User Spotlight Series 2.0

RTDS Technologies

Power-HIL System for Evaluating Physical EV On-board Chargers using RTDS

Episode 4: May 25, 2022, Winnipeg, 09:00am

RIGA

A Laboratory of University of Manitoba

University of Manitoba

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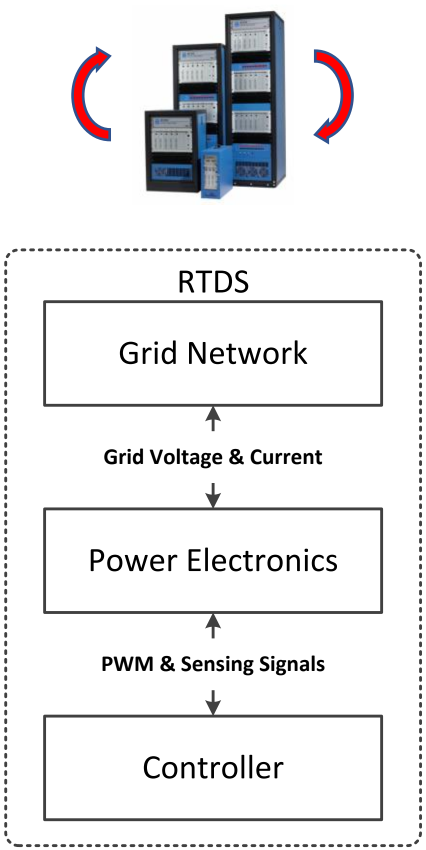
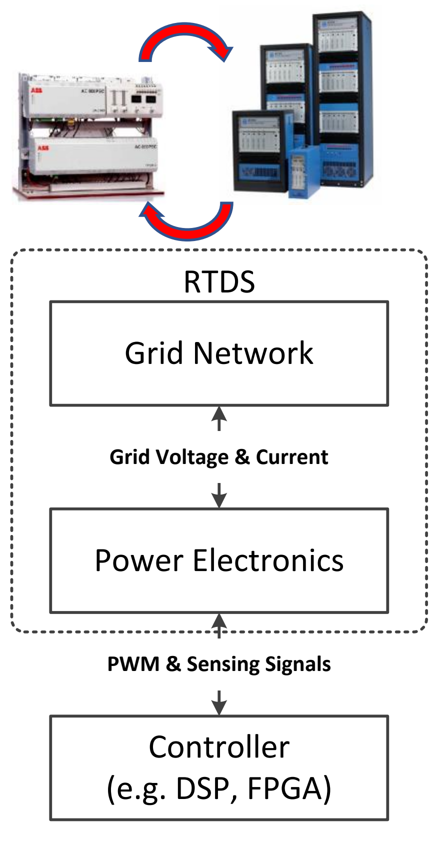
Introduction

- Power-Hardware-in-the-Loop (PHIL) Real Time Simulation
- Power Electronic (PE) Systems in an Electric Vehicle (EV)
- EV On-board Charger (EVC)
- Conceptual Idea of a PHIL-EVC System
- Experimental Results
- Conclusion and Future Work

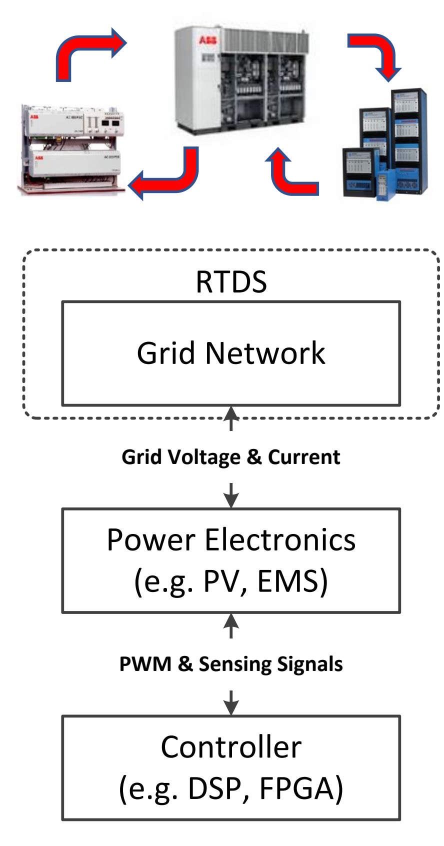
RTDS and Modern Power Electronics (PE)



