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SOLAR PHOTOVOLTAIC SYSTEM WITH BATTERY CHARGING AND DISCHARGING OPERATION USING ANN MPPT TECHNIQUE

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ABSTRACT

This paper present the new artificial neural network maximum power point monitoring technique it's used to essence the optimal power for a 1300W solar PV system. This method is used to maximize power point under various irradiance problems. By effectively controlling boost converter, Solar PV generation has an essential role in battery charging operation. The bidirectional converter is used for battery charging and discharging operations to inspect the outcomes of different irradiance conditions. This project work is MATLAB software.

Keywords: Solar PV Module, Boost Converter, Bidirectional Converter, Artificial Neural Network-Based MPPT, And Battery.

I. INTRODUCTION

Traditional energy sources like oil, coal, and gas have shown to be incredibly efficient environmental chauffeurs. To get over this issue it utilized sustainable resources, considering they can potentially in idea satisfy many times the globe's power needs. End-to-end power solutions can be provided by sustainable resources such as biomass, wind, sun, hydropower, and geothermal energy are all based on locally available sources [1].Solar power generally relies on temperature as well as solar irradiance problems. For a small alter in solar irradiation and also temperature worth optimal, feasible power removal from the solar PV system is various maximum power points can be acquired from the PV curve of PV setup. Boost converter helps to attain maximum power points of PV panel. The different maximum PowerPoint methods utilized the essence the optimal power, such as continuous voltage (CV), temperature level (T), open voltage (OV), comments voltage (FV), perturbation and monitoring (P&M), step-by-step conductance (IC), fuzzy logic controller (FLC), and artificial neural network [3], [4]. The aim of the project is a solar photovoltaic system using the ANN MPPT technique with battery charging and discharging operation. To generate optimal power, the artificial neural network MPPT technology is used at varying irradiances, a bidirectional converter is used for battery charging and discharging [5].

II. DESIGN SOLAR PV SYSTEM

The solar photovoltaic system transforms the Sun's radiation, through light, into functional electrical energy. It makes up the solar array and the relaxation of the system's components. PV systems can be classified by various aspects, for example, Rack-mounted, residential, Rooftop, ground-mounted, and fixed-tilt systems. A comparable circuit of the solar PV system is illustrated in Figure.1.

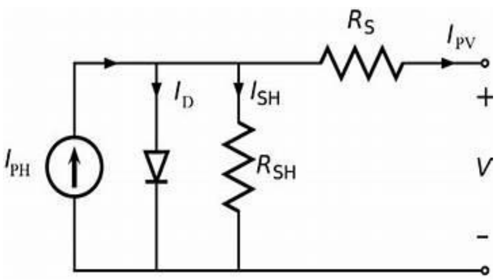

Figure 1: Comparable circuit of solar PV system

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The equation for this comparable circuit using Kirchhoff's current law:

$$I = Iph - Id - Ish \quad (1)$$

$$Ish = \frac{V + RsI}{Rsh} \quad (2)$$

The I-V characteristics of the PV panel in Equation. (1) and Equation. (2).

$$I = Iph - Io\left[\exp\left(v + \frac{RsI}{Vt}\right) - 1\right] - V + \frac{RsI}{Rsh} \quad (3)$$

Where Iph is the photon current at given irradiance at a given temperature, Id is the diode current, Rs and Rsh is a series resistor, shunt resistor, Ipv or Io output current of the solar PV panel, and Vt is the thermal voltage.

P-V and I-V characteristics are illustrated in Figure.2 and Table.1. shows the specification of the 150W PV module at 1000 w/m^2 and 25°C. Series connected module per string is 3 and parallel string is 3. Maximum power produces 1300W [2].

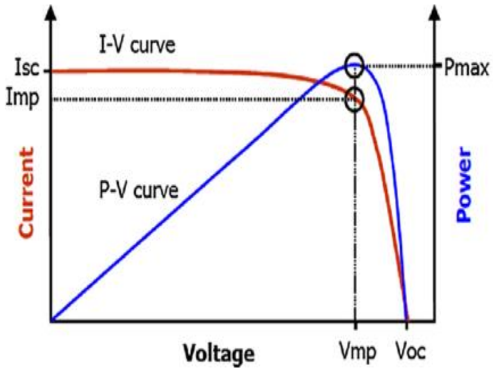

Figure 2: P-V and I-V characteristics of solar PV module

Table 1. 150W PV module at 25°C and 1000 w/m^2

SN.	Specification	Value
1.	voltage at maximum power point (Vmpp)	34.5V
2.	Current at maximum power point (Impp)	4.35A
3.	Maximum output power	150W
4.	Cells per module	72
5.	Parallel strings	3
6.	Series connected modules per string (Ns)	3
7.	Open circuit voltage (Voc)	41.8V
8.	Short circuit current (Isc)	5.05A

Solar PV system using ANN MPPT technique with battery charging and discharging operation of the circuit diagram is illustrated in Figure.3.

