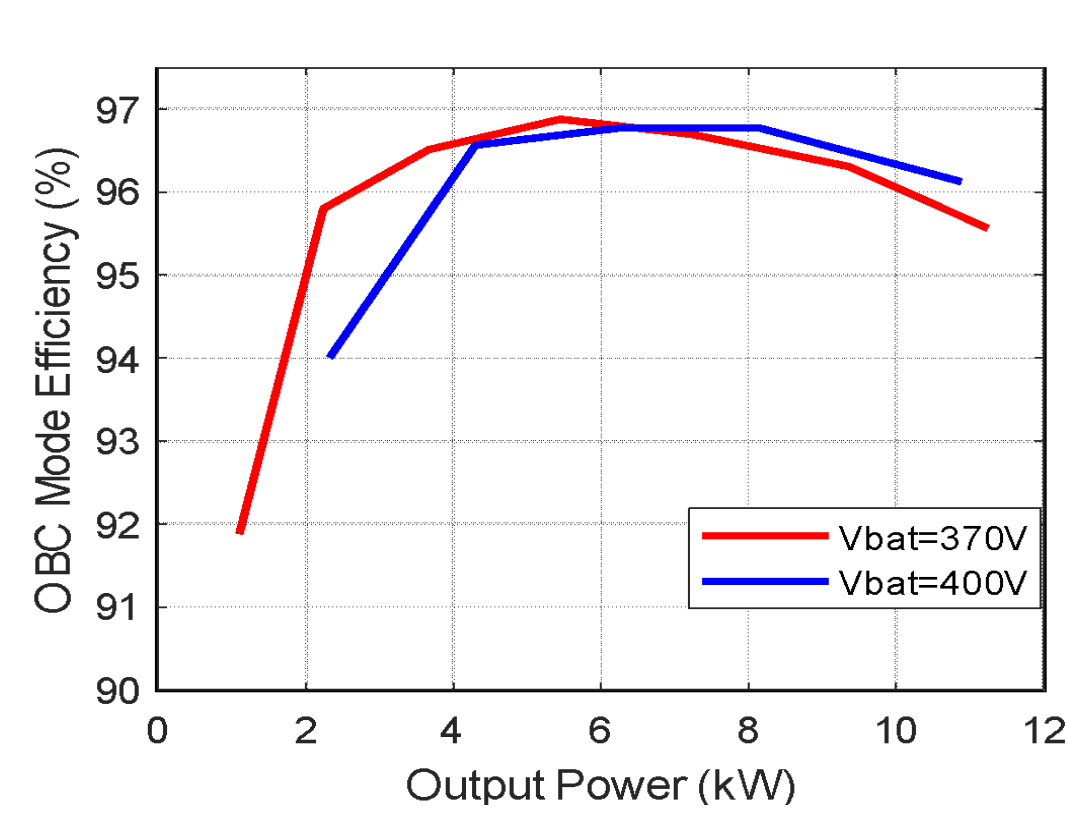


Fig. 6. OBC Mode Experimental Efficiency curve for 370V and 400V Battery.