Real Time Simulation

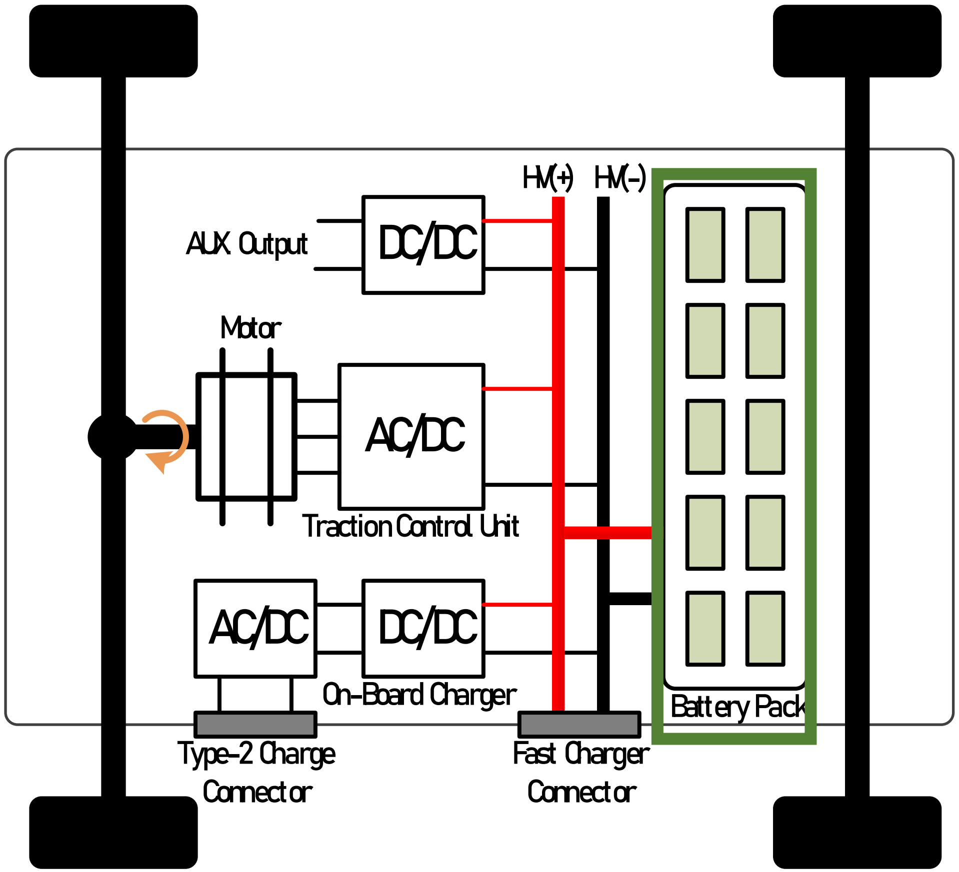


Controller-HIL Simulation



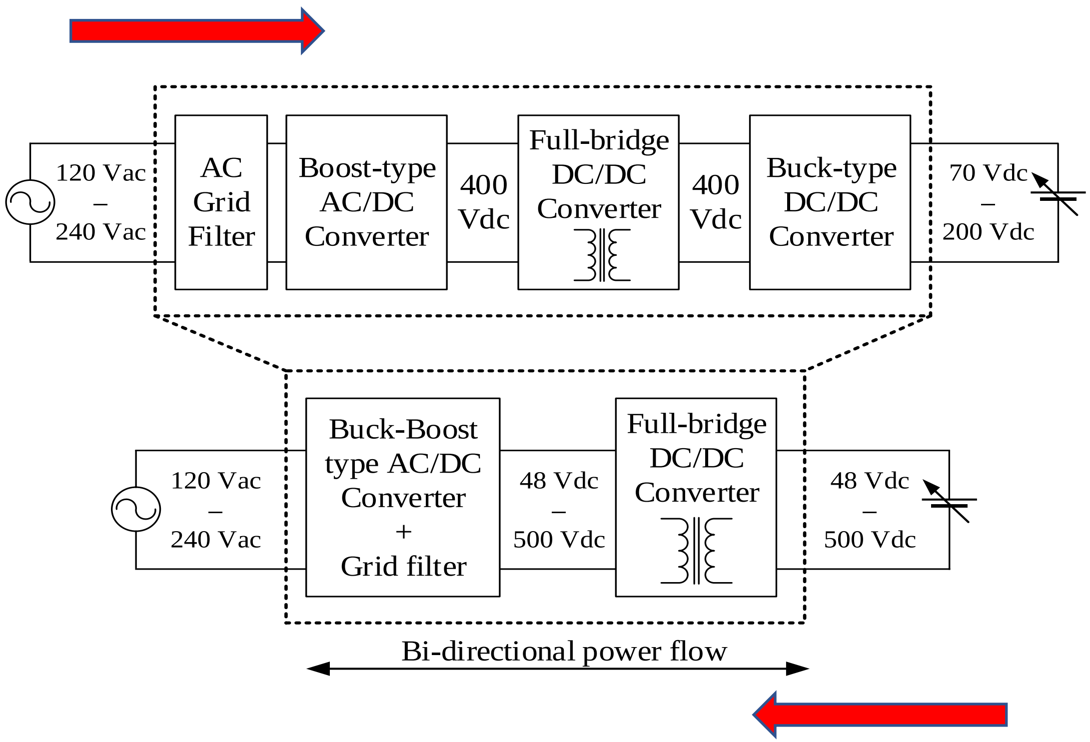
Power-HIL Simulation

PE Devices in an Electric Vehicle (EV)



- Internal PE Systems,
  - Traction Control Unit
  - On-Board Charger
  - Aux. Power Supply
- External PE System,
  - DC fast Charger
- Critical Electrical Elements
  - Battery Pack
  - Motor
  - Grid Terminal

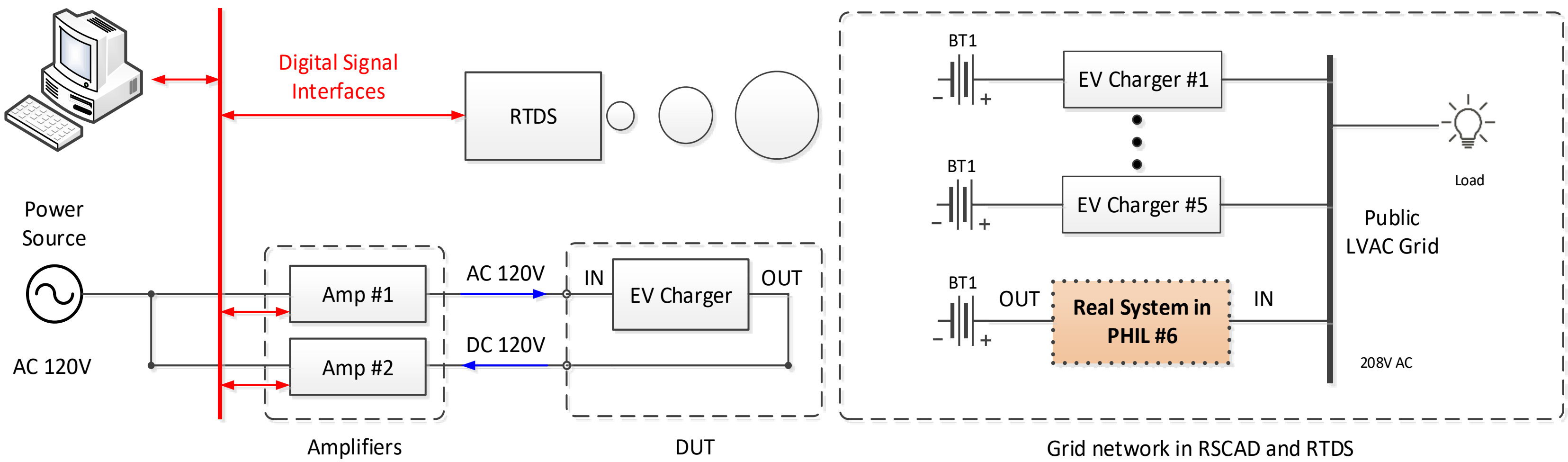
Block Diagram of EV On-board Chargers



Source: delta-q.com

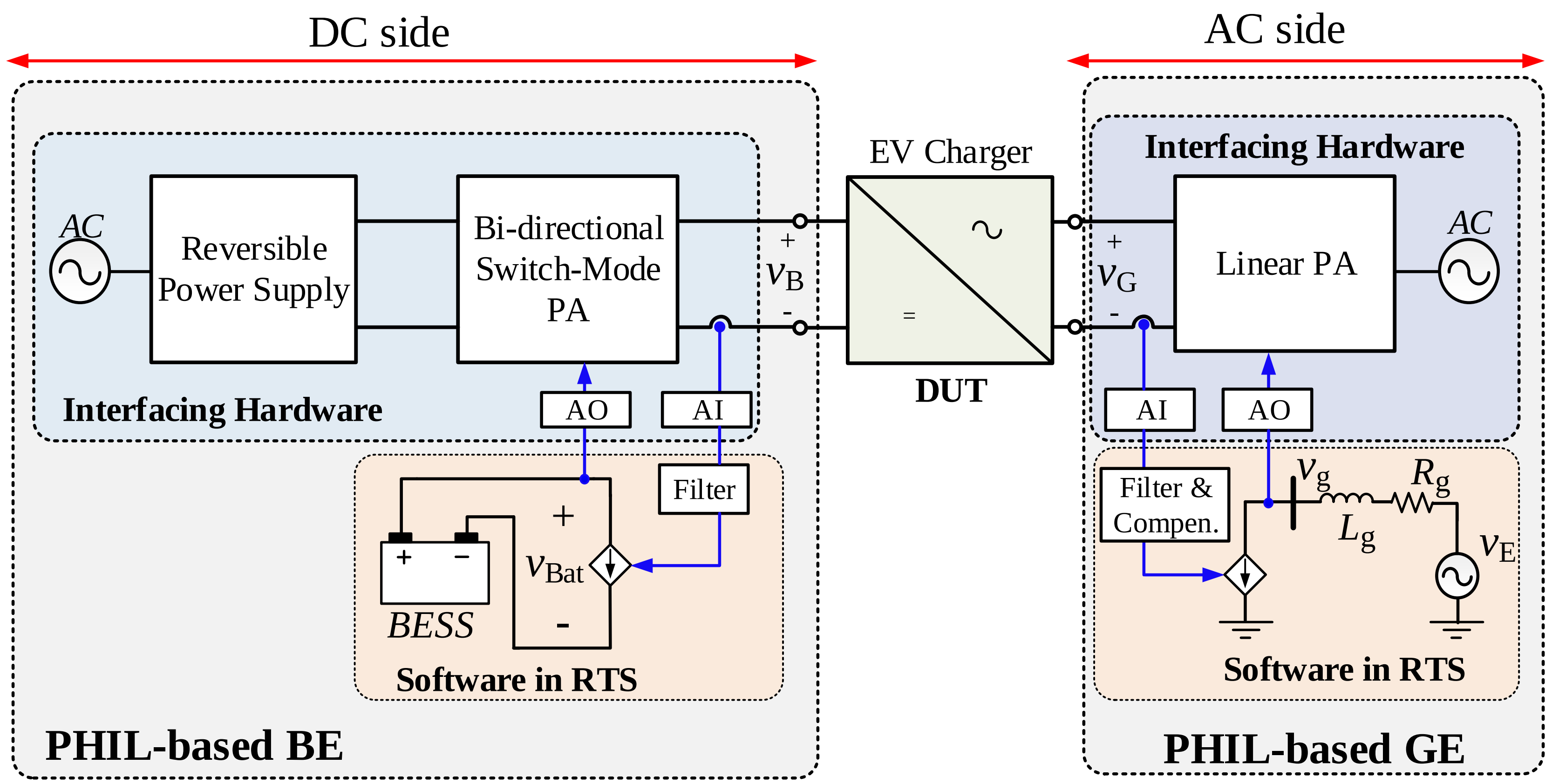
- AC Terminal – connecting to AC grid.
- DC Terminal – connecting to DC battery.