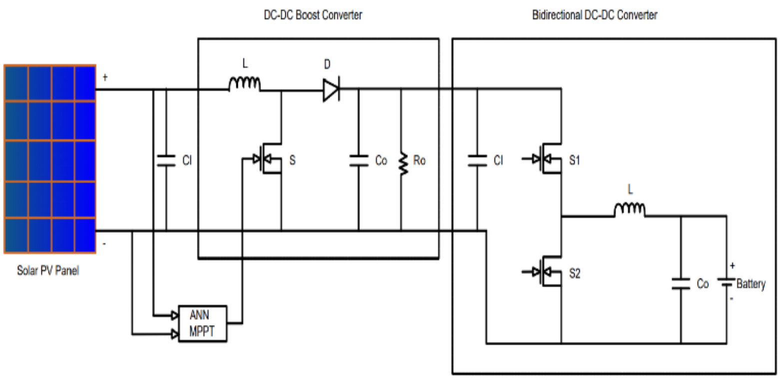

Figure 3: Circuit representation of solar PV system using ANN MPPT technique with battery charging and discharging operation

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III. DESIGN BOOST CONVERTER

A boost converter is among the easiest types of switch-mode converter. As the name recommends, it takes an input voltage as well as boosts or enhances. The two most prevalent types of switches are MOSFET and IGBT. There are two modes of operation for the boost converter. The first mode is switched is open the input current increases and flows through the inductor and the capacitor stores energy. The second mode is switched is closed The input current currently flows through the inductor and the capacitor release energy. The circuit representation of the boost converter is illustrated in Figure.4 [6].

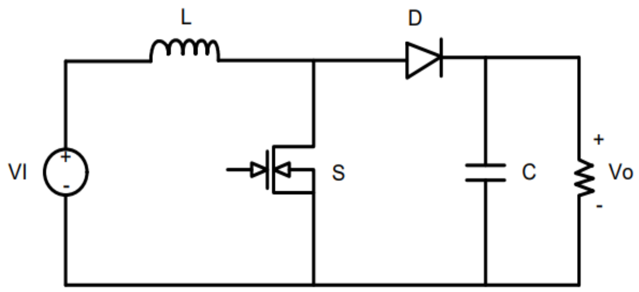

Figure 4: Circuit representation of the boost converter

Design the components values of boost converter by given formulae. Table.2. shows the components of the boost converter.

$$Duty\ cycle\ (D) = 1 - \frac{VI}{Vo} \tag{4}$$

$$Ripple\ current\ (\triangle IL) = \frac{VI * D}{Lfs} \tag{5}$$

$$Ripple\ voltage\ (\triangle VC) = \frac{Io * D}{Cfs} \tag{6}$$

$$Inductance\ (L) = \frac{VI * D}{\triangle IL * fs} \tag{7}$$

$$Capacitance\ (C) = \frac{Io * D}{\triangle VC * fs} \tag{8}$$

Table 2. Component values of the Boost Converter

SN.	Component	Value
1.	Inductor	7mH
2.	Input capacitor	1000μF
3.	Output capacitor	231μF
4.	Resistor	20Ω
5.	Input voltage	130V
6.	Output voltage	260V
7.	Switching frequency	25khz

IV. DESIGN BIDIRECTIONAL CONVERTER

The term "bidirectional converter" refers to a converter that can step up or down. an associated controller and gate-signal generator convert DC voltage from one side of the converter to the other. Bidirectional converters help transform between power storage space areas and utilize, as an example, in battery charging and discharging procedures, and Electric cars. Bidirectional converter operating in two-mode. First is a buck mode is on, switch S1 closed and switch S2 open then the battery is in charging mode. The second is a boost mode is on, switch S2 closed and switch S1 open then the battery is in discharging mode. The circuit representation of the bidirectional converter is illustrated in Figure.5.

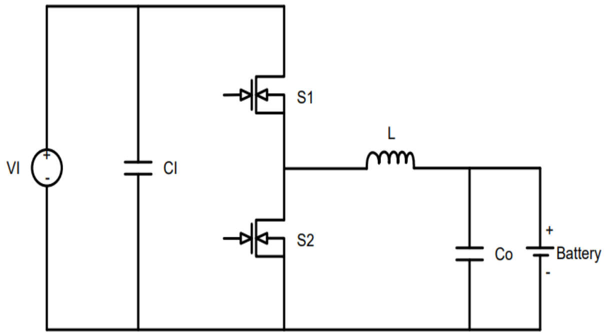

Figure 5: Circuit representation of the bidirectional converter

The controller block diagram of a bidirectional converter is shown in Figure.6. To control the battery current when charging and discharging, we employed a PI controller. Change the current reference value is positive then charge the battery and if the current reference value is negative then discharge the battery [7], [8], and [9].