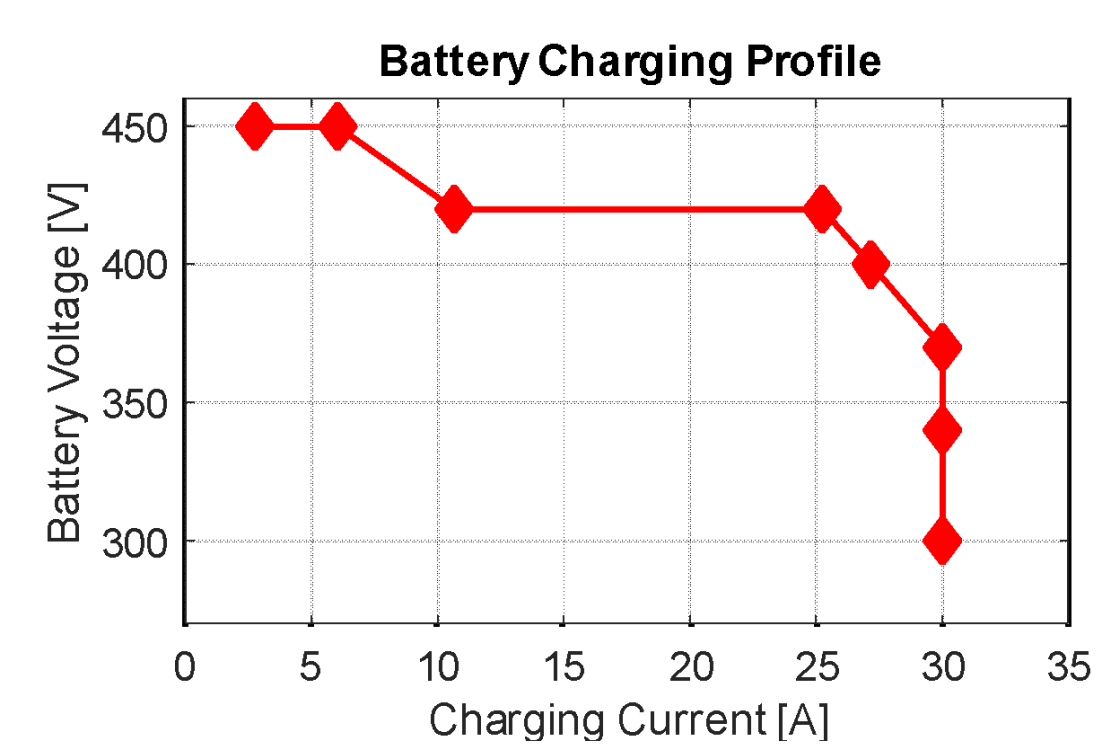


Fig. 7. Charging Profile of 11kW Onboard Charger.

### V2L Mode:

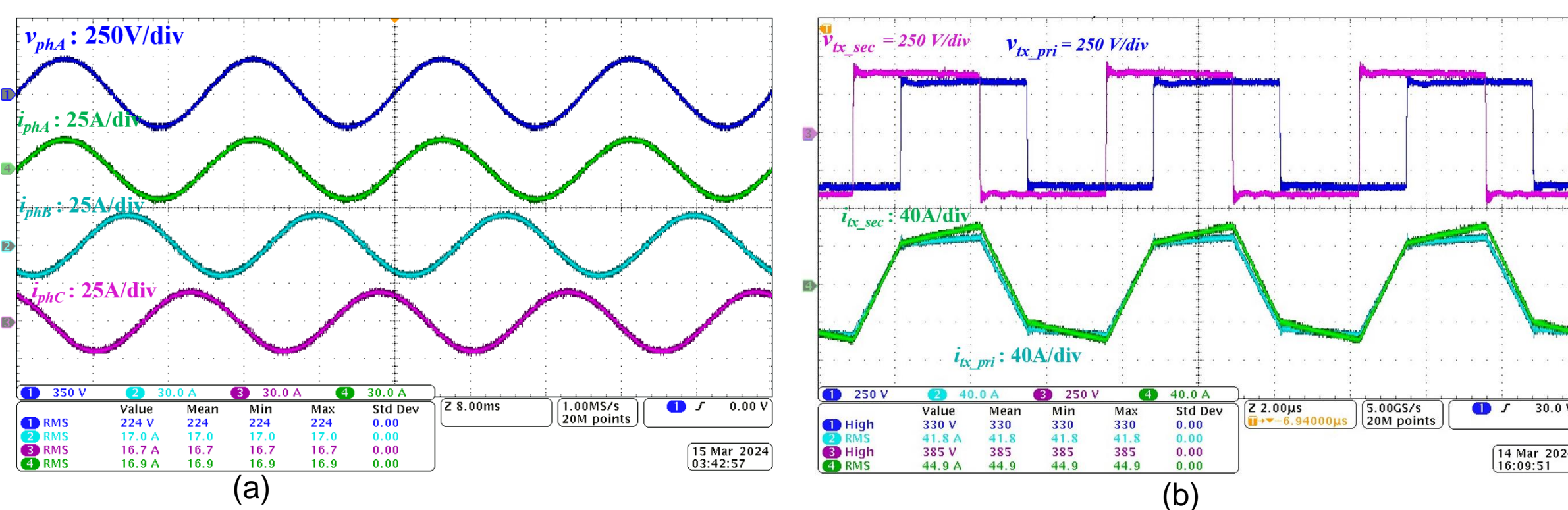


Fig. 8. 11kW V2L test waveforms at 400VDC input and 230VAC output.  
 (a) Inverter stage, (b) DAB stage

