EE 791 [Course Project]

Integrated on-board charger for Solar Electric Vehicle

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Run-Through

Showcased the need for an integrated on-board charger for solar electric vehicle.

Implementation of partially solar powered electric vehicle

Solar roof dimension: 3100 x 1850 mm2

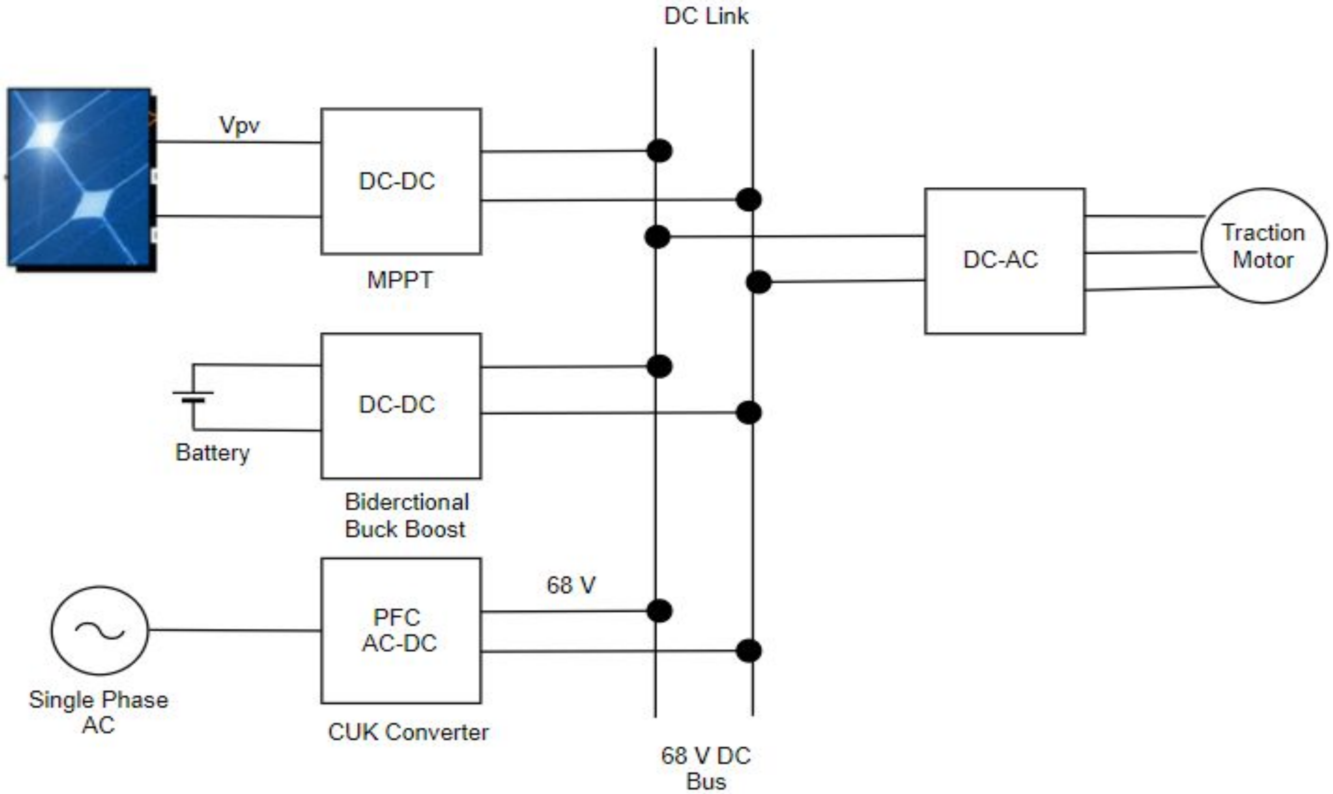
3 panels, 48 Voc, 130W each

Power rating of MPPT dc-dc converter: 390 W

Capacity of Battery pack: 12 x 120 x 5 = 7.2 KWh

Usable capacity of battery: 0.7 x 7.2 = 5.04 Kwh

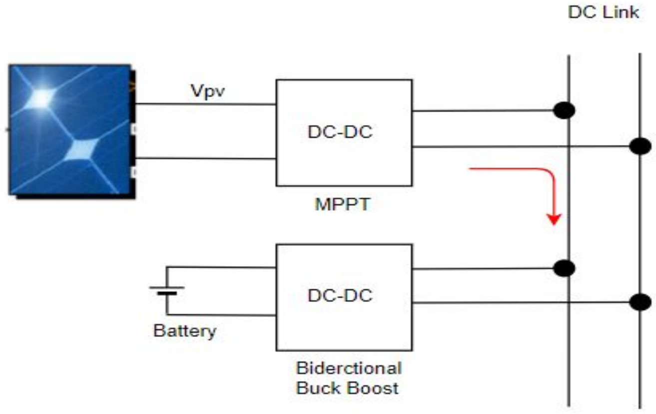
Architecture of system



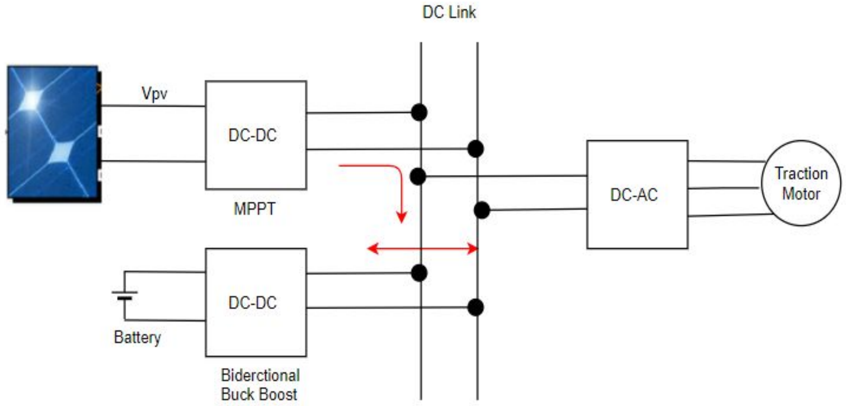
Proposed Circuit topology

- It uses single phase bidirectional charger for an EV that inject solar PV array directly on the DC link
- System charges the EV battery using the solar PV power under running condition and stalling condition & charges using grid during insufficient solar irradiance
- While charging the EV the DC-DC converter works in buck mode and operates in boost mode while discharging
- Converter also regulates the DC bus voltage and harness the maximum generated power from the solar PV array