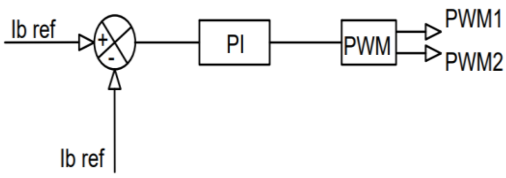

Figure 6: Controller block diagram of a bidirectional converter

Design the components value of the bidirectional converter by given formulae. Table.3. shows the components of the bidirectional converter.

$$Buck\ mode\ is\ on\ Vbuck = DVboost \tag{9}$$

$$Boost\ mode\ is\ on\ Vboost = \frac{Vbuck}{1-D} \tag{10}$$

$$Ripple\ voltage\ (\Delta VC) = 0.02 * VI \tag{11}$$

$$Ripple\ current\ (\Delta IL) = 0.4 * Io \tag{12}$$

$$Inductor\ (L) = \frac{Vo * (Vi - Vo)}{\Delta IL * fs * Vi} \tag{13}$$

$$Capacitor\ (C) = \frac{\Delta IL}{8 * fs * \Delta VC} \tag{14}$$

Table 3. Component values of the bidirectional converter

SN.	Component	Value
1.	Inductor	1.5mH
2.	Input capacitor	1000μF
3.	Output capacitor	2μF
4.	Battery	60V 100 Ah
5.	Input voltage	250V
6.	Output voltage	120V
7.	Switching frequency	25khz

V. ARTIFICIAL NEURAL NETWORK-BASED MPPT

The artificial neural network is an info processing standard that's motivated incidentally organic nerve system, such as the mind, procedure info. It's the unique framework of the info refining system. It's made up of a lot of extremely connected parts that work together to solve problems. The mathematical symbol x_n is used to represent network inputs. Each of these inputs is multiplied by the link weight, w_n total = $w_1 x_1 + ... + ... + w_n x_n$ These items are just summed, fed with the transfer function, f( ) to produce a result, and after that output. A block representation of ANN MPPT is shown in Figure.7.

The network is gained through training using the Levenberg-Marquardt formula. Another formula is utilized the enhance the training. For different mixes of solar irradiance and temperature level degree well worth obligation proportion is identified and ANN is trained. In order to get the desired outcomes, the weights of layers must be adjusted during neural network training. Throughout the training, procedure weights are gotten used to tracking the target values with minimum error. The efficiency function of ANN is the mean squared error. If a is the present output, t is the target, after that MSE:

$$F = \frac{1}{N} \sum_{i=} N\,(ti - ai)^2 \qquad (15)$$

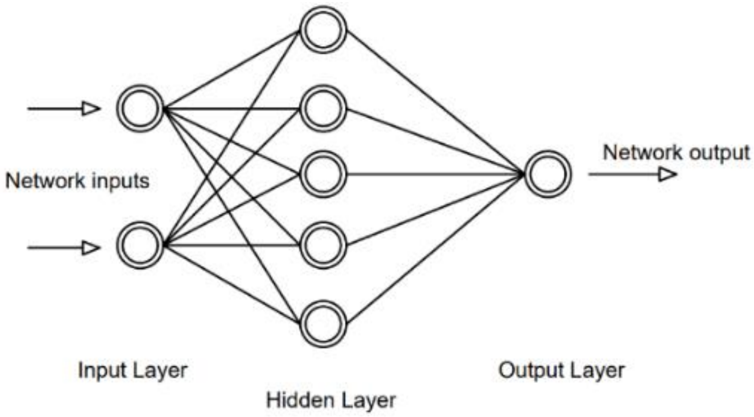

Figure 7: Block representation of ANN Structure

The four steps to designing the ANN MPPT first step is the data collection, the second step is the selection of The training of the neural network is depicted in the network structure, and the third and final phase is the testing of train data Figure.8, and the Block of function fitting neural network is shown in Figure.9 [10], [11].