Overview of A PHIL-ECV System

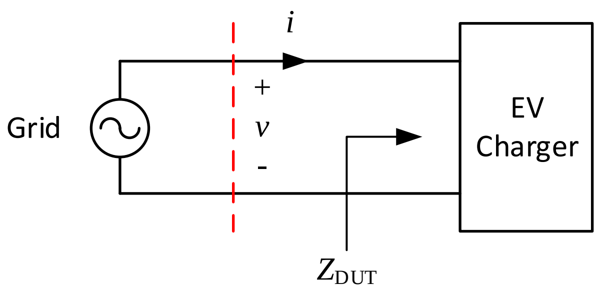


- PHIL with a EV Charger (DUT) can be used as,
  - Burn-in System.
  - EVC function evaluating system.
  - Power Quality study from the grid side.

Hardware Configuration of PHIL-EVC



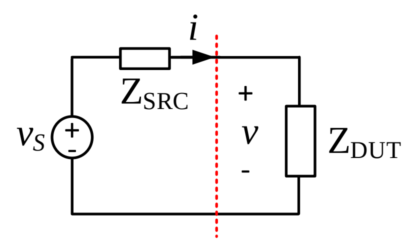
AC Grid Model – SW-HW Interface

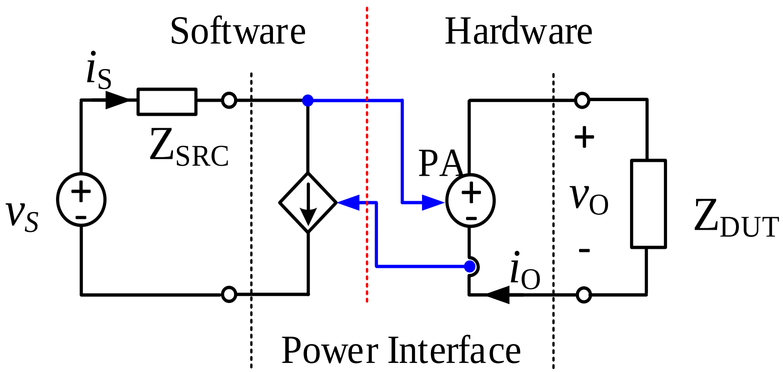


Physical System

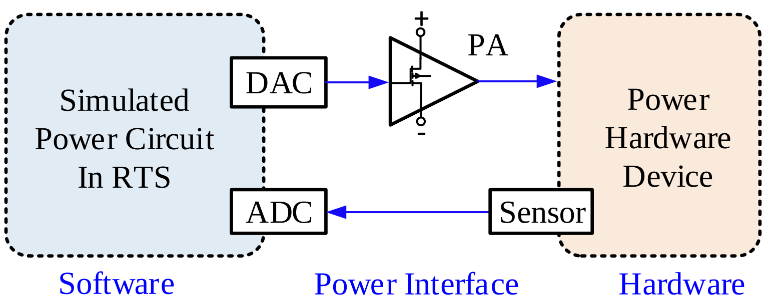
Equivalent Circuit

Original Circuit



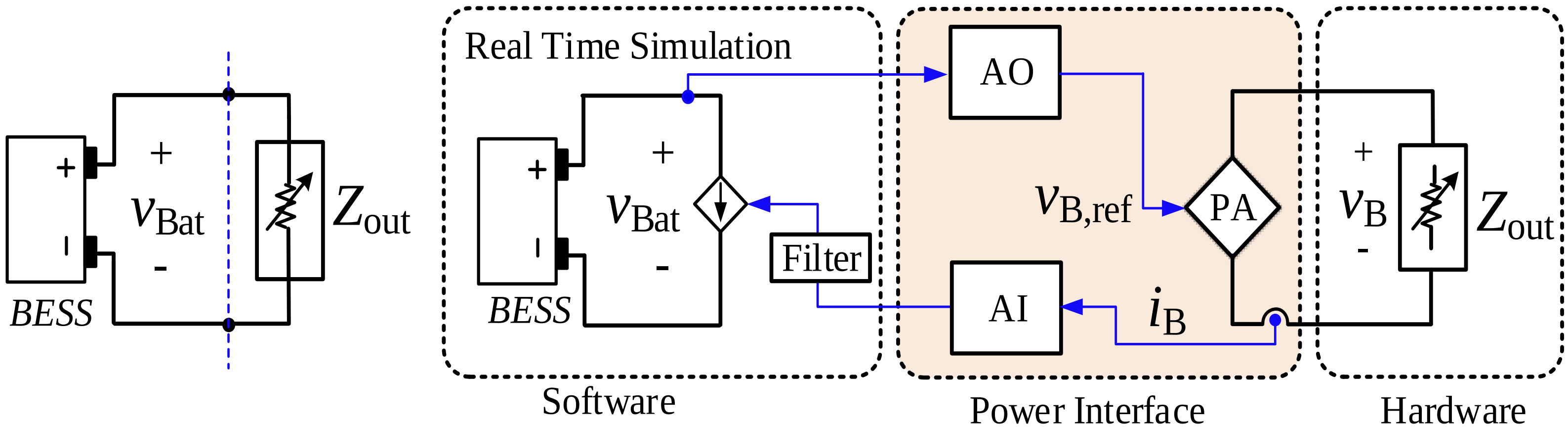


A Voltage-type Ideal Transformer Method (ITM)