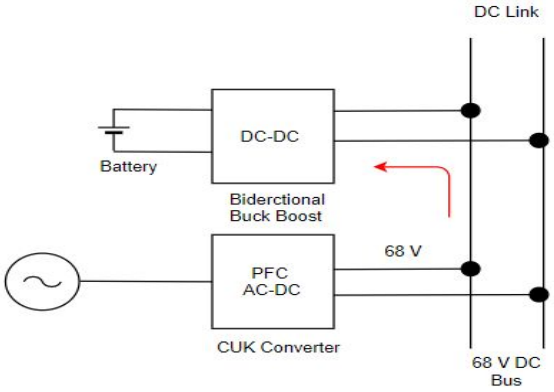
Modes of Operation



1.) Power exchange between Solar Panel and Battery (Stalling mode)

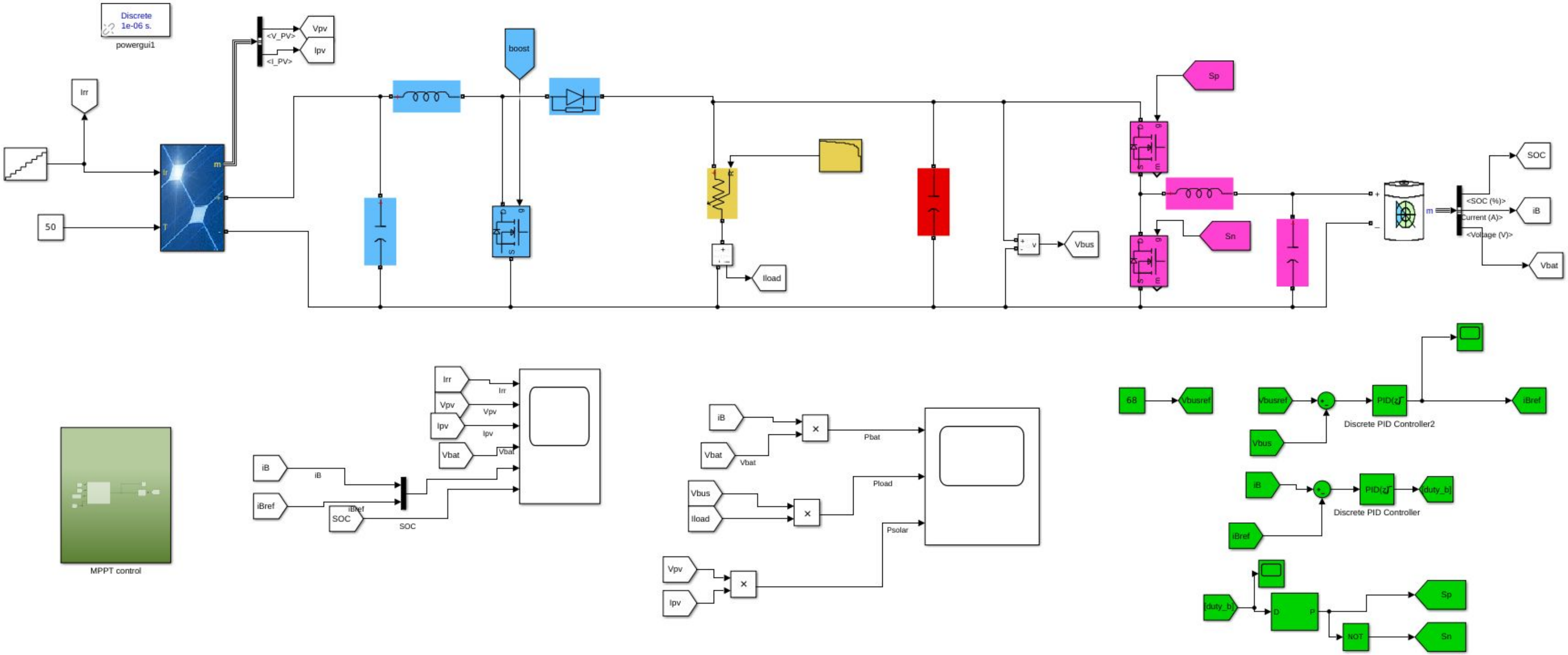


2.) Power exchange between Solar Panel and Battery (Running mode)



3.) Grid to battery

Integrating solar power with vehicle

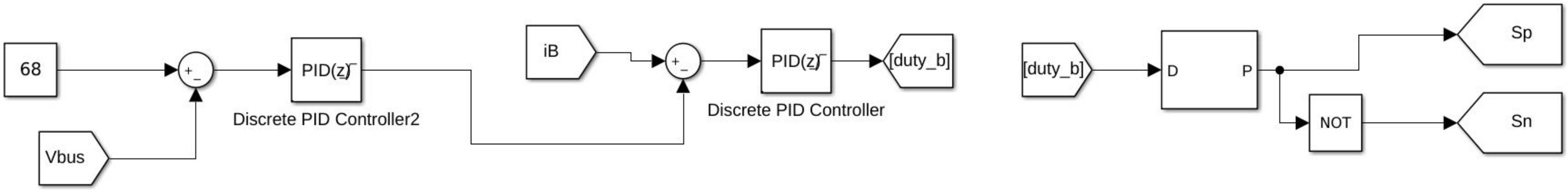


Inductor and capacitor design

Switching Frequency = 20 KHz

MPPT Boost converter	Inductor = 11mH	ΔI_L = 0.08 A
Bidirectional Buck / Boost converter	Inductor = 5.5 mH	ΔI_L = 0.1 A
	Capacitor = 1 μF	ΔV_C = 0.5 V
DC Link	Capacitor = 2200 μF	
CUK converter	I/P Inductor = 2.88 mH	ΔI_{Li} = 0.25 A
	O/P Inductor = 25 μH	
	Capacitor = 4.105 μH	ΔV_C = 0.05 V