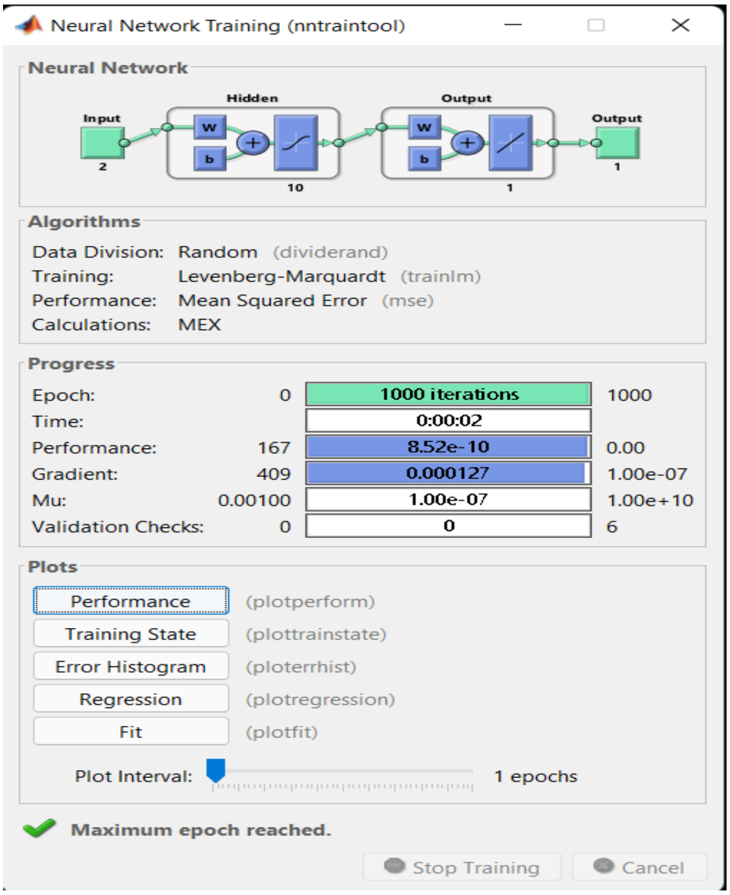

Figure 8: Train neural network

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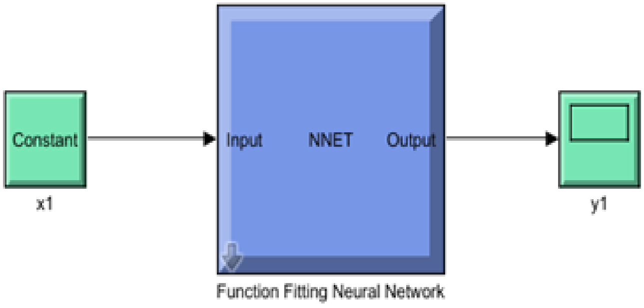
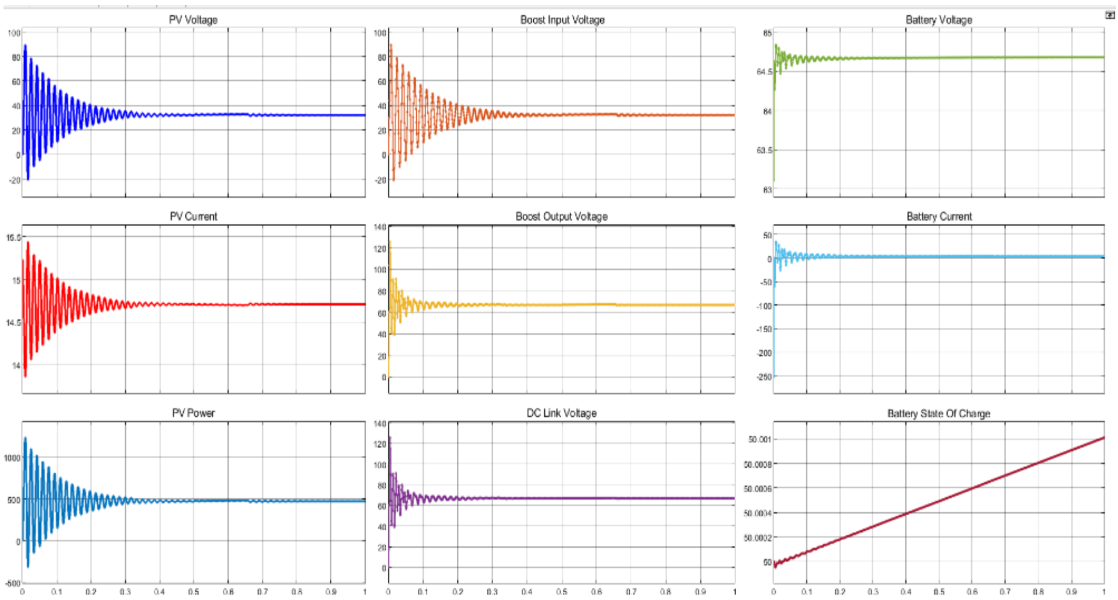


Figure 9: Block of function fitting neural network

VI. SIMULATION RESULTS OF SPV SYSTEM WITH BATTERY CHARGING AND DISCHARGING OPERATION USING ANN MPPT



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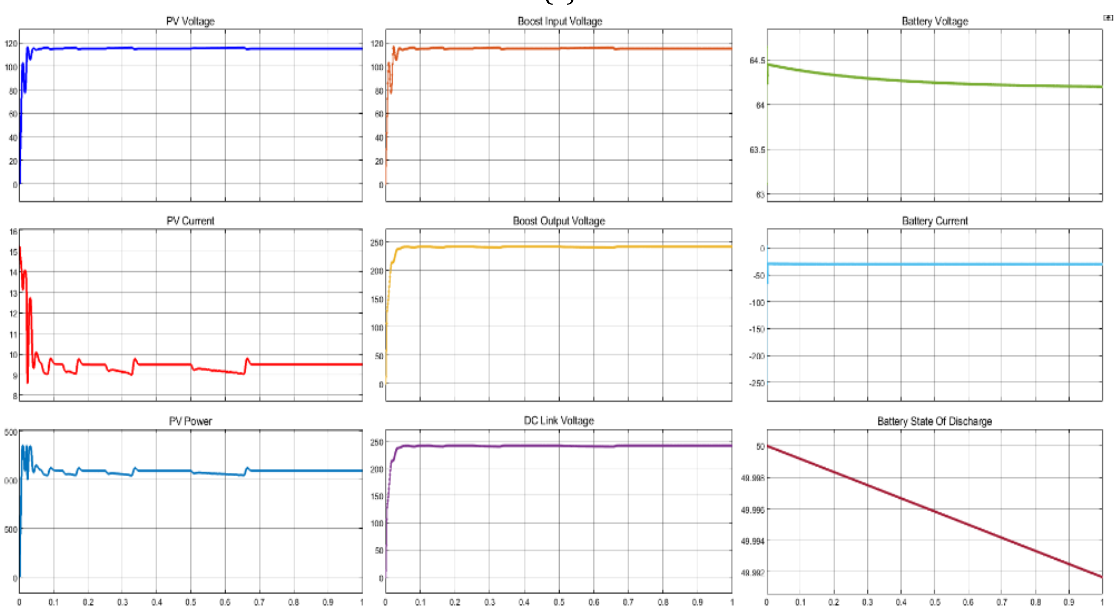

