Adaptive EV Charger with reconfigurable and efficient DC-DC converter for commercial charging station

Project Review Presentation

Subject: Power Electronics

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Literature Survey

- EV charging efficiency is affected by power transfer and voltage conversion ratios.
- Existing chargers lack adaptability to a wide range of battery voltages.
- Soft-switching techniques improve efficiency but have limitations.
- Bidirectional chargers support vehicle-to-grid (V2G) power transfer.
- DAB and LLC converters are commonly used but require optimization.
- Advanced control techniques is used: Dual Phase Shift (DPS) and Frequency Modulation (VCO-based) improve efficiency, reduce current stress, and enable seamless switching between charging modes.

Problems Identified

- Wide variation in charging voltages makes efficient design complex. Existing solutions require multiple converters, increasing cost and complexity.
- Hard switching leads to increased power losses. Soft switching across different charging modes requires complex control strategies which need precise implementation to optimize efficiency.
- Changes in power transfer cause increased peak current stress, impacting the reliability and longevity of the system.
- Limited bidirectional power transfer efficiency.
- LLC converters struggle with reverse power transfer due to a lack of voltage gain above unity, requiring an alternate control strategy.

Objectives

- Design an off-board EV charger with a 108-300V range for compatibility and optimal efficiency across charging conditions.
- Using soft-switching which minimizes energy losses and peak current stress across charging modes.
- Achieve seamless vehicle-to-grid (V2G) and grid-to-vehicle (G2V) operations, , enhancing energy flow flexibility.
- Integrating multiple modes within a single converter to reduce hardware complexity.
- Presenting MATLAB/Simulink results to confirm the charger’s effectiveness across varying load conditions.