Bidirectional DC/DC control



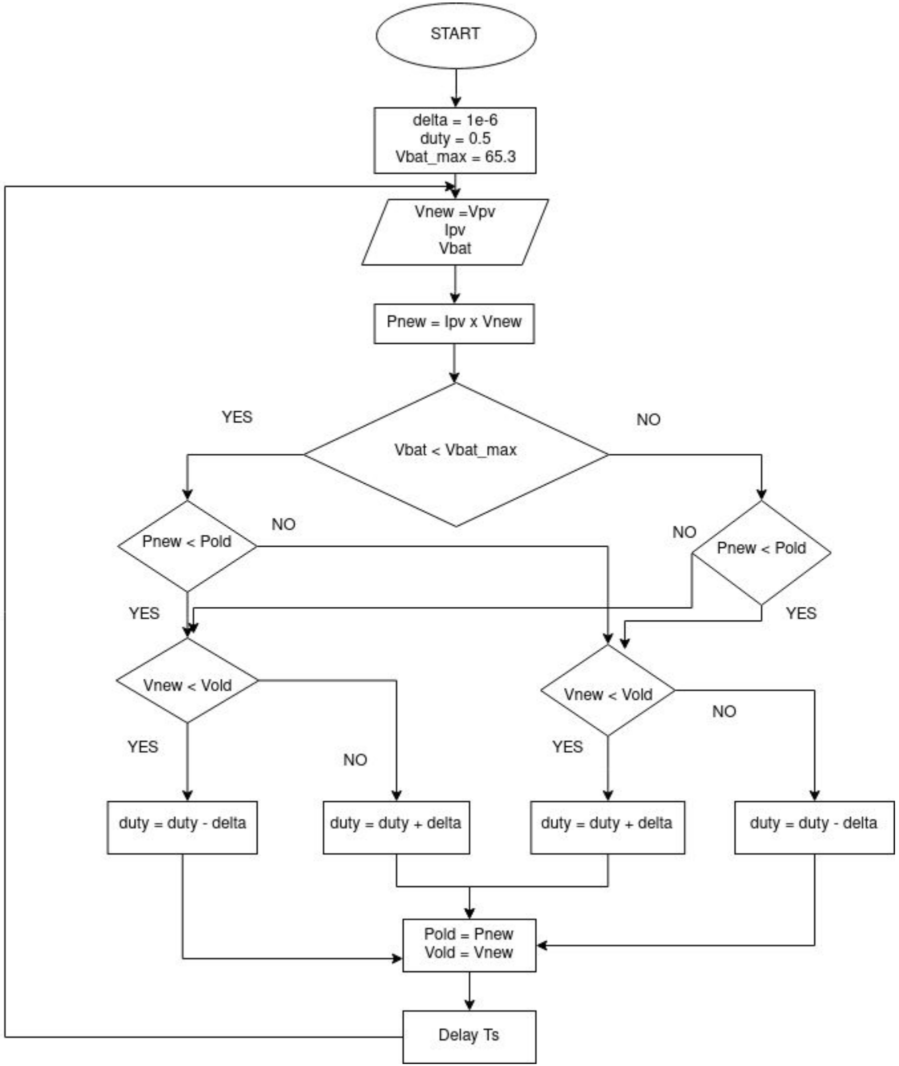
- Controller 1 generates battery current reference by comparing bus voltage with 68 V.
- Controller 2 generates duty cycle for the MOSFET by comparing actual and reference battery current
- 68 V was chosen because of buck - boost operation.

MPPT algorithm

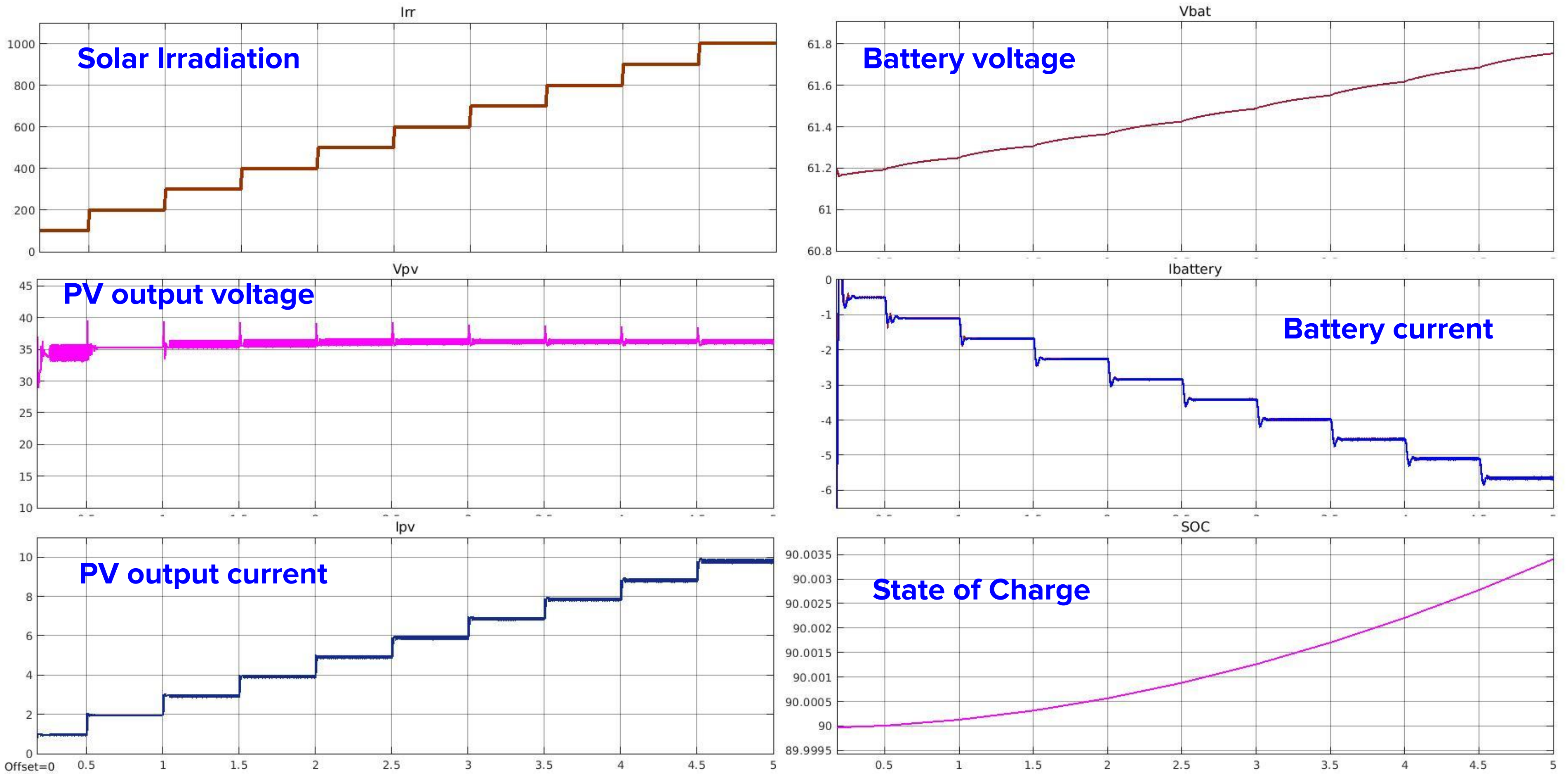
The MPPT algorithm uses P & O method.