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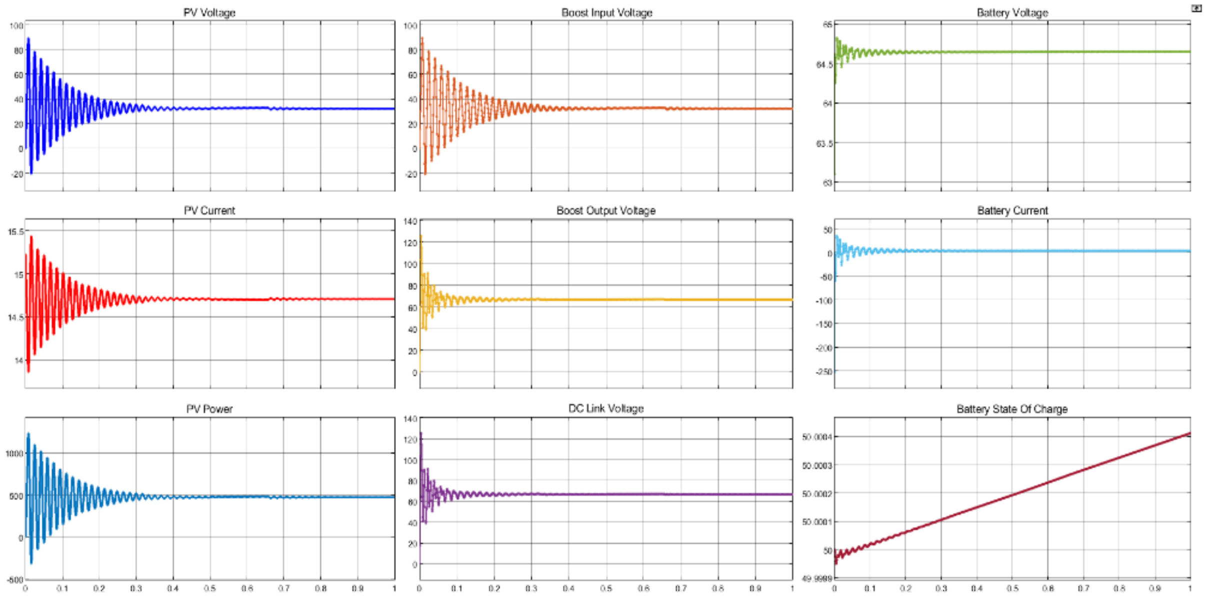

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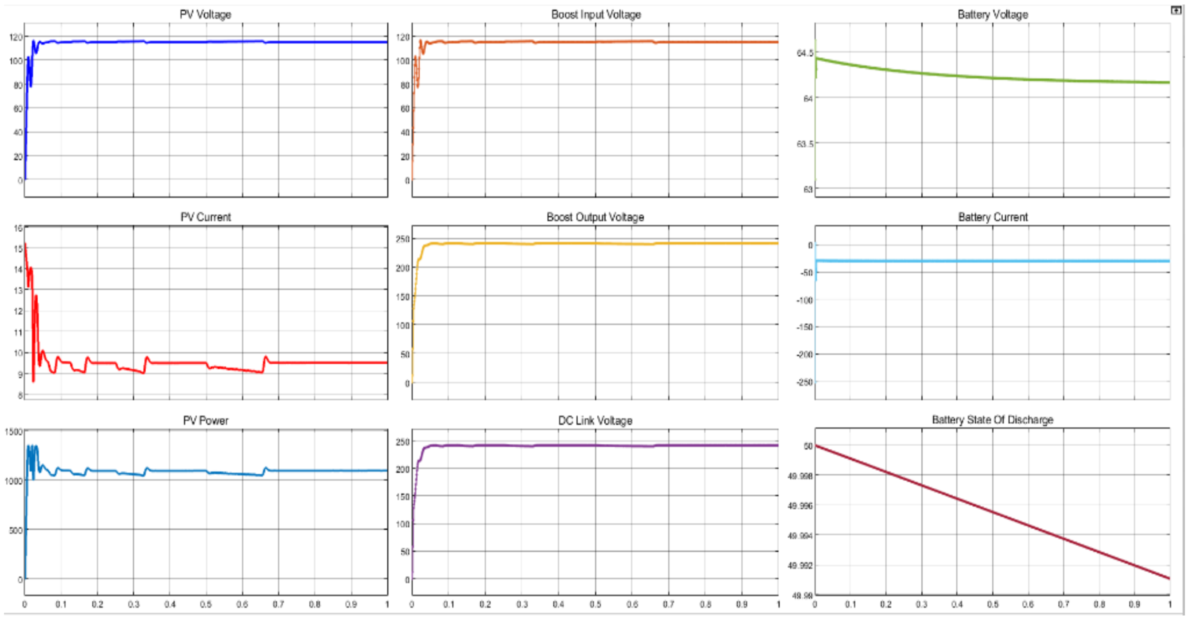