SW-HW Connections

DC Battery Model – SW-HW Interface

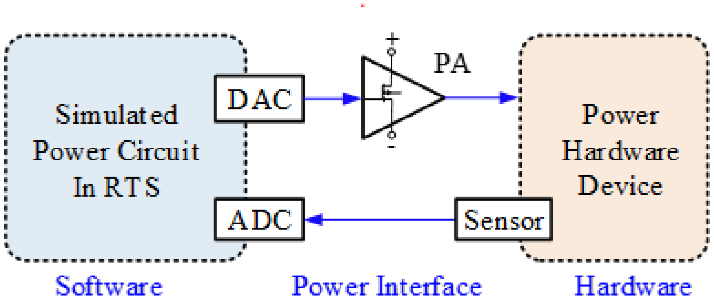


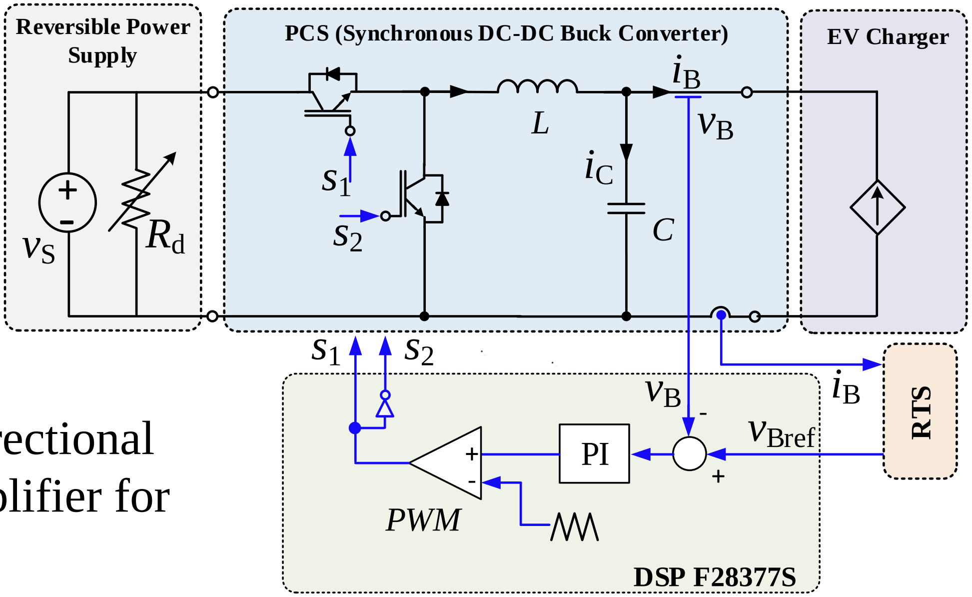
(a) Lithium-ion (Li-ion) Battery Real Time Simulation

(b) PHIL ITM at the DC Side

Design and Development of PE Amplifiers

- AC – Linear Amplifier
  - Fast Dynamic
- DC – Switch-mode Amplifier
  - High power density
  - Low cost
  - Efficient

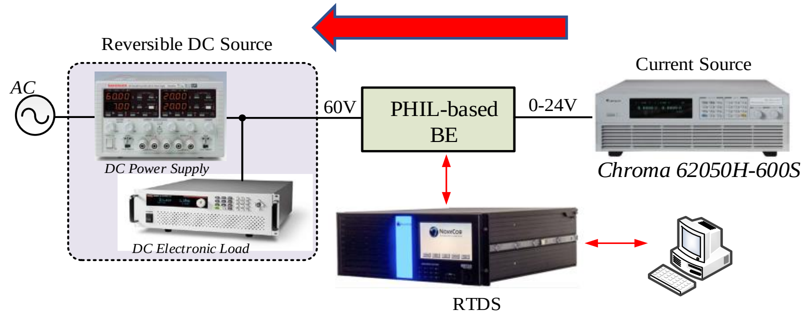




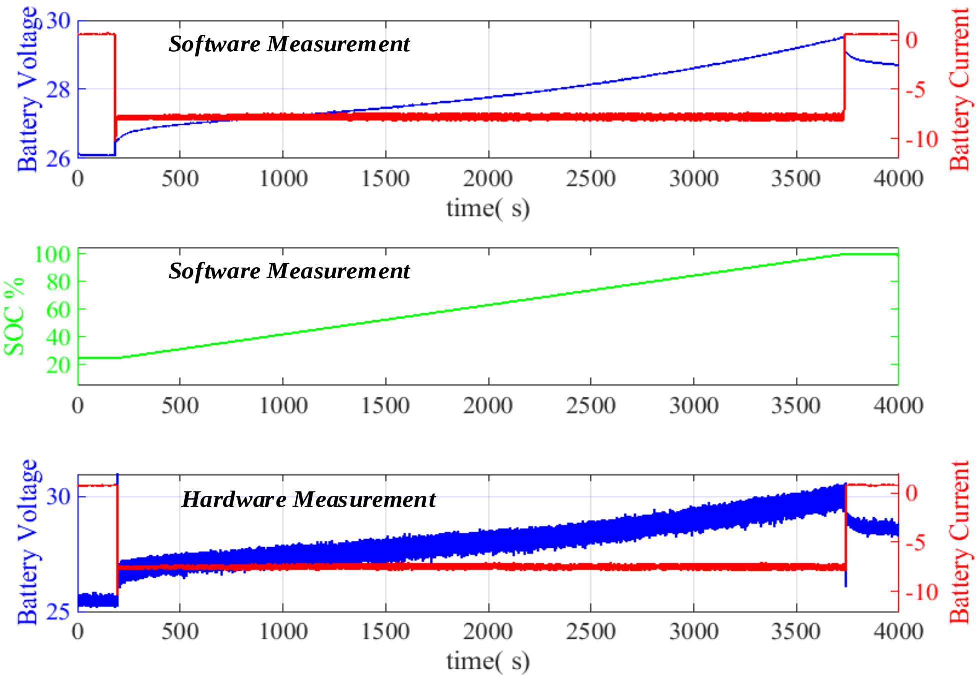
Architecture of the bi-directional switch-mode Power Amplifier for Battery Emulation

Experiment – Battery Emulator Charging

Test bench for evaluating battery charge tests with PHIL.

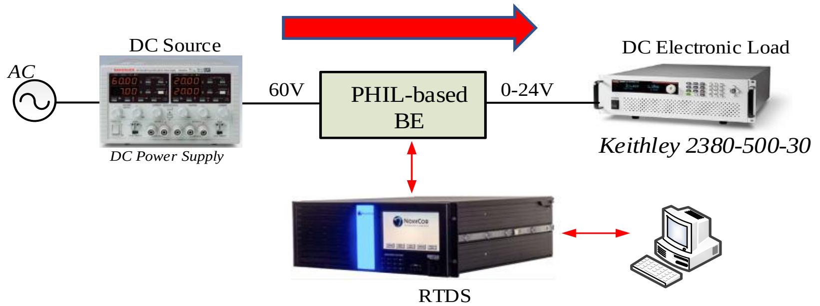


Charge curve of the emulated 24V/ 10Ah Li-ion battery model using PHIL-based BE in both software and hardware.