Block Diagram

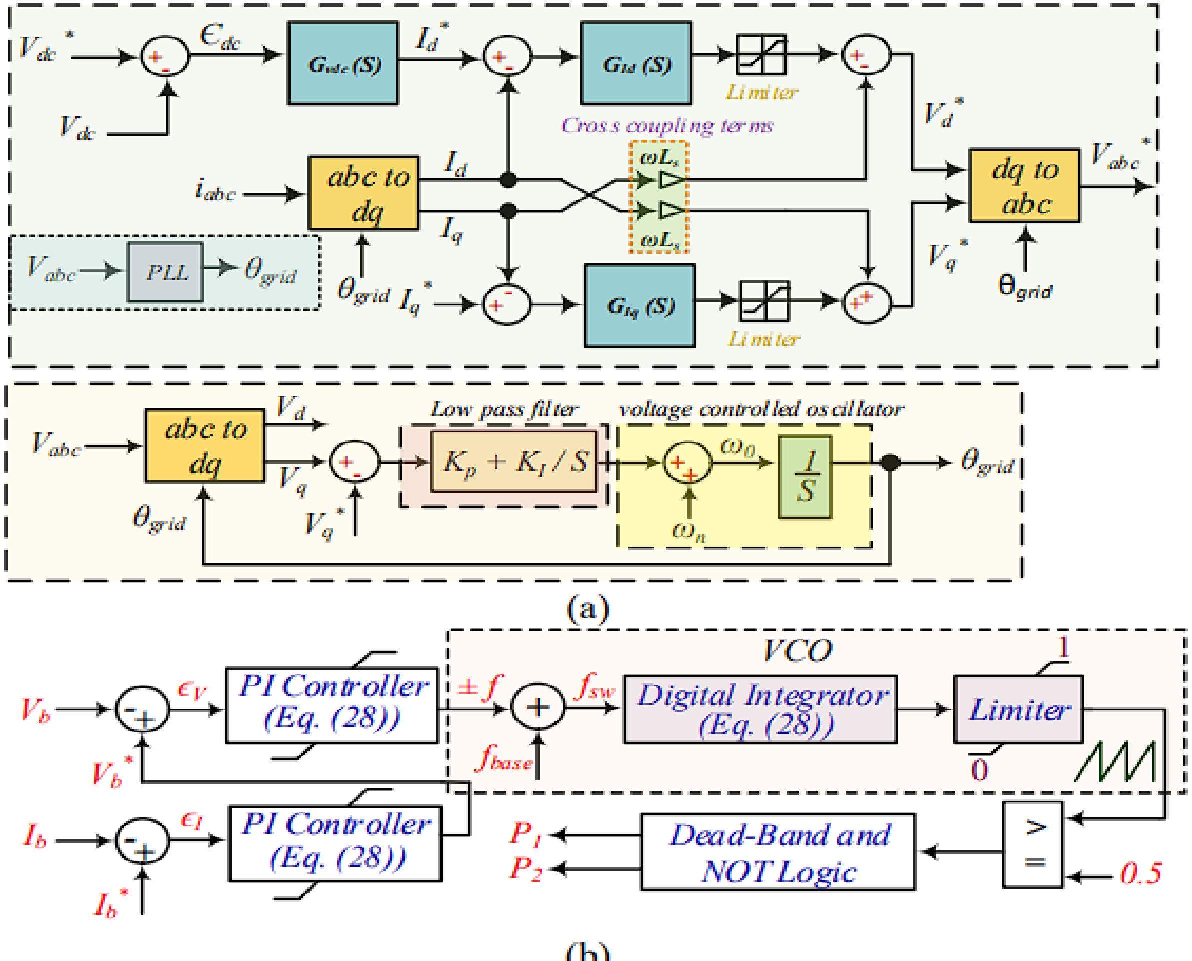
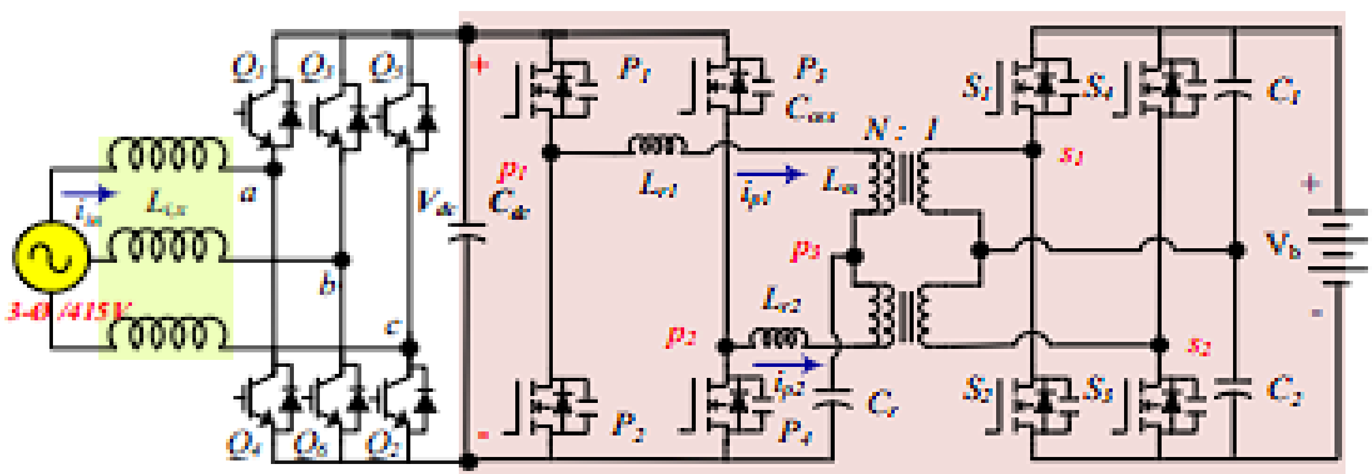


Fig.7 Control of both power conversion stages (a) control for front end active rectification and (b) control for mode 2 and 3 of DC-DC stage.