Under some cases when the load is absent or very low, the solar panel may inject its maximum power produced to battery and increase battery voltage beyond safe-limit even though, it is not fully charged.

So, the panel should be made to operate at some point below MPP, to avoid voltage rise beyond safe limit.



1. Simulation of stalling mode (Solar PV to Battery)



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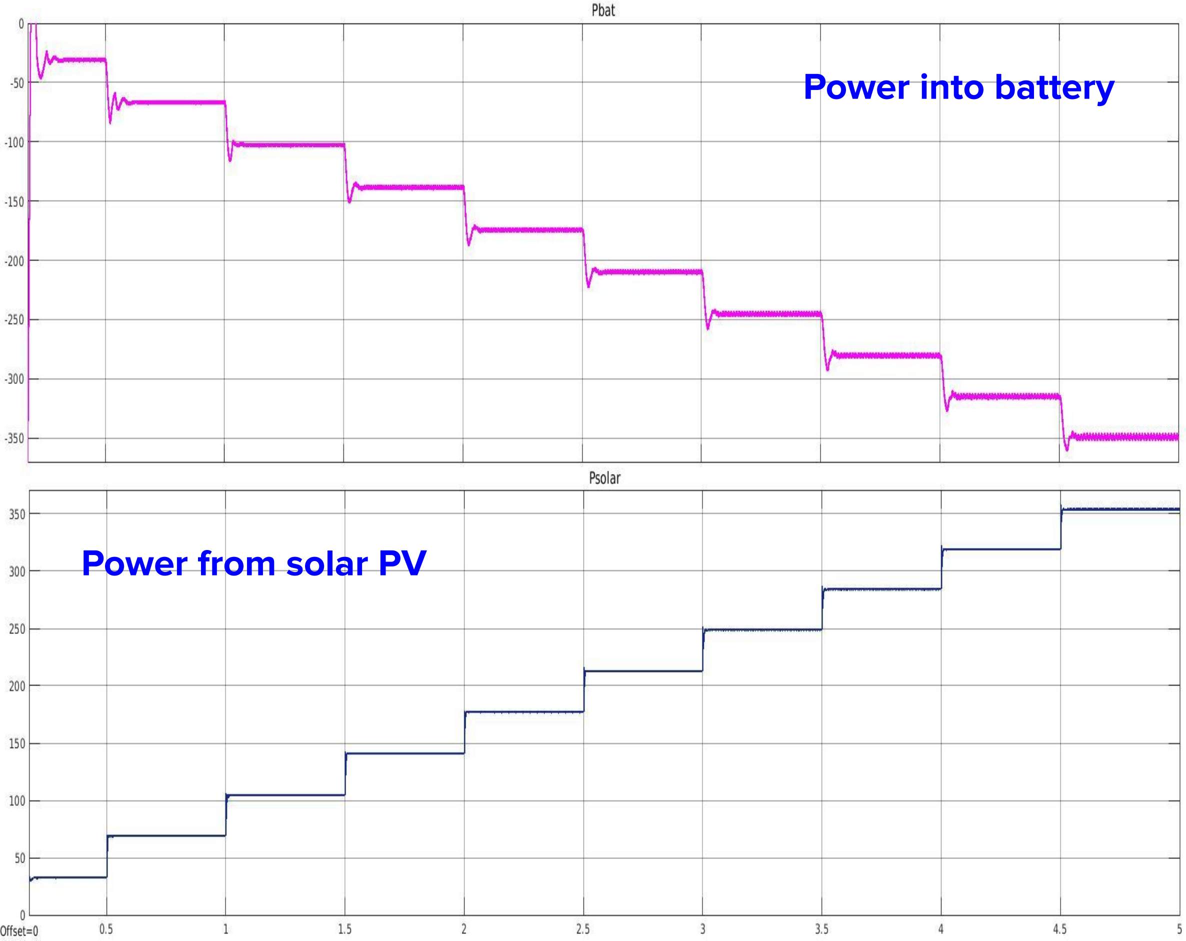
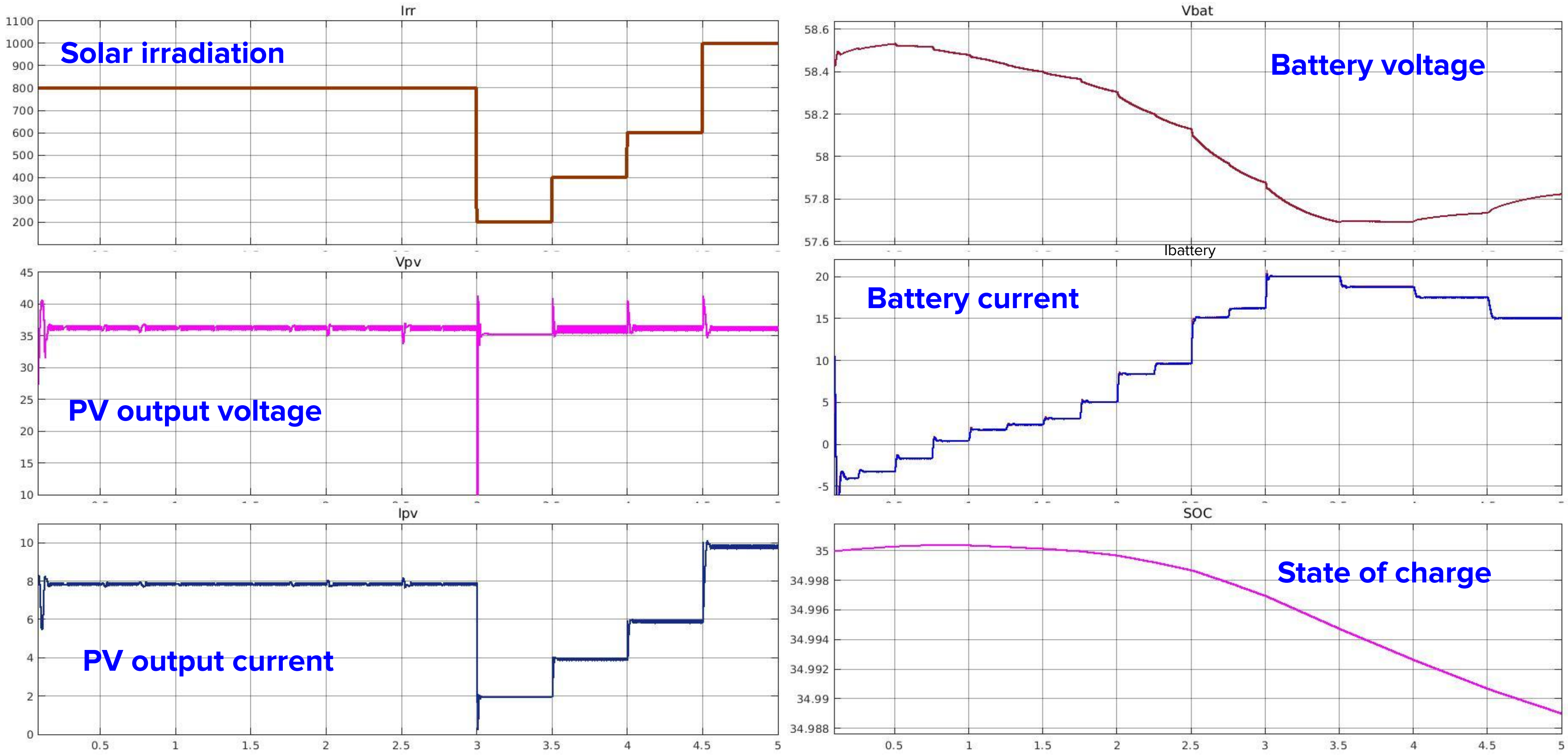
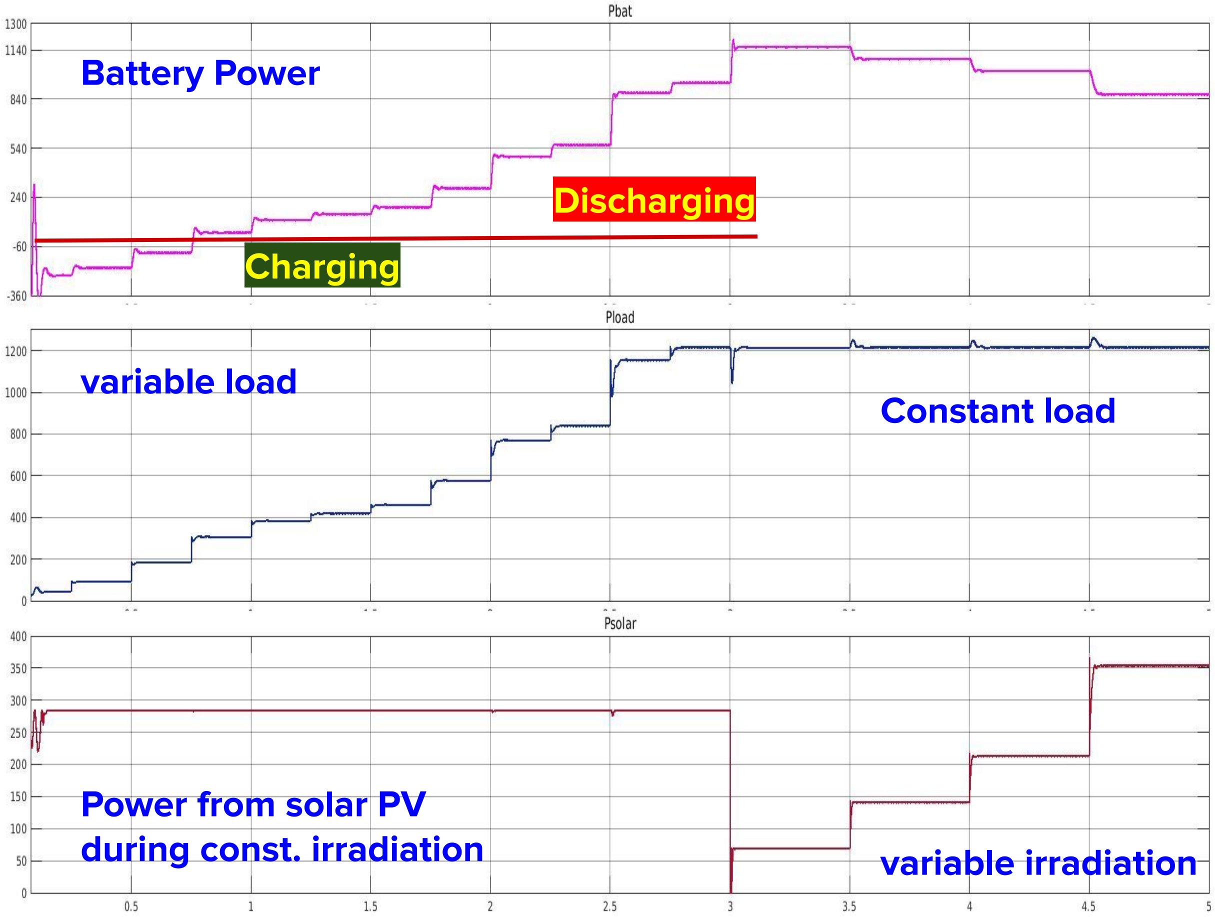