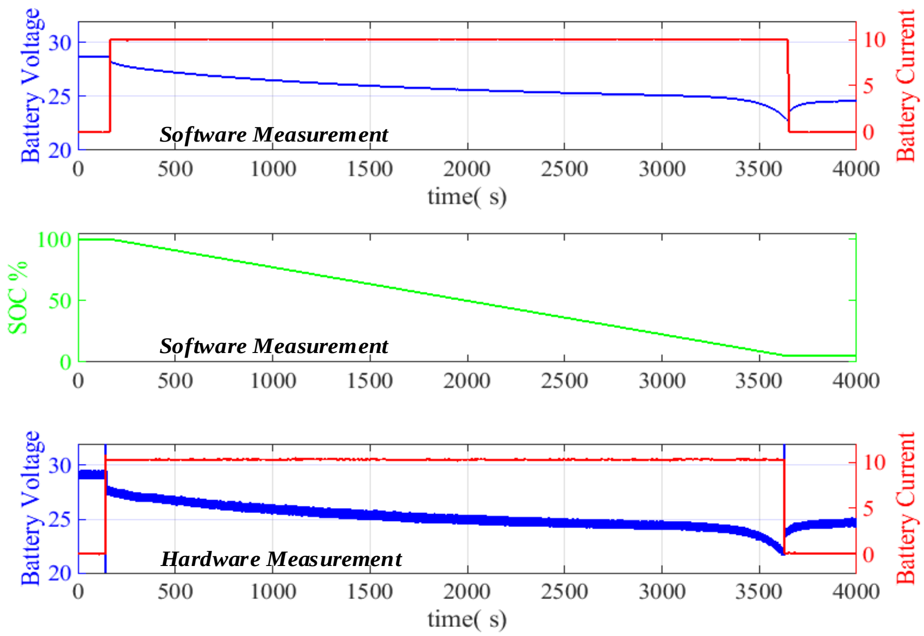


Experiment – Battery Emulator Discharging

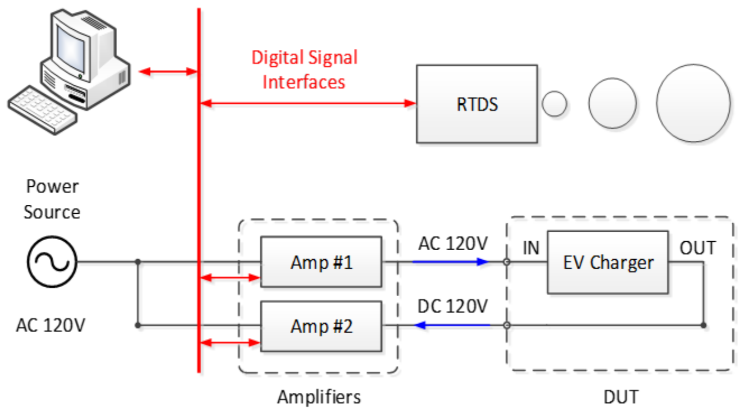
Test bench for evaluating battery discharge tests with.

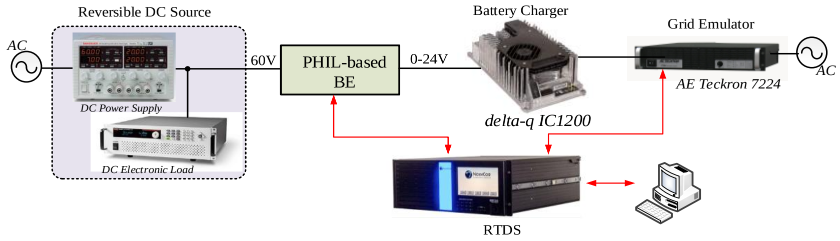


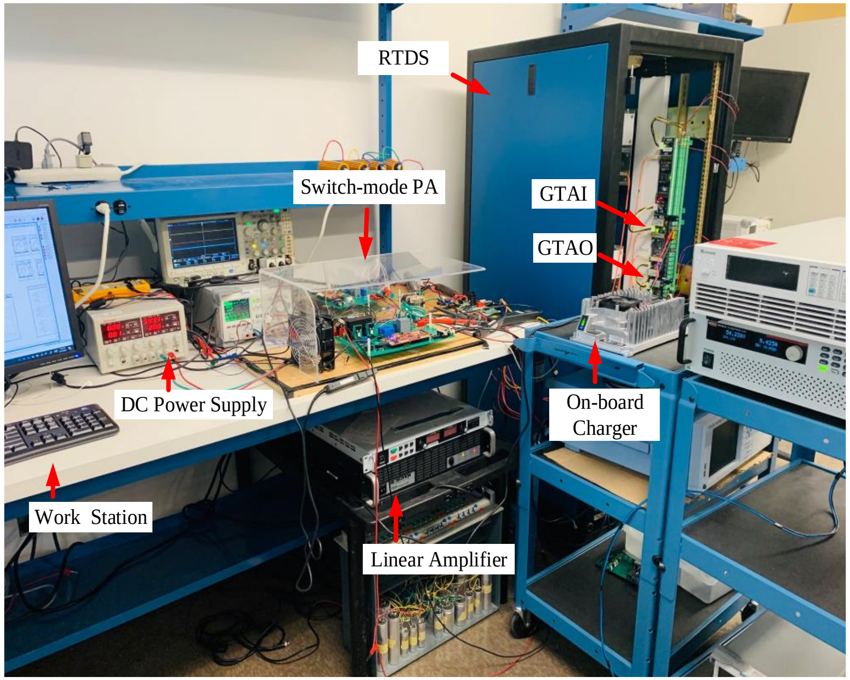
Discharge curve of a 24V/ 10Ah Li-ion Battery model with PHIL-based BE for 10 A continuous discharge current.



