Titles and Members, Institutions

Title

Development of a 50kW DC Fast Charging Station for Electric Vehicles

Principal Investigator (PI)

Dr. Souvik Chattopadhyay

Institution

Indian Institute of Technology Kharagpur

Objectives Aim and Scope, need for study

Objectives

A new topology for a 50 kW DC fast charging station of the following specifications

- Power rating: 50kW
- DC output voltage: 200V-485V, (Nominal voltage: 400V)
- Maximum charging current: 125A
- AC input voltage: 380V-415V (RMS), 50Hz, Three phase
- Efficiency: >94%

The basic features of this proposed charger include

- *Magnetic Isolation* - High-frequency(HF) transformer instead of bulky 50Hz transformer
- *Single-stage conversion* - Reduction in device count
  - Eliminating short life-span electrolytic capacitors
- *PLC communication* - CCS-2 connector between EV and EVSE

The core advantages of the proposed topology are

- *Minimum capacitor requirement* - Utilizing the 3-phase balanced power input
- *Modularity and scalability* -One HF transformer for each phase, therefore, simpler design for magnetics.
  - Symmetrical per-phase structure with reduced switch current stress.

The needs for study are in the following zones

- *Increasing the ZVS switching range of AC side devices*
- *Increasing the output DC voltage range while keeping a flat efficiency curve over the range.*

Technical Progress

- *Component selection and Purchase:* A Single-line diagram of an 18kW setup and a detailed BOM (including devices, heat sinks, fans, thermal insulator pads, sensors, switchgear and protection components, capacitors, assorted discrete electronic components, and ICs) is prepared first followed by procurement.
- *PCB design, Fabrication, and Population:* PCBs (slide) are designed, fetched, and then populated with SMD resistors, capacitors, and ICs followed by a basic test of all individual boards. Instead of a single power board, 6 identical small boards are used to increase scalability and modularity.