(d)

Figure 10: Irradiance 1000w/m^2 & Temperature 25°C (a) Charging operation without load (b) Discharging operation without load (c) Charging operation with resistive load (d) discharging operation with resistive load

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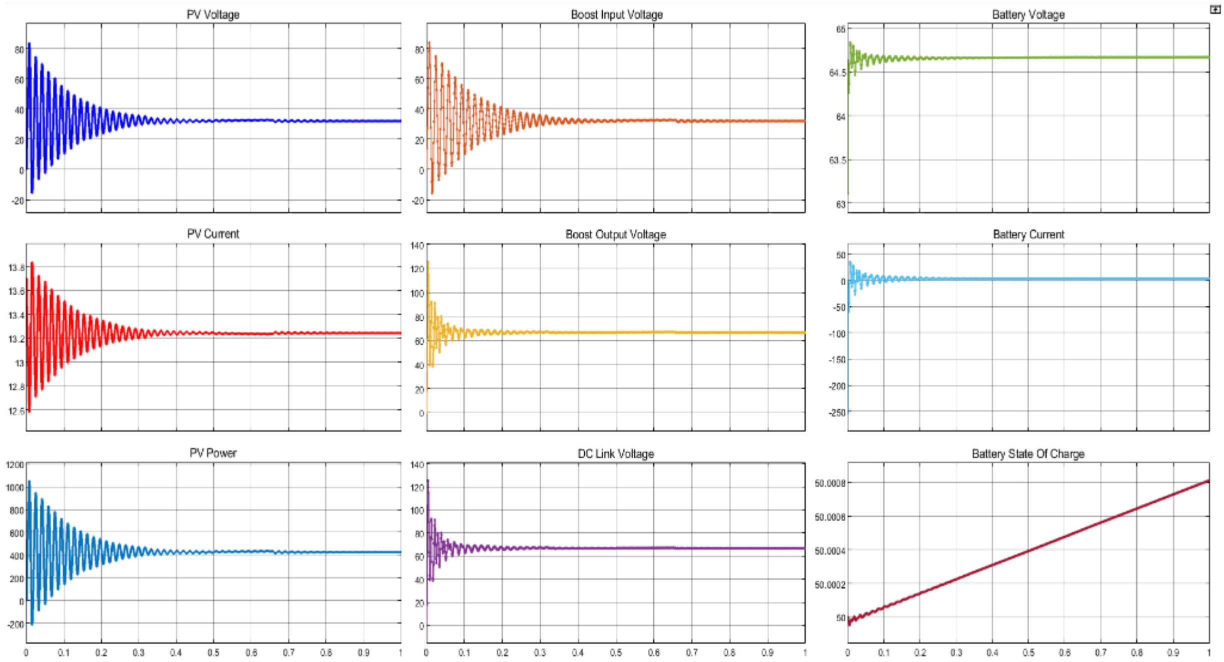

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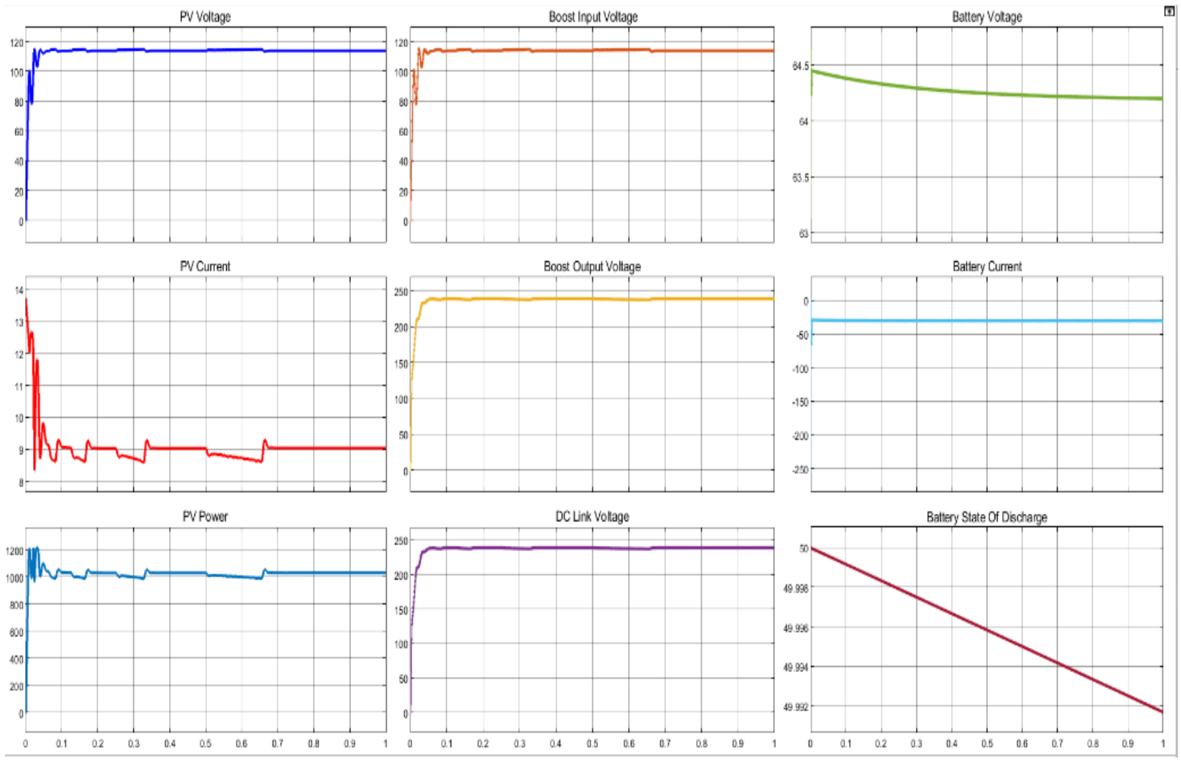