PHIL Experimental Setup

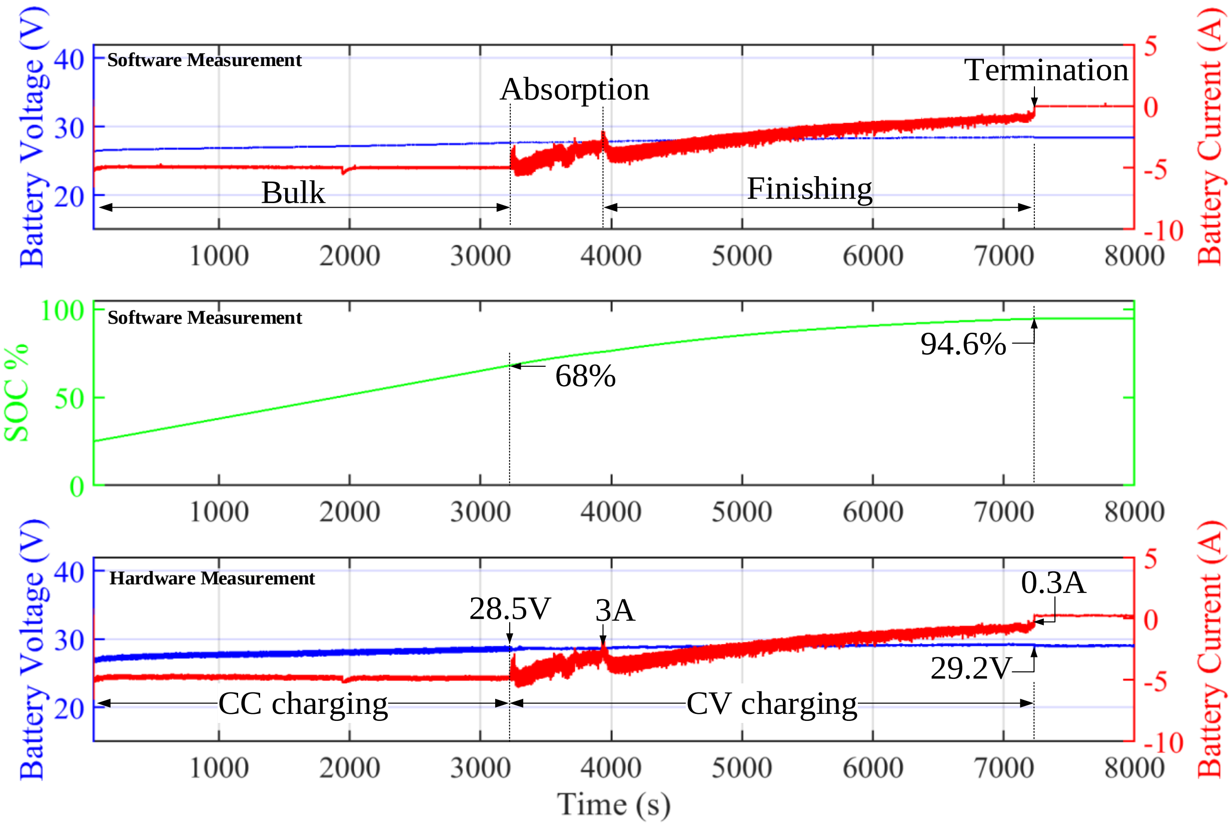






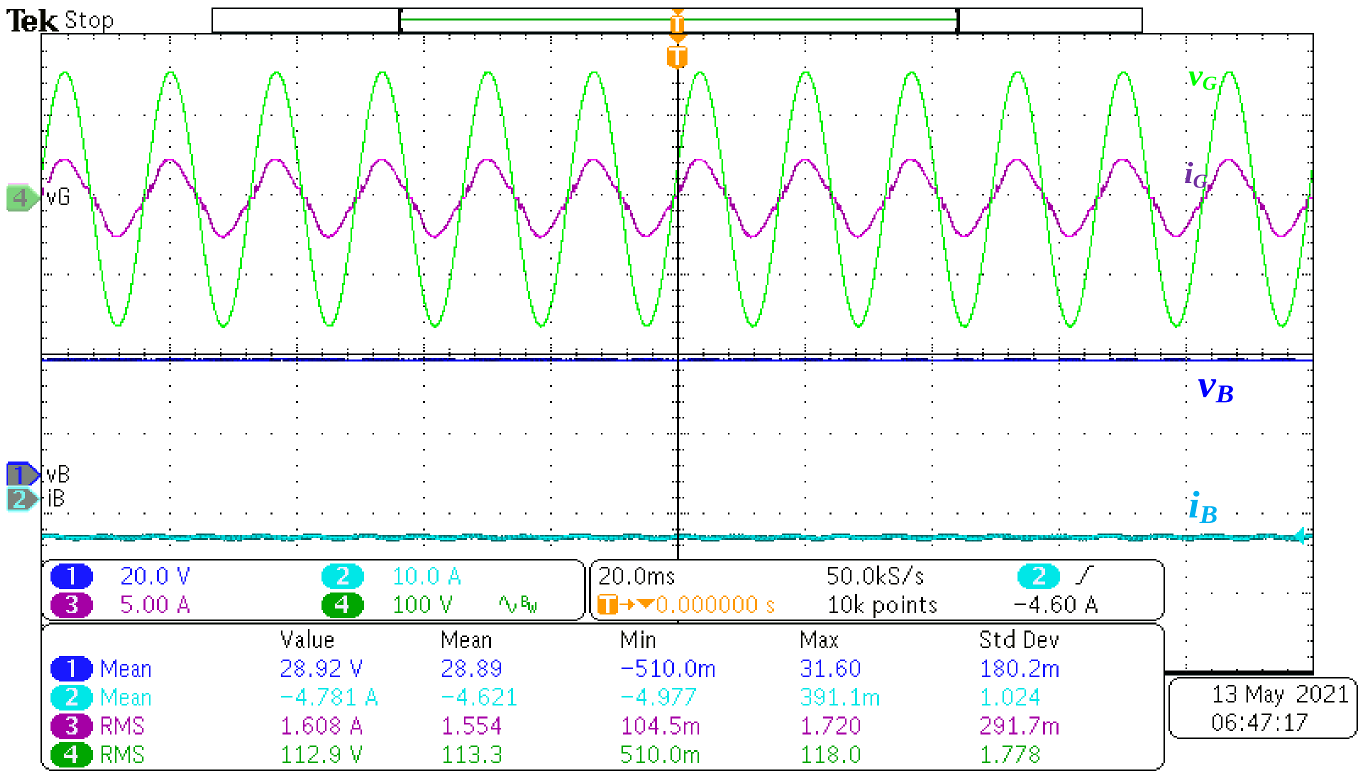
- A 1.2kW Battery Charger (Delta-Q IC1200)
- PHIL –
  - Battery (DC) - Power Electronics Amplifier
  - Grid (AC) – Linear Amplifier

Experiment – Battery Side (DC) Behaviour



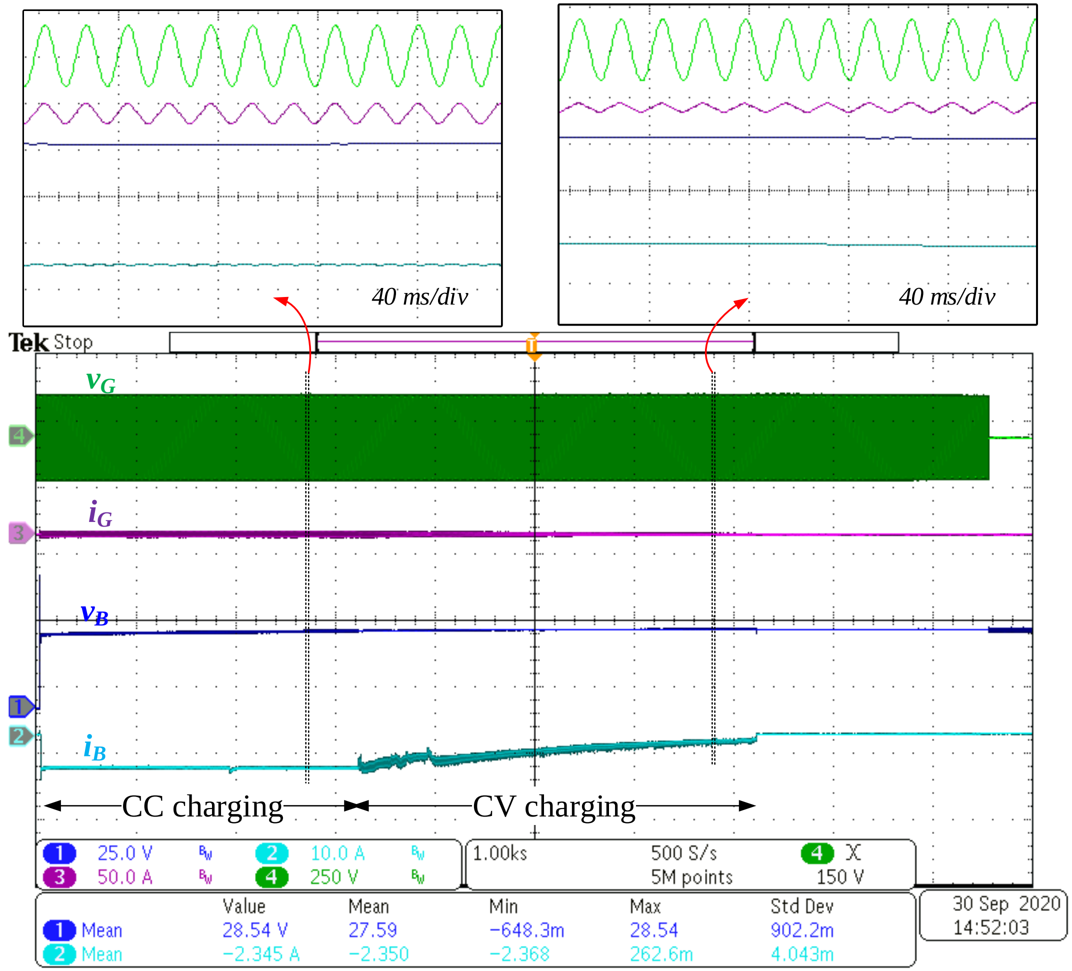
Experimental results of battery emulation obtained with a grid connected EV charger.

Experiment – Grid Side (AC) Behaviour

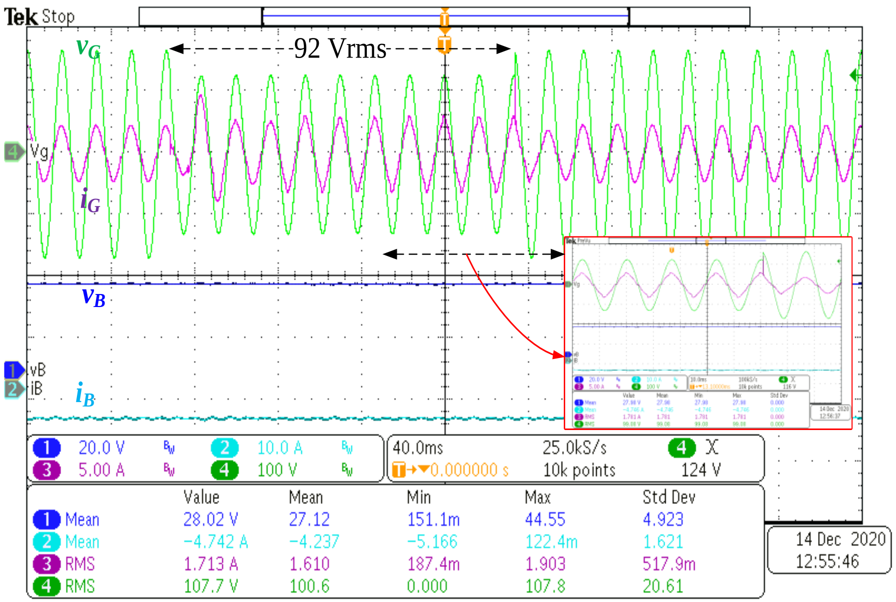


Experimental results of Input current of delta-Q IC1200 in PHIL.