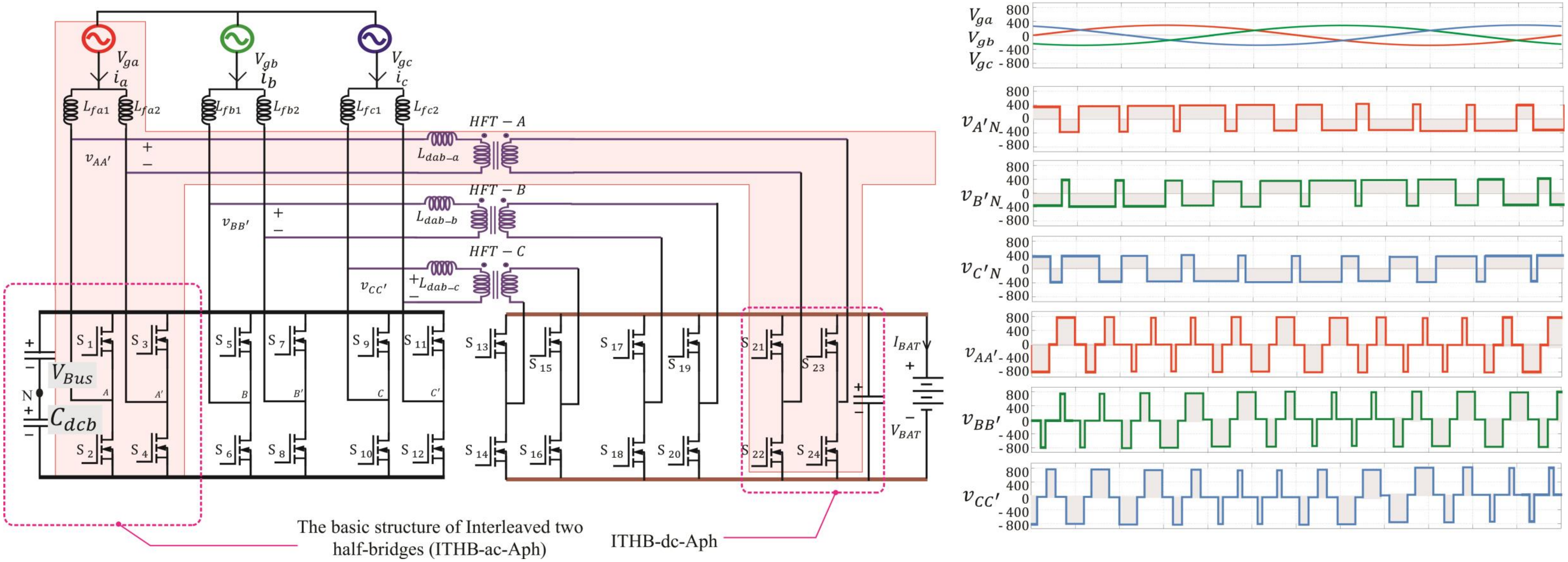


Figure 4: The proposed topology

Technical Progress

- *Magnetics Design and Making:* Ferrite cores, litz. wires, and Bobbins are purchased according to the design, and all the magnetic components are made.
- *Mechanical Assembly :* An MS steel panel is designed in 3D software, ordered, and then the mechanical assembly is done.

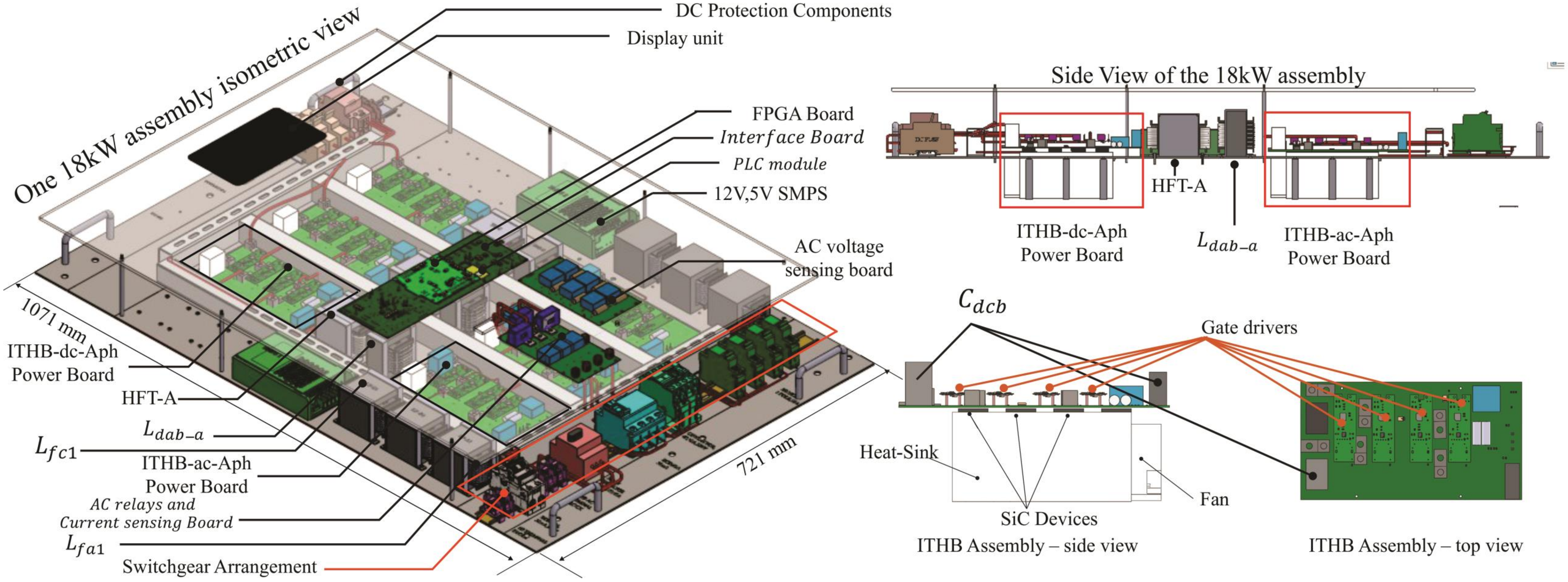


Figure 5: The mechanical assembly details for an 18kW EV charger

Outcomes (PCBs)