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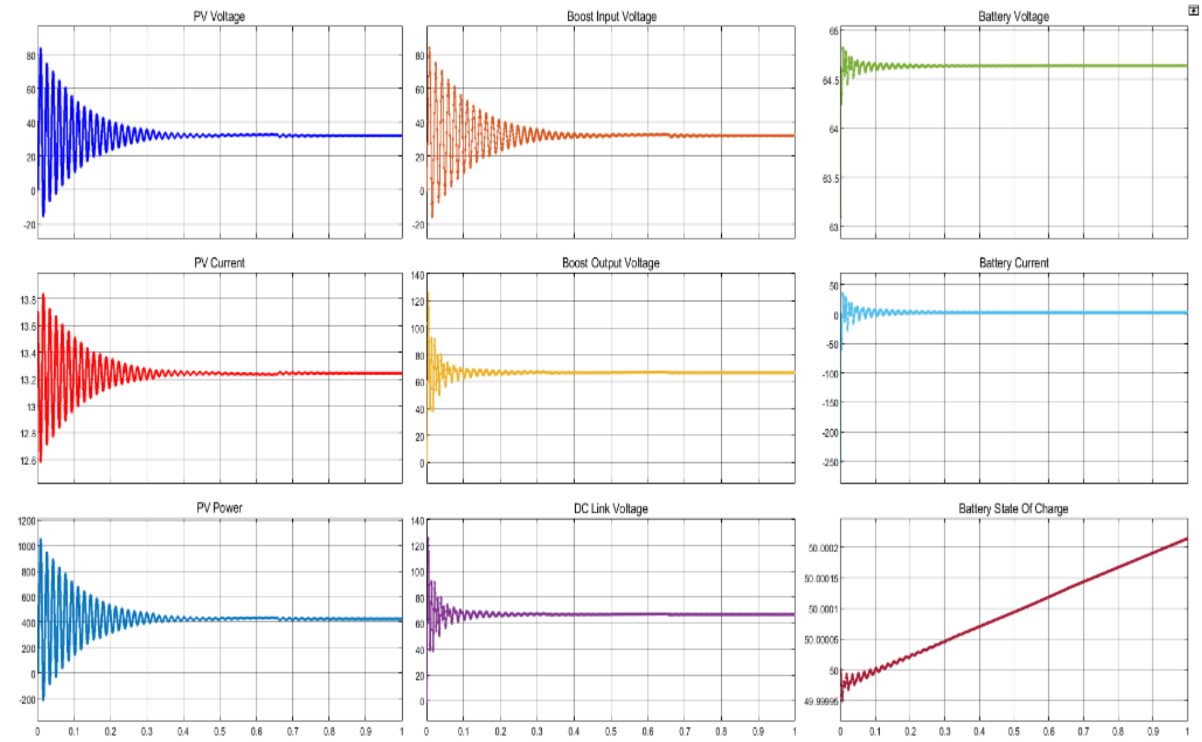