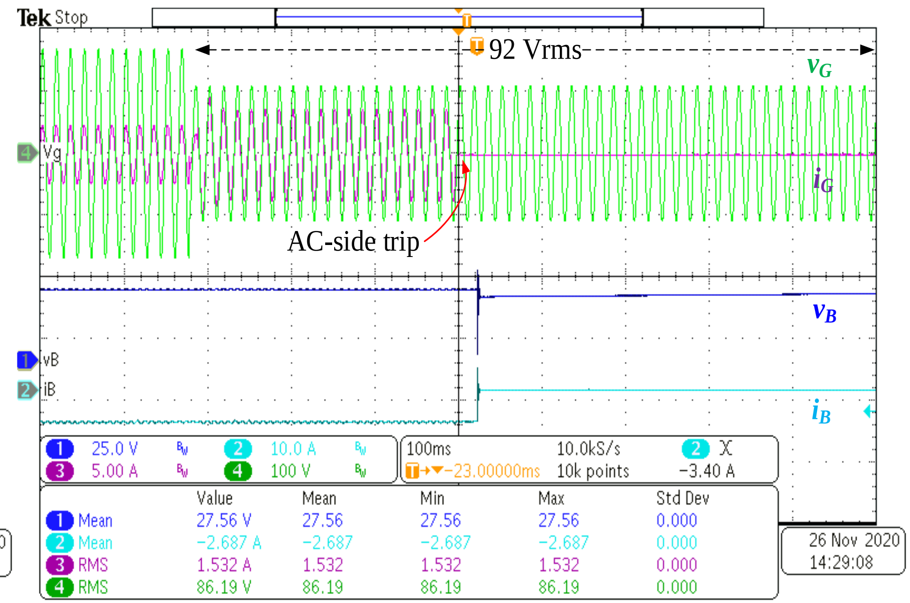
Experiment – Both AC and DC Terminals



Case Study – Voltage Sag

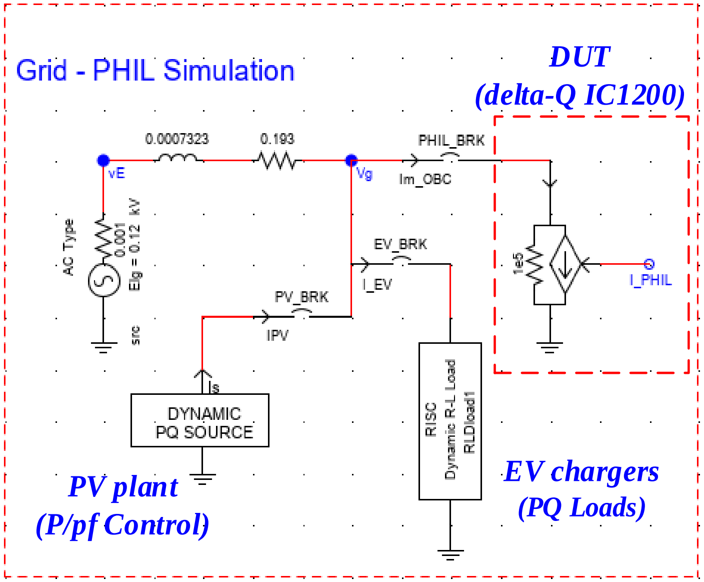


Transient response of the EV charger under grid voltage fluctuations (120 Vrms-92 Vrms-120Vrms).

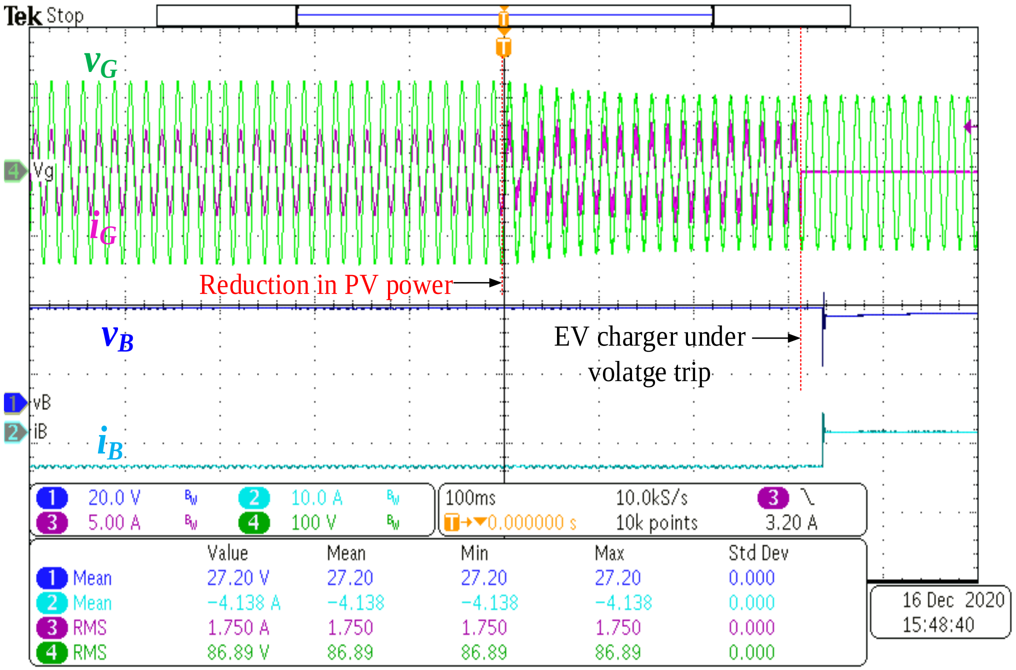


Transient response of the EV charger for an extreme voltage sag (120 Vrms-78 Vrms).

Case Study – Weak Grid w/ PV Power Change



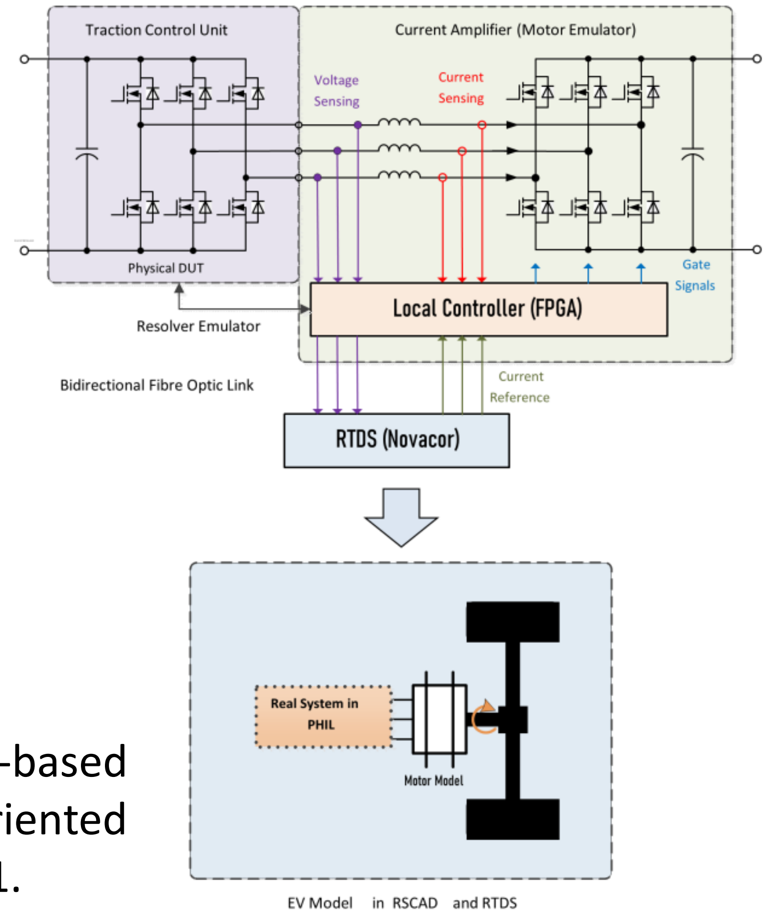
The LV network simulated in RTS software.