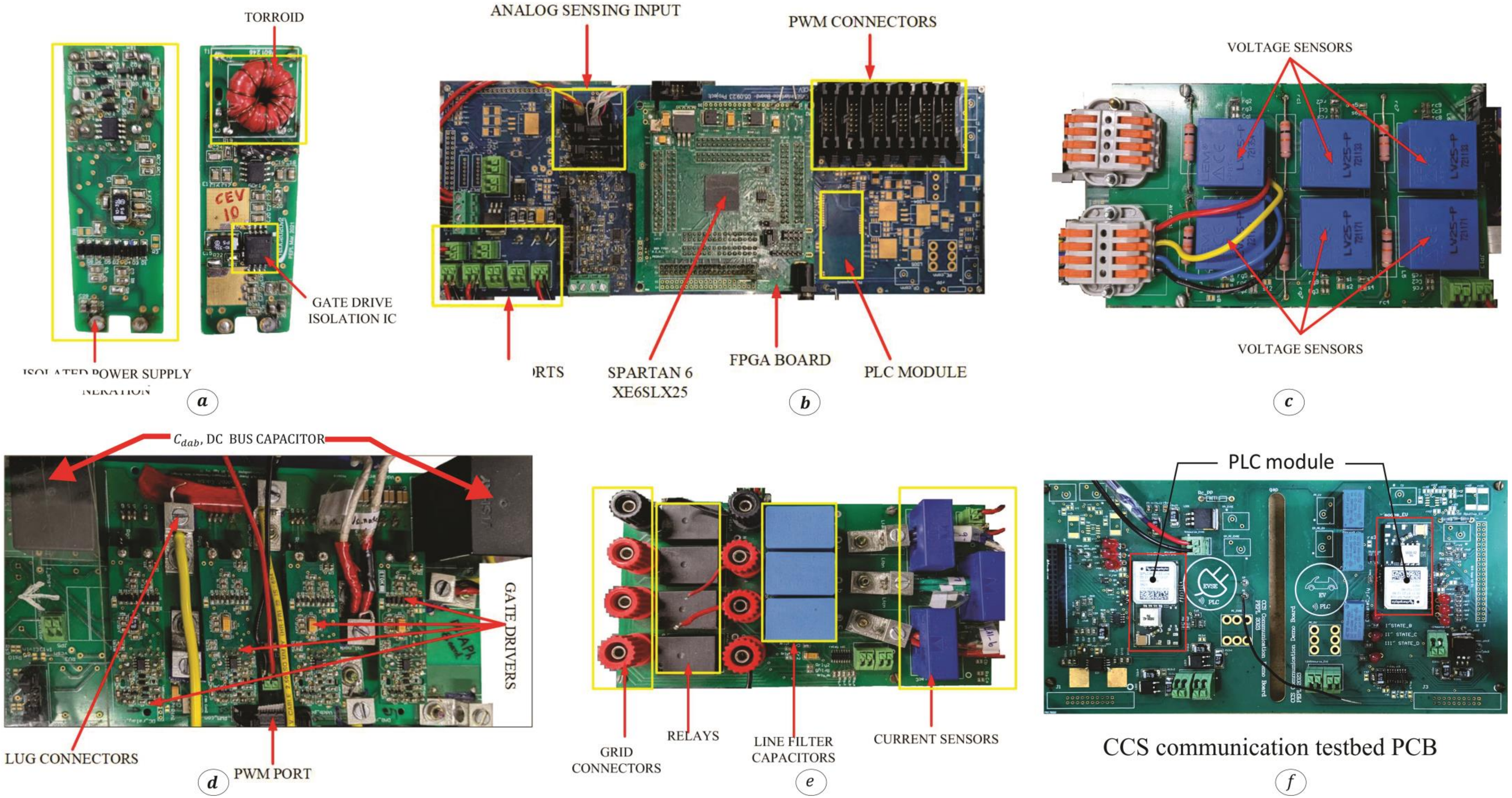
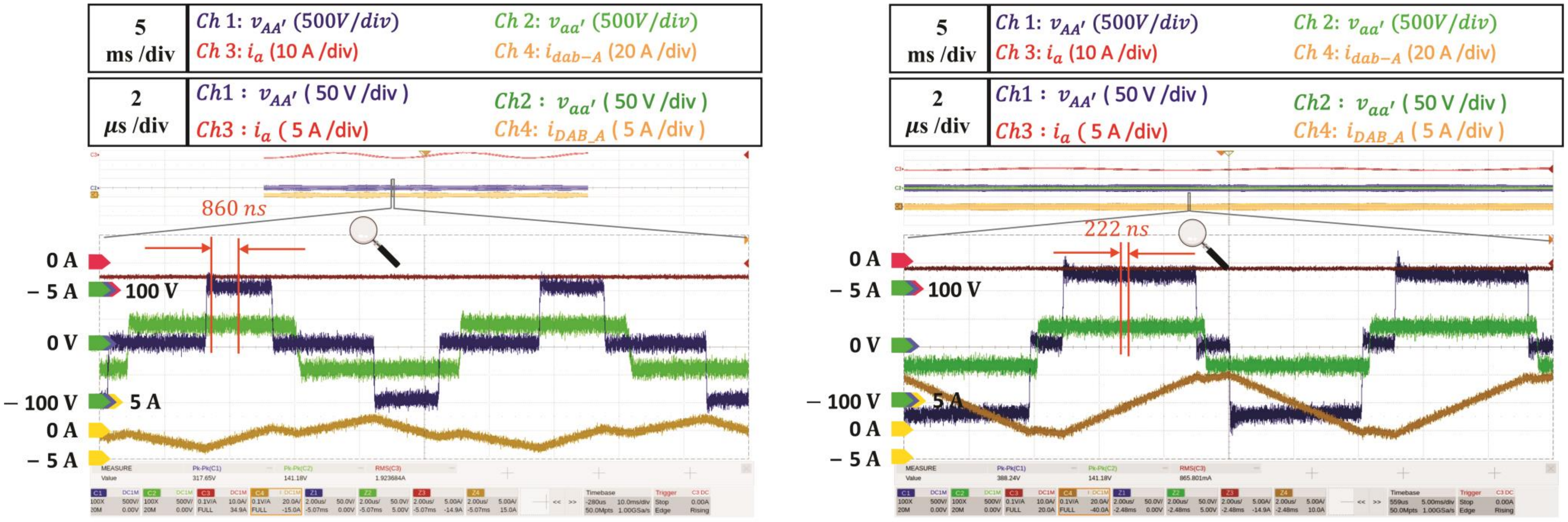