Different irradiances were simulated and the battery was fed with the power , the PV panel generates

2. Simulation of running mode (Solar PV to Battery/load)



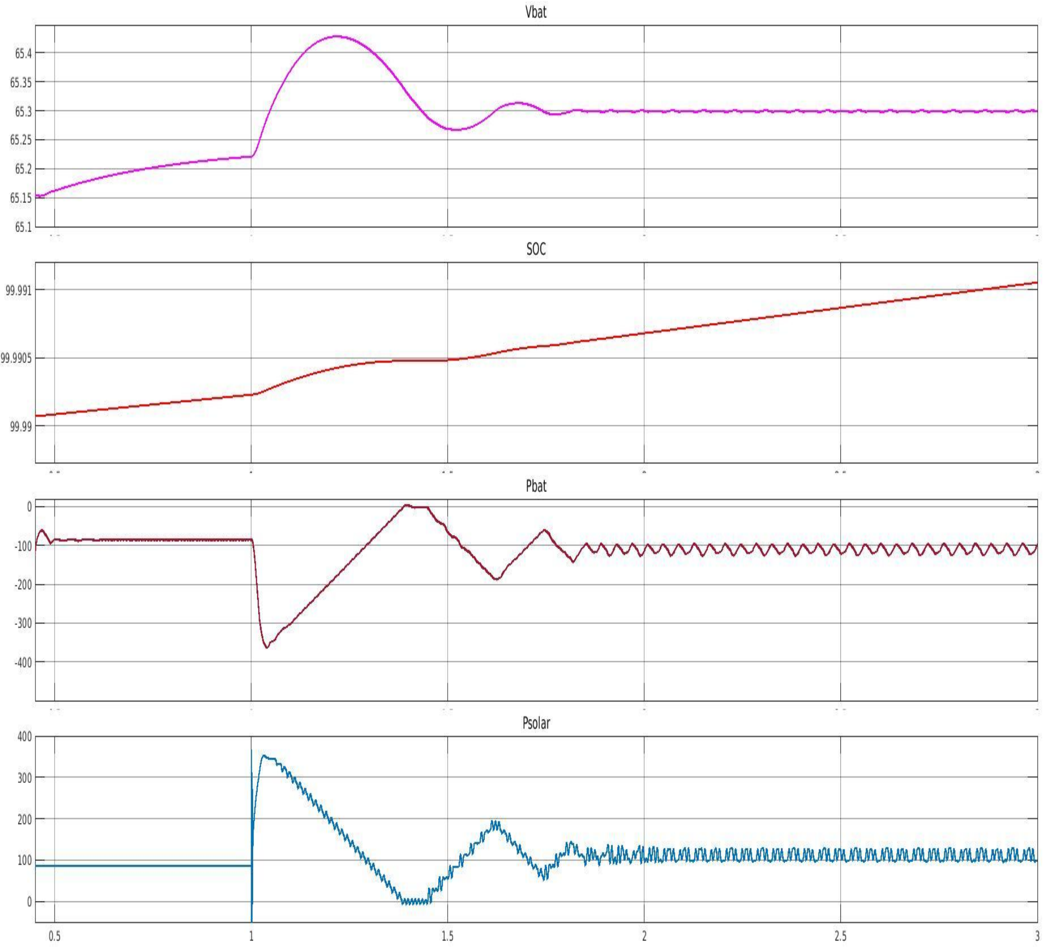
2. Simulation of running mode (Solar PV to Battery/load)....



For first half of simulation, Irradiance was kept constant and load was varied across its range

For next half of simulation, the load was kept constant and different irradiances were simulated.

Simulation of Overvoltage protection



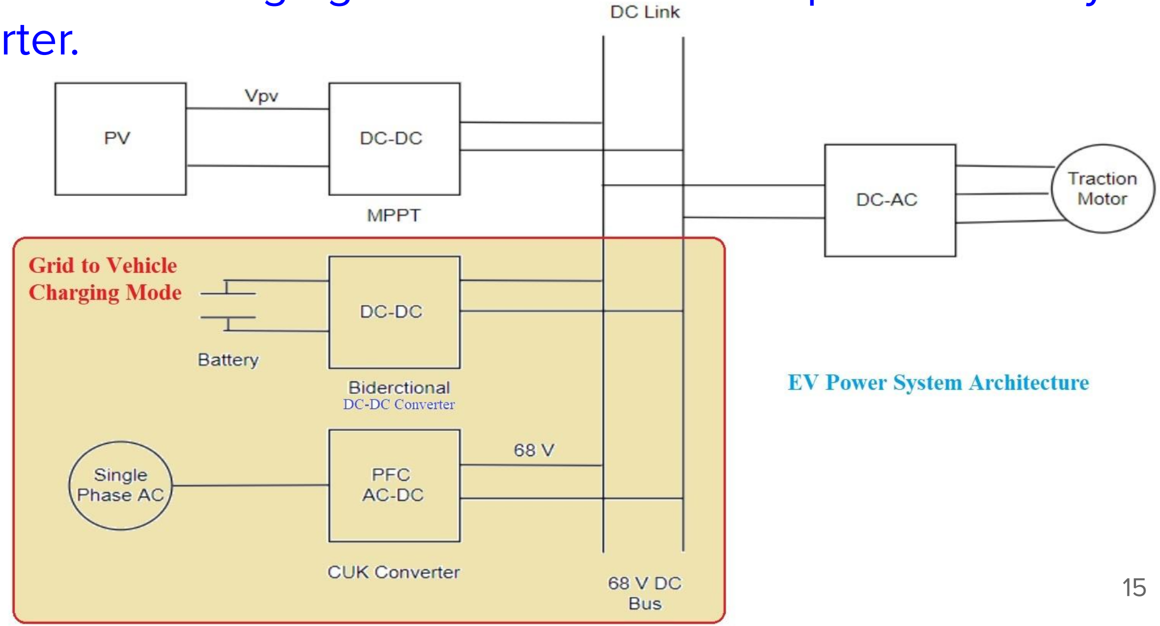
- No load condition was simulated
- Solar panel output initially was around 100 W (250 W/m^2)
- Then as the solar output increased to 390 W (1000 W/m^2),the voltage rises rapidly.
- When the battery voltage exceeded 65.3 V, solar panel was made to operate at lesser power (100W) than MPP (390W)

3. Grid to Battery

In this mode, there is no solar PV power. Only grid has to charge the battery.