Experimental results of delta-Q IC1200 under sudden decrease in PV power from 10 kW to 100W on a weak LV grid.

Extend to Traction Control Unit (TCU)

- PHIL can be used for EV Traction Control Unit (TCU)
- DC – Battery Pack
- AC – Motor



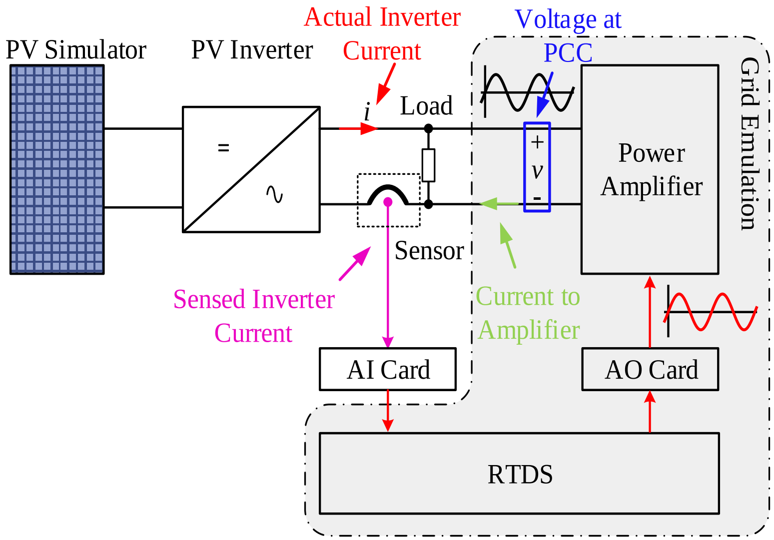
T. Eskilson, and C. Ho, "Power Electronics-based Power-HIL System for an EV Field Oriented Motor Controller", *IEEE ECCE21*, Oct. 2021.

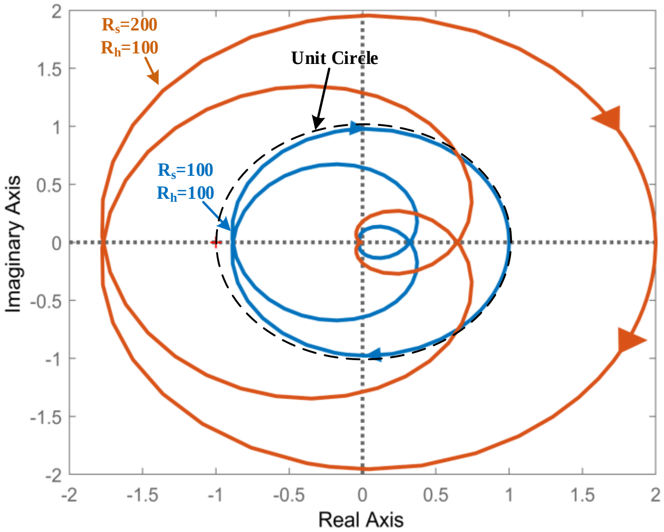
Conclusion

- PHIL created a flexible testing platform to evaluate EV On-board Chargers using "**Virtual Reality**" approach.
- All the elements connecting to the EVC are real time simulated. But it gives a full power test for the EVC with practical results.
- Types of battery, grid conditions and fault senecios can be modified by a few clicks.
- It saves energy during commercial product burn-in test with condition changing.
- Further Power Quality and V2G function will be easily studied before doing any real installation.

Suggested Reading

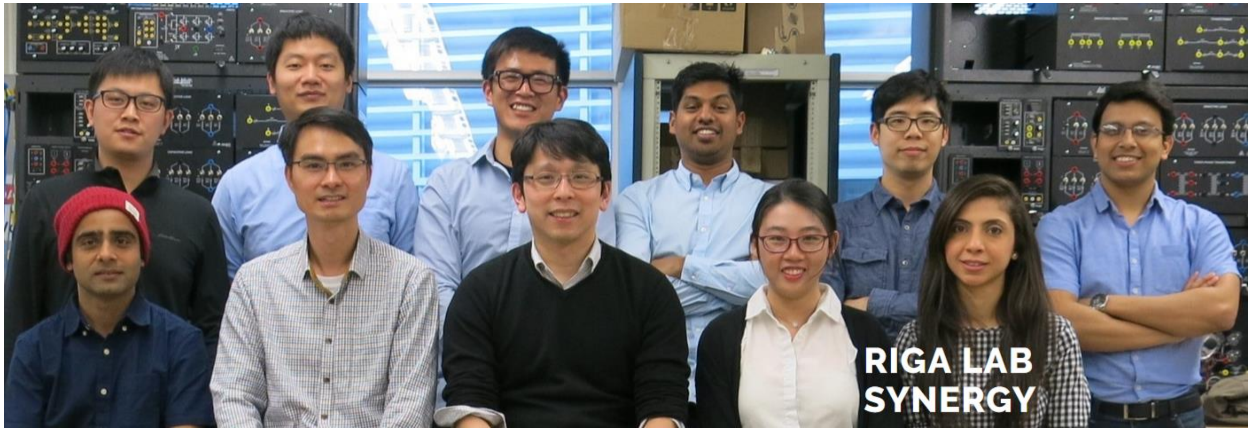
- M. Pokharel, and C. Ho, “Development of Interface Model and Design of Compensator to Overcome Delay Response in a PHIL Setup for Evaluating a Grid-Connected Power Electronic DUT ”, *IEEE Trans. on Ind. Appl.*, (Early Access)
- I. Jayawardana, C. Ho, and Y Zhang, “A Comprehensive Study and Validation of a Power-HIL Testbed for Evaluating Grid-Connected EV Chargers”, *IEEE J. Emerg. Sel. Topics in Power Electron.*, vol. 10, no. 2, pp. 2395-2410, April 2022.
- M. Pokharel, and C. Ho, “Stability Analysis of Power Hardware in the Loop (PHIL) Architecture with Solar Inverter”, *IEEE Trans. Ind. Electron.*, vol. 68, no. 5, pp. 4309-4319, May 2021.





Acknowledgement

- Hard work from RIGA Lab,
  - Dr. Mandip Pokharel, KGS Group, Canada.
  - Dr. King Man Siu, Uni of North Texas, USA
  - Mr. Avishek Ghosh, Uni of Manitoba, Canada
  - Mr. Troy Eskilson, Uni of Manitoba, Canada
- Support from,
  - RTDS Technologies Inc., Canada
  - Delta-Q Technologies Inc., Canada
  - Research Manitoba, Canada
  - NSERC Discovery Grant, Canada



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