Figure 8: (a) Gate driver (one per device) (b) Control Interface Board with Spartan-6 XE6SLX25 FPGA board (designed in Lab), PWM outputs, analog inputs, sensing filters and PLC modem connection (c) AC voltage sensing board (d) Power board with four devices connected in an active H-bridge manner (6 such identical boards are required for an 18kW unit) (e) Relays and Line current sensing board (f) A separate board to test PLC communication (Low-level circuit + High-level data transfer) complied with CCS charging protocol.

Closed-loop results discussion

- *Digital PI and PR controller VHDL coding :* After testing the open loop code (results discussed in the previous slide), the digital domain PI and PR controller code is written for DC and AC quantity control respectively.
- *Close-loop control Implementation:* First, the bus voltage is controlled by employing a PI controller by adjusting the phase shift. Next to that, along with the DC bus control, the per-phase AC output is controlled using a proportional-resonant (PR) controller controlling the modulation index.



(a) (b)

Figure 7: Closed-loop performance test of the 18kW unit DC-AC operation while resistance is connected at the AC 3-phase terminals: Bus voltage, ${V_{BUS}}^{ref}$=100V, Battery Input, V_{BAT}= 40V (a) $i_{ac\_peak}^{ref}$=2.82A (b) $i_{ac\_peak}^{ref}$ = 1.20A. As resistances are connected at the AC terminals, current controlled means active power is getting controlled. Both the zoom instances are taken near the line current negative peak. When the current is controlled at a 2.82A peak, power demand is greater, so the phase shift is adjusted to 30 degrees (860ns in 100kHz switching) approximately. But when the current reference is 1.2A peak, the phase shift automatically adjusts to 8 degrees approximately.