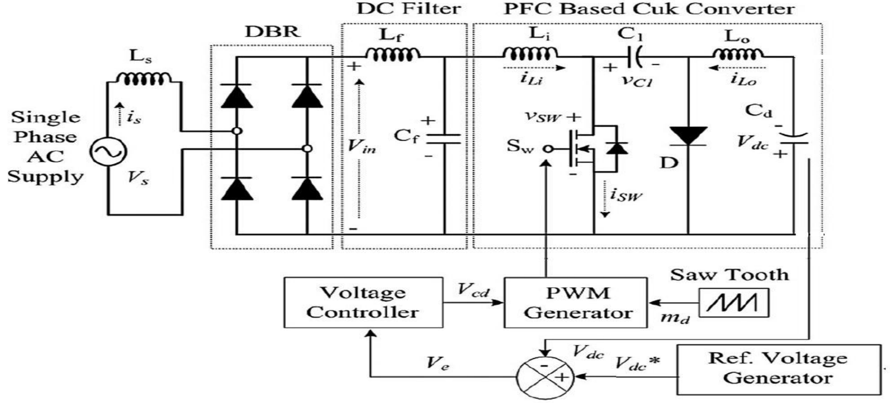
The highlighted portion of the circuit shown in the figure will be active during this mode.

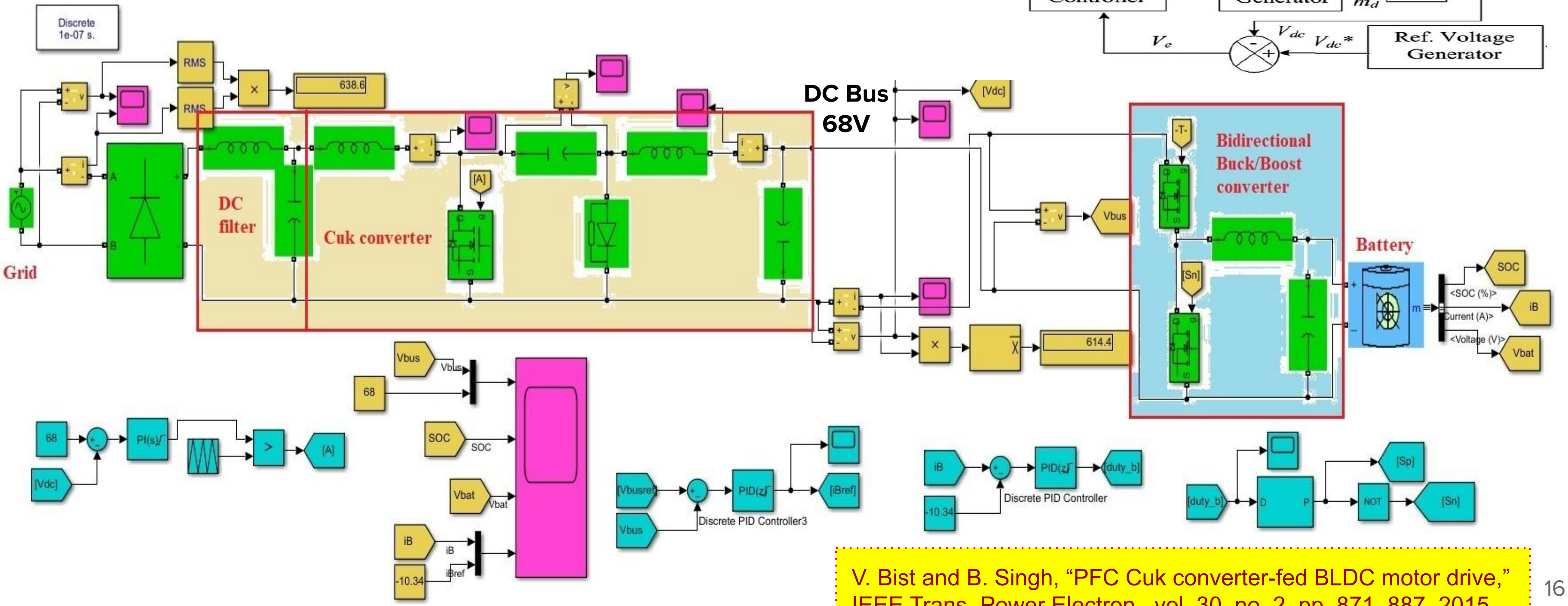
According to SoC of battery CC/CV charging schemes will be implemented by bidirectional buck-boost converter.