Circuit Diagram with working

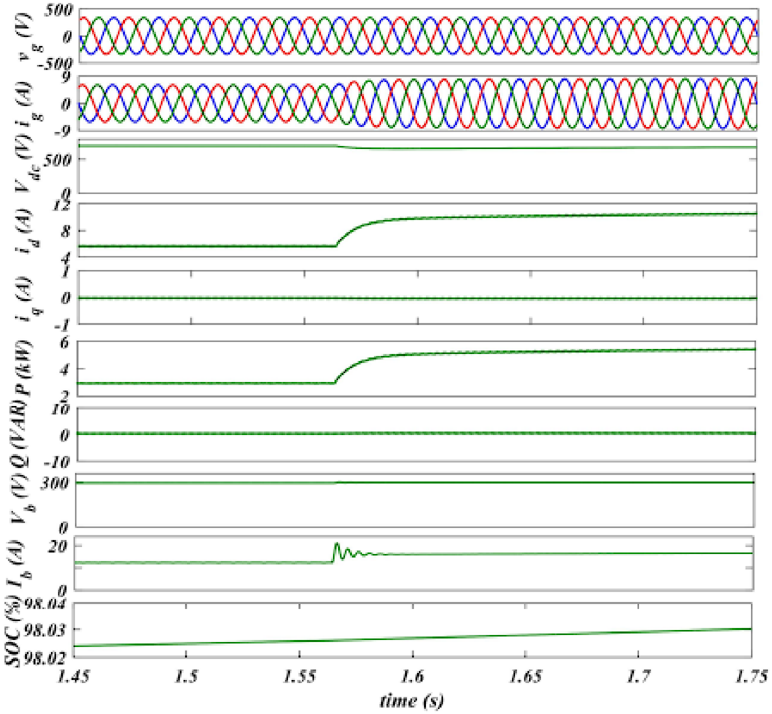
The EV charger comprises two-stage power conversion system, with a three-phase VSC front end converter and a reconfigurable type full bridge (FB) isolated converter with active rectification for DC-DC power conversion. The figure below shows the circuit diagram of off-board charger. The VSC is connected to three phase grid through interfacing inductor and on output side it is connected to DC link capacitor. The DC-DC isolation stage regulates the charging rate. In DAB mode of operation, diagonal switches are triggered with conduction angle ‘d’ and between both bridges another phase shift ‘ϕ’ is introduced for power transfer control. In FB-LLC mode, diagonal switches have a 50% conduction duty and power transfer is controlled by changing the driving voltage's switching frequency. This makes further regulation in tank circuit impedance, which varies the voltage across the primary winding of isolation transformer. For HB-LLC mode, the gate pulses of one leg are removed. Under this mode, only one winding is used in power regulation which improves the system efficiency under light loading scenarios. Each operating mode is selected based upon battery charging mode. Based on amount of power transfer, number of switches into operation are decided, which controls the soft-switching region.



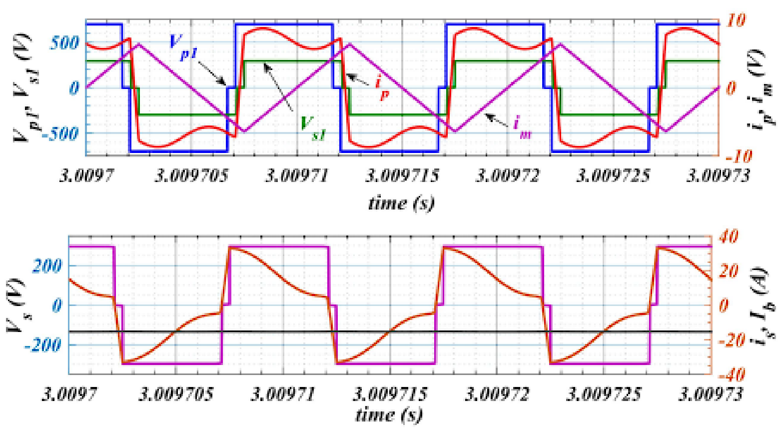
Methodology

- Developed a three-phase bidirectional off-board EV charger with an isolated DC-DC stage, using SRF control for AC-DC conversion and multiple modes (DAB, FB-LLC, HB-LLC) for DC-DC conversion.
- Used mathematical models for power transfer, peak current stress, and voltage gain, optimizing the DAB mode with Particle Swarm Optimization (PSO).
- Designed a 5 kW system and simulated it in MATLAB/Simulink, analyzing soft-switching, peak current stress, and vehicle-to-grid (V2G) performance.
- Evaluated system operation under varying charging rates, ensuring wide voltage adaptability, efficiency.

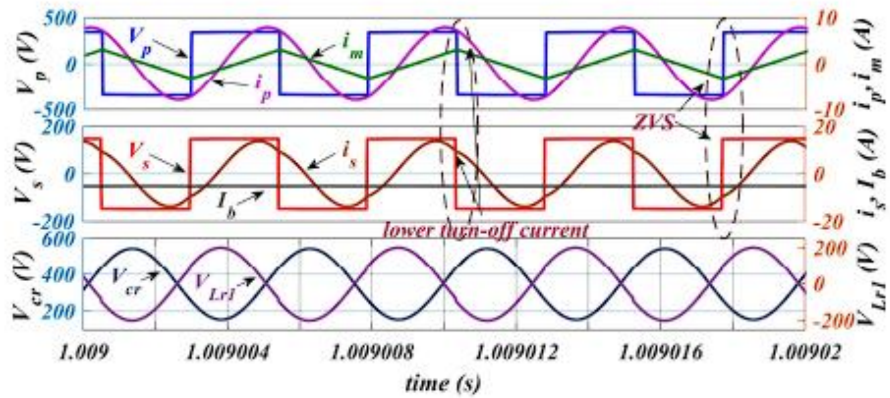
Simulation Results



(a)