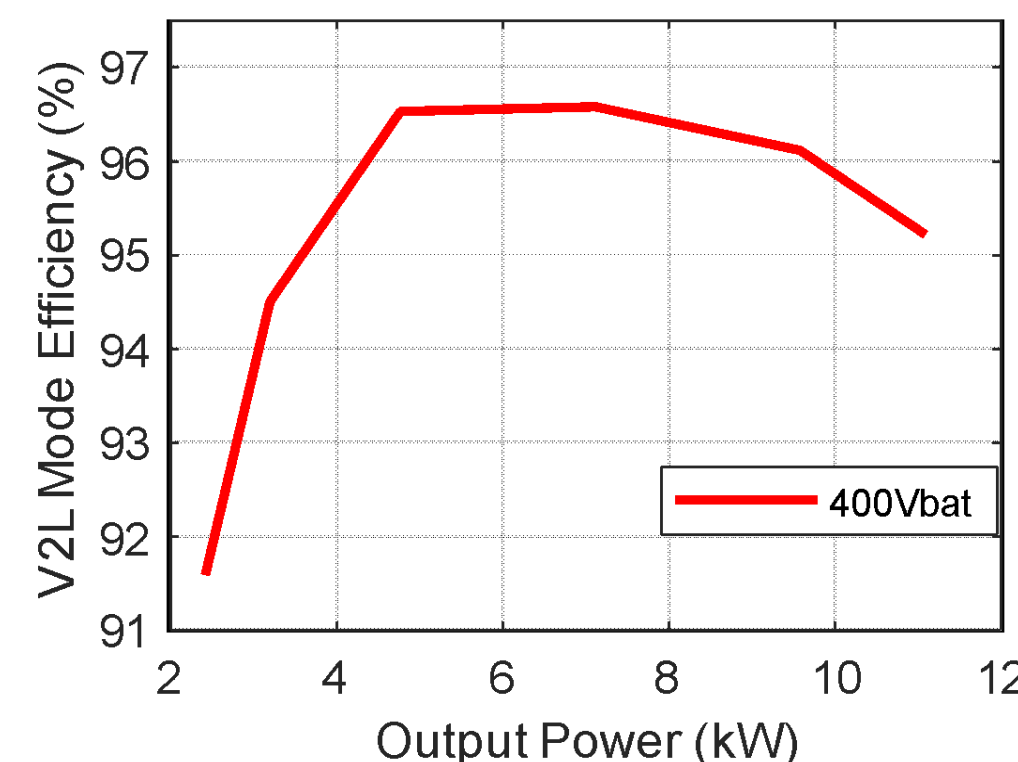


Fig. 9. V2L Mode Experimental Efficiency curve for 400V Battery.

### APM Mode:

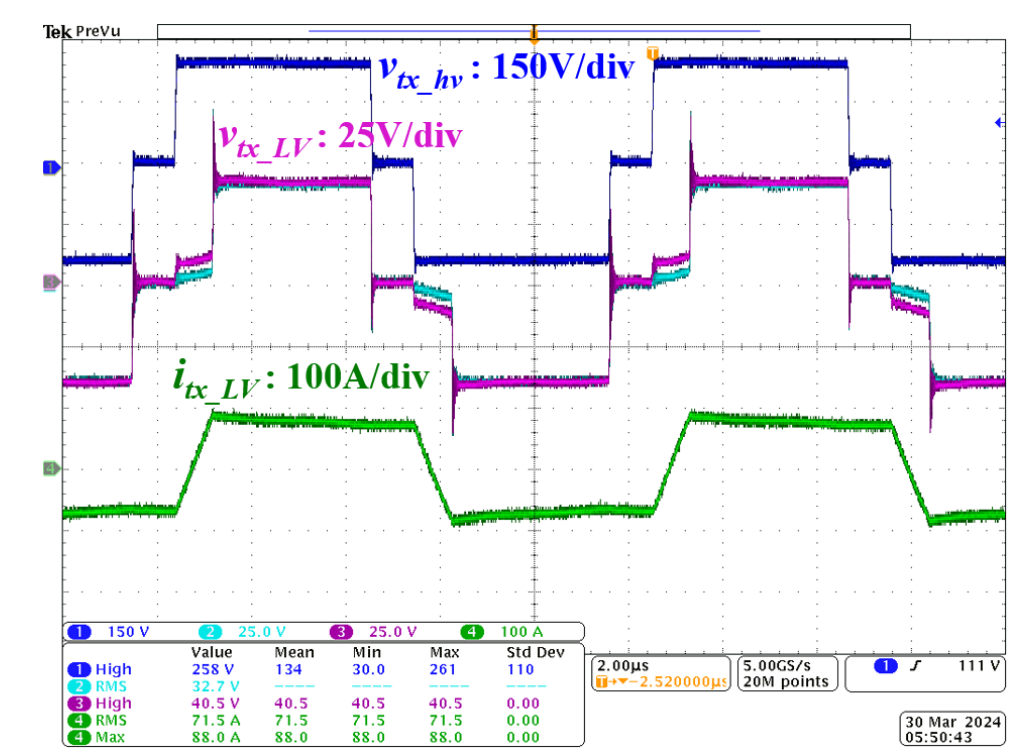


Fig. 10. Xfmr waveforms for 2kW APM at 240V HV input and 12V LV output.

## CONCLUSIONS:

- Tested proposed iCharger at 11kW for OBC & V2L mode and 2kW for APM.
- The proposed charger can accommodate both 400V and 800V batteries and offer bidirectional OBC and APM functions, which are enabled by the multi-level and three-port converter topology with a three-winding transformer.

## FUTURE WORKS:

- Different modulation methods including DPS, and TPS can be implemented to increase the efficiency for the OBC stage at very light load conditions.
- Investigate the bi-directionality of the APM