EV Power System Architecture

3. Grid to Battery (Simulation Study)

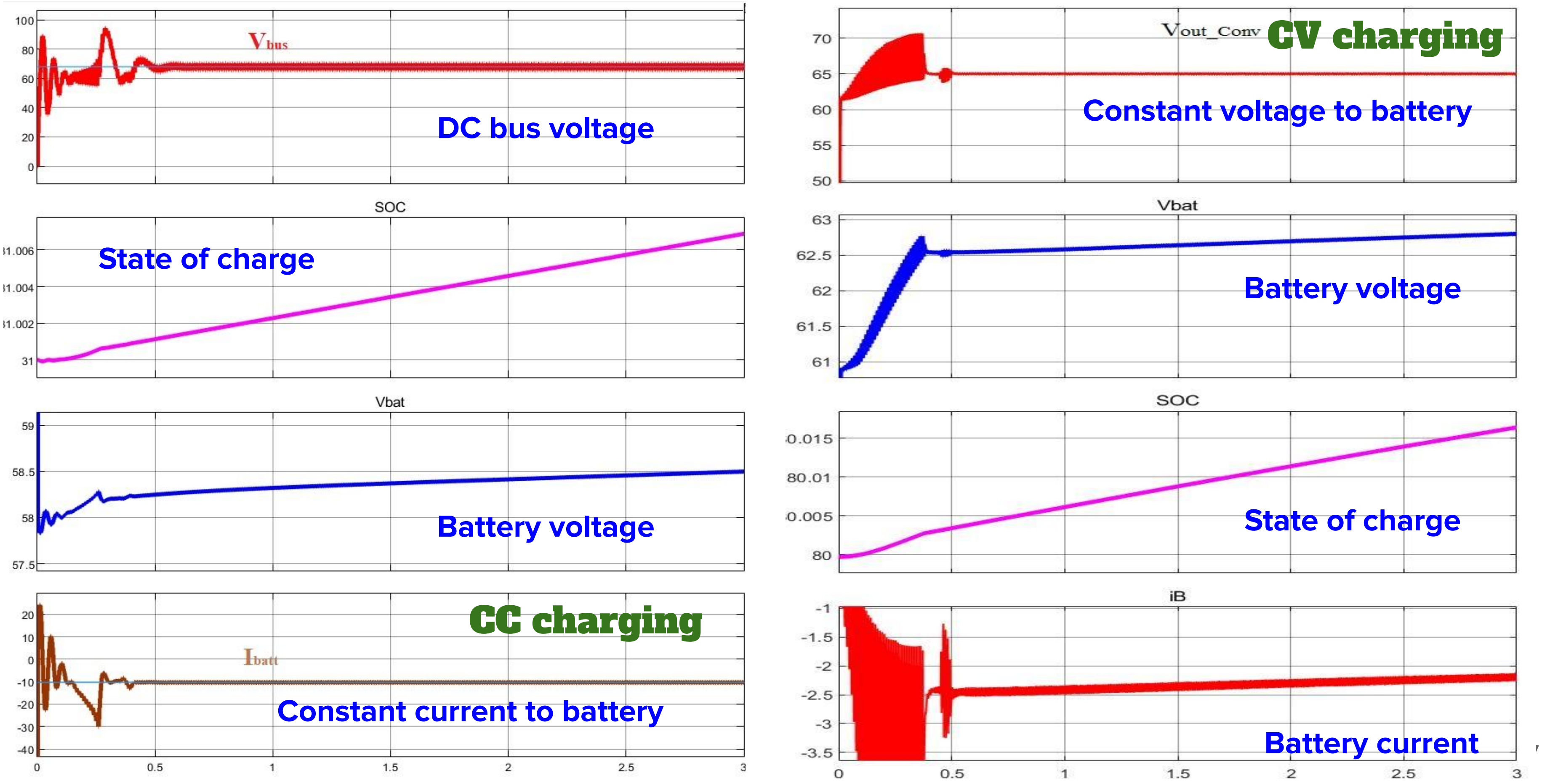




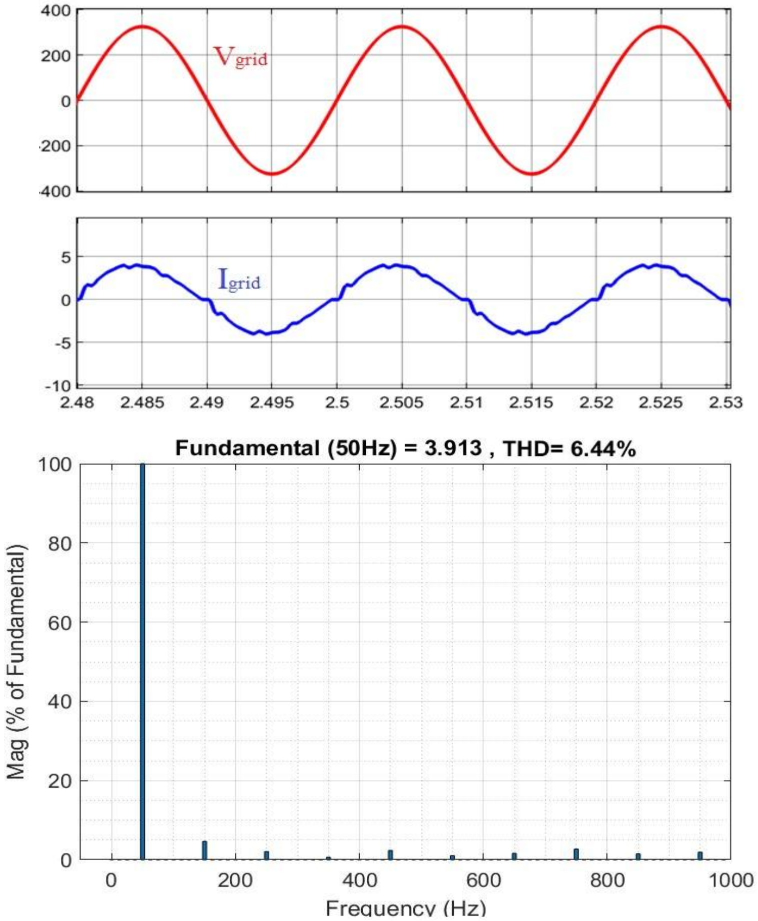
DC Bus 68V

V. Bist and B. Singh, “PFC Cuk converter-fed BLDC motor drive,” IEEE Trans. Power Electron., vol. 30, no. 2, pp. 871–887, 2015.

3. Grid to Battery (Simulation Study)...



3. Grid to Battery (Simulation Study)...



- ➔ Grid voltage and current shown in figure left.
- ➔ Power factor is near unity.
- ➔ THD of grid current is 6.44%.
- ➔ High switching ripple is eliminated by input filter.

Conclusions

- Integrated on-board charger for solar electric vehicle is designed and simulated.
- Three modes of operation are analysed and simulated in detail.
- The simulation study shows that the designed charger satisfies the requirements from grid side, requirements from solar PV side and requirements from Battery side.
- For this charger, circuit modelling and topological study is performed in this work. Detail loss modelling and efficiency estimation can be done further also cost estimation of the charger gives some practical perspective.


Thank you !!!