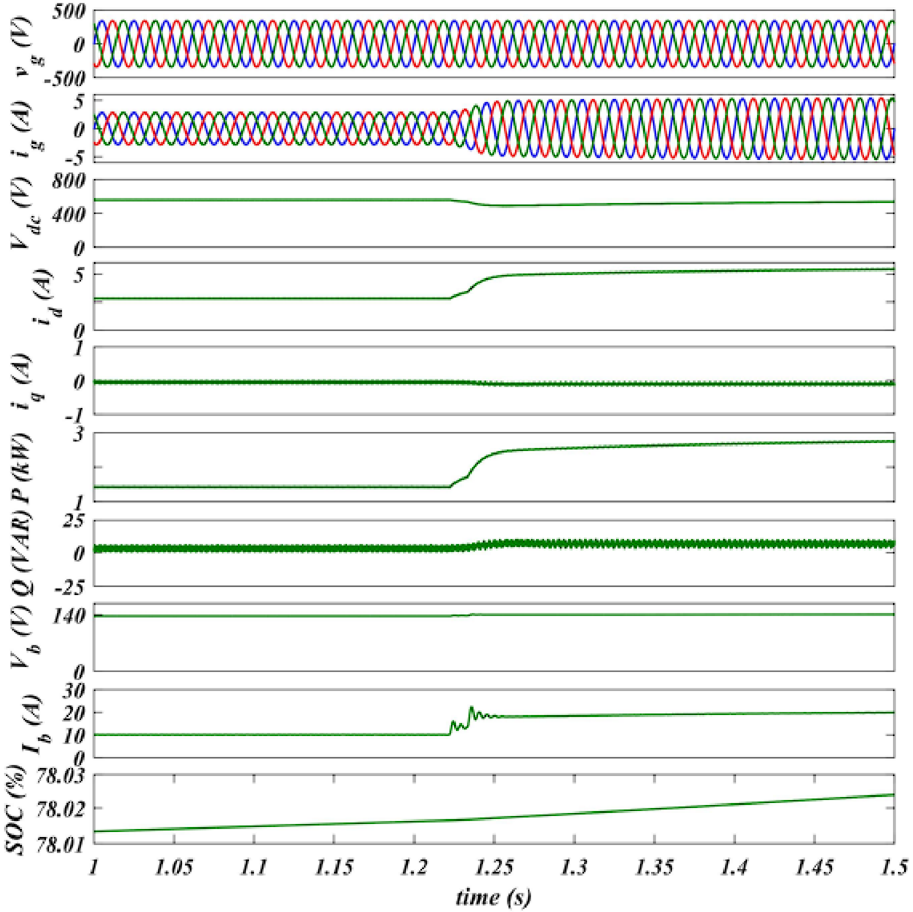


(b)

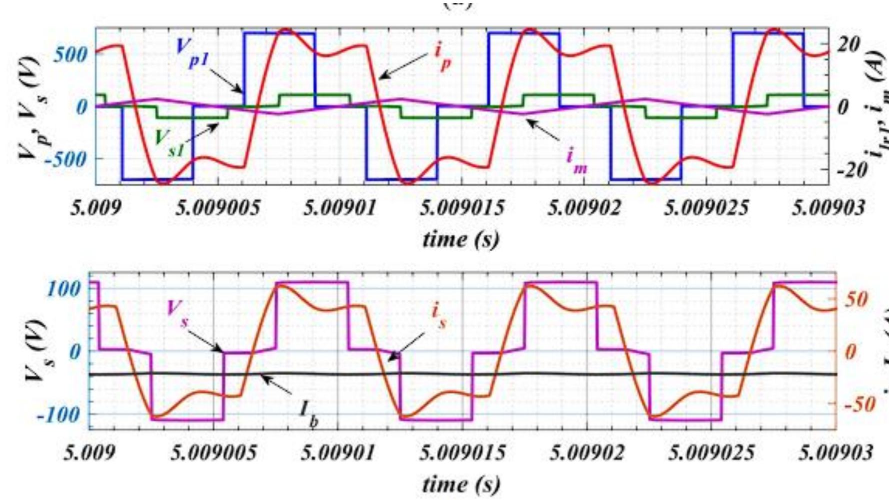


(c)

Fig.8 Simulated performance with charging of $V_b = 240\ V$ (a) PFC and battery charging performance with step change from *10 A* to *15 A*. (b) & (c) DAB and DLLC mode with 15 A and 5 A charging current, respectively.