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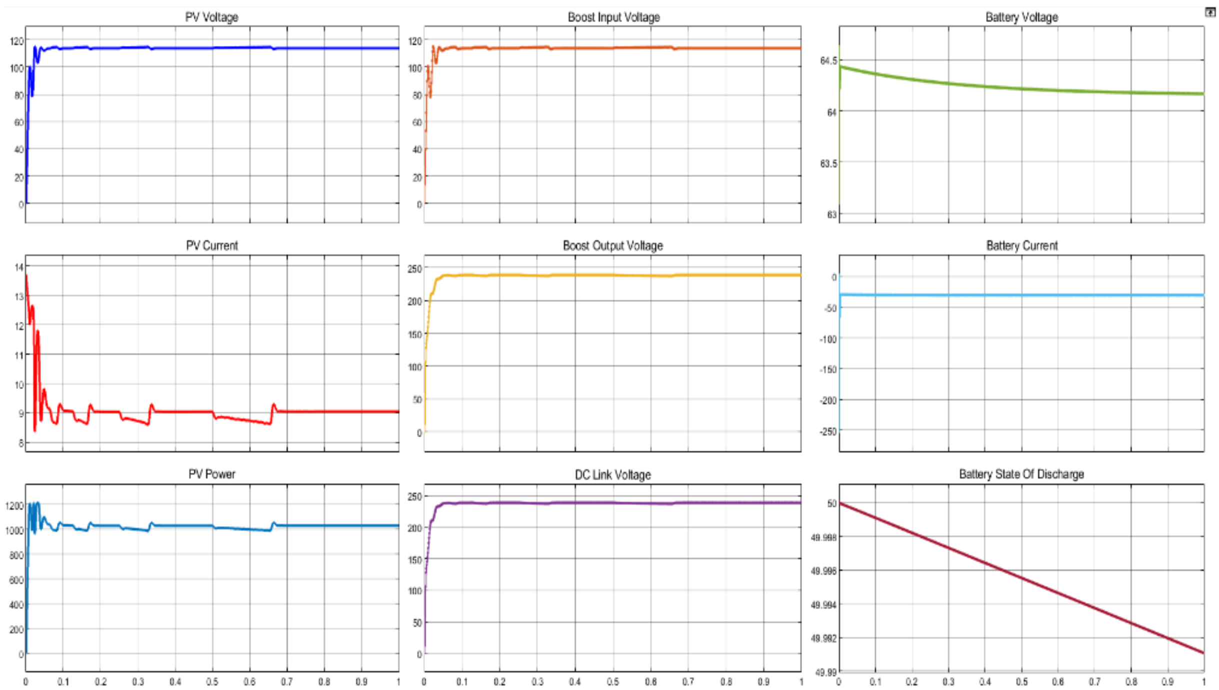

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Figure 11: Irradiance 900w/m^2 & Temperature 25°C (a) Charging operation without load (b) Discharging operation without load (c) Charging operation with resistive load (d) discharging operation with resistive load

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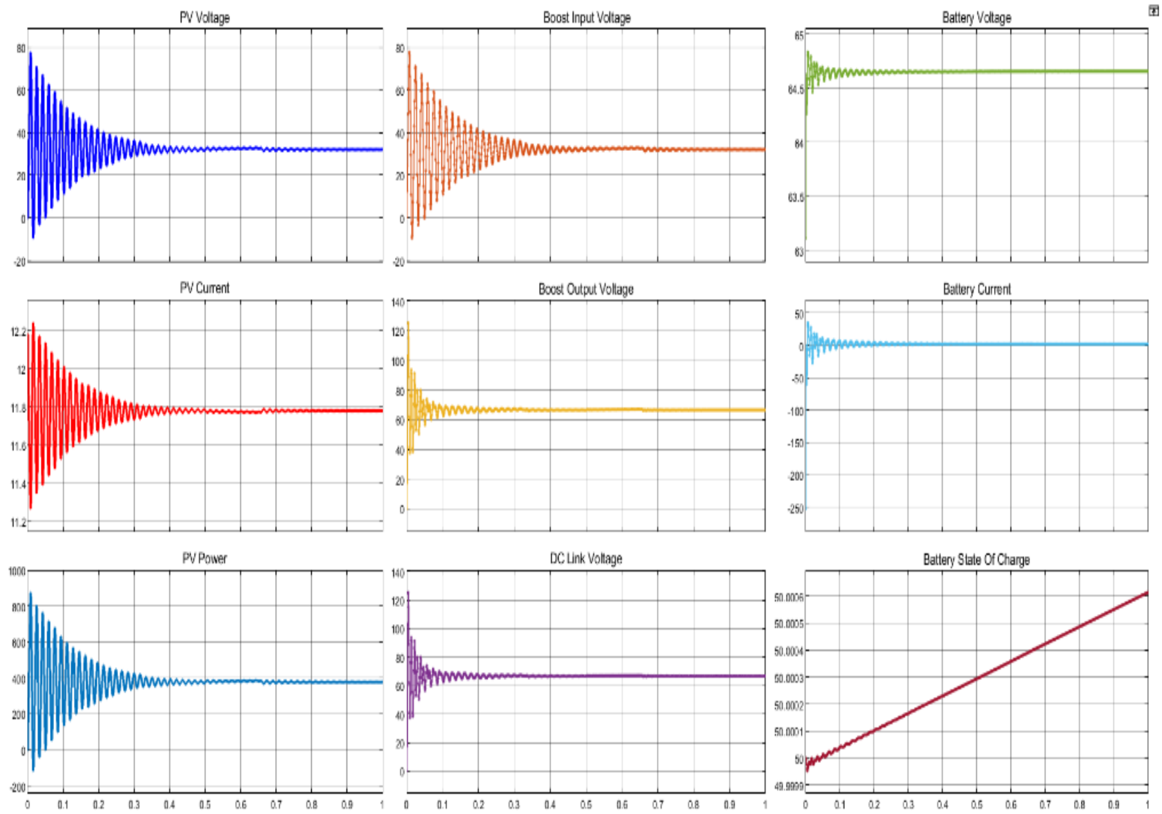

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