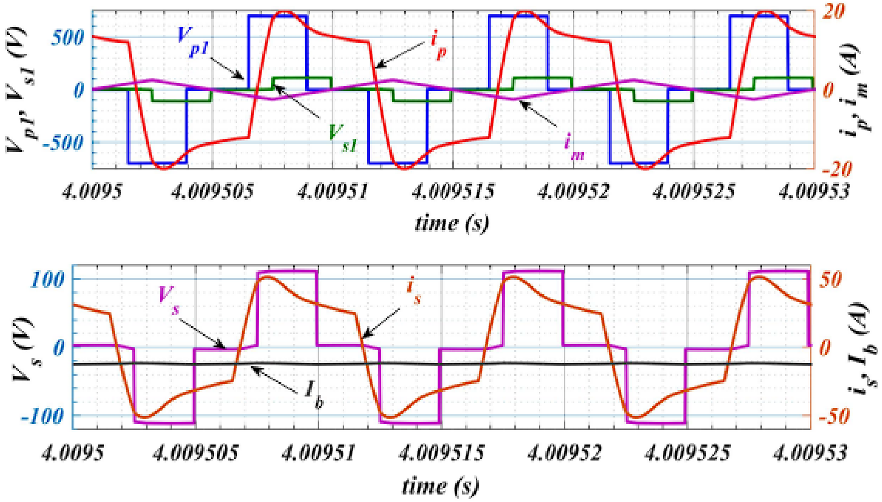


(a)

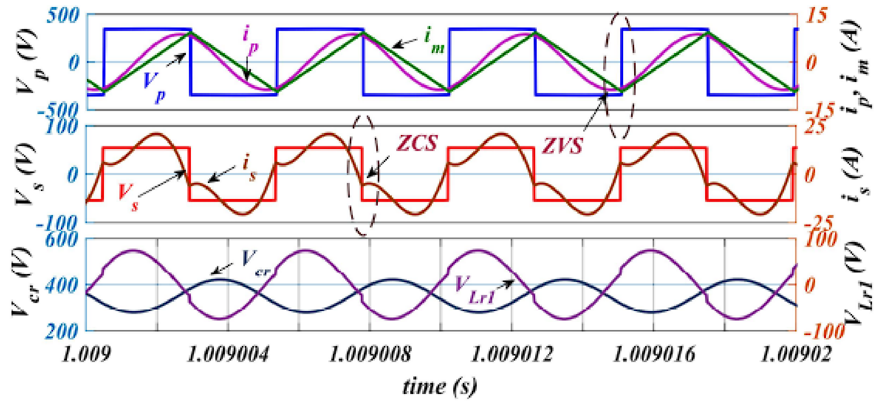


(b)

bridges with lower turn-off losses. Charging performance with 120 V battery is shown in Fig.10. Here, Fig.10(a) shows front end converter performance with step change in charging current from *10 A* to *20 A*. During step change, converter maintains minimum undershoot of *40 V* with *40 ms* settling time.



(c)



(d)

Fig.10 Simulated performance with charging of $V_b = 120\ V$ (a) PFC and battery charging performance with step change from *10 A* to *20 A*. (b) & (c) DAB mode with *20 A* and *10 A* charging current, respectively and (d) DLLC mode performance with *5 A* charging current.

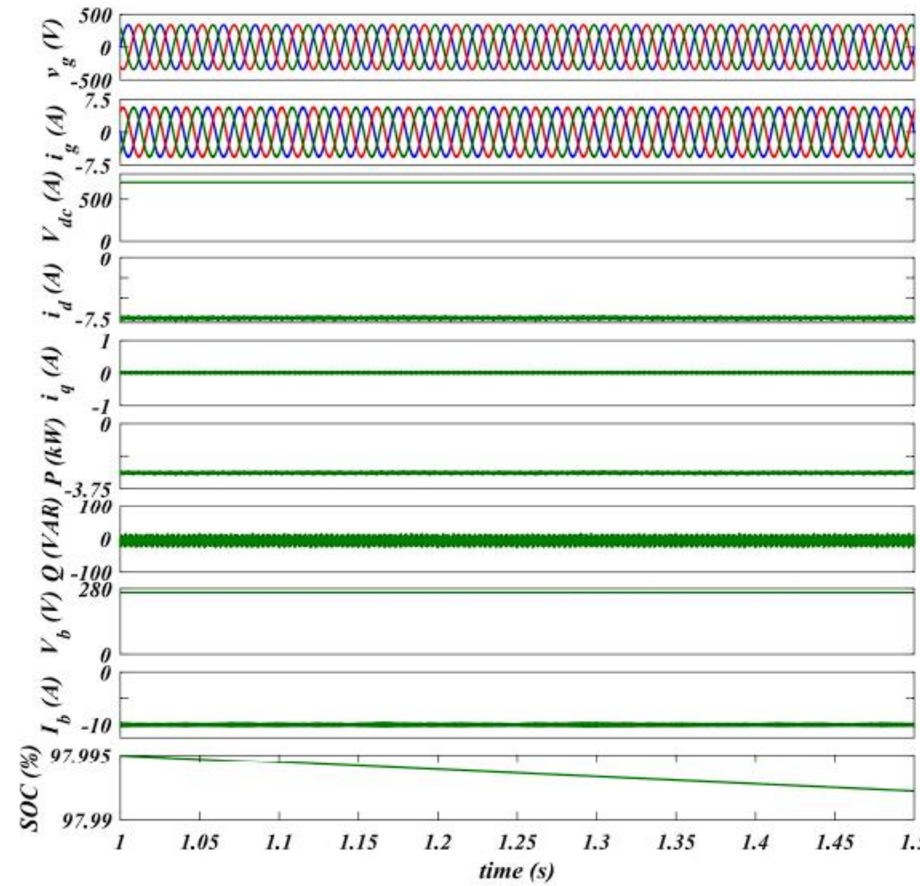
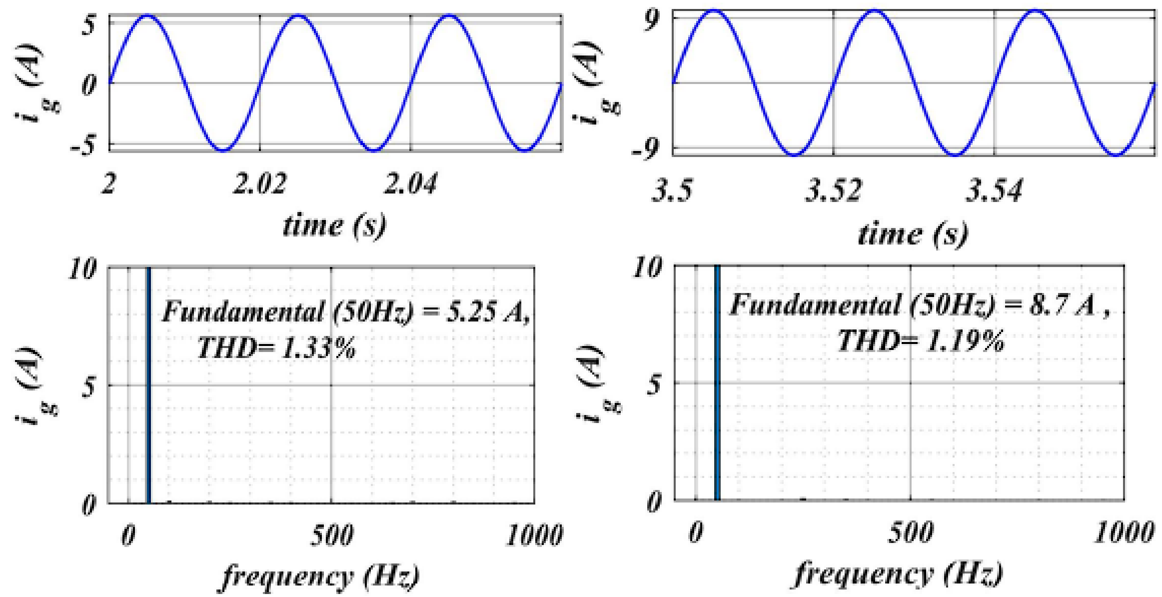


Fig.11 Vehicle to grid performance with $V_b = 240\ V$ and $I_b = 10A$.



(a) (b)

Fig.12 PFC performance of front end VSC with (a) I_b = *20 A at 130 V* and (a) I_b = *15 A at 295 V*.

Work Plan

- Phase 1: Literature Review & Theoretical Analysis.
- Phase 2: System Design & Parameter Selection.
- Phase 3: Simulation and Optimization.
- Phase 4: Experimental Validation & Testing.
- Phase 5: Performance Evaluation.
- Phase 6: Documentation and final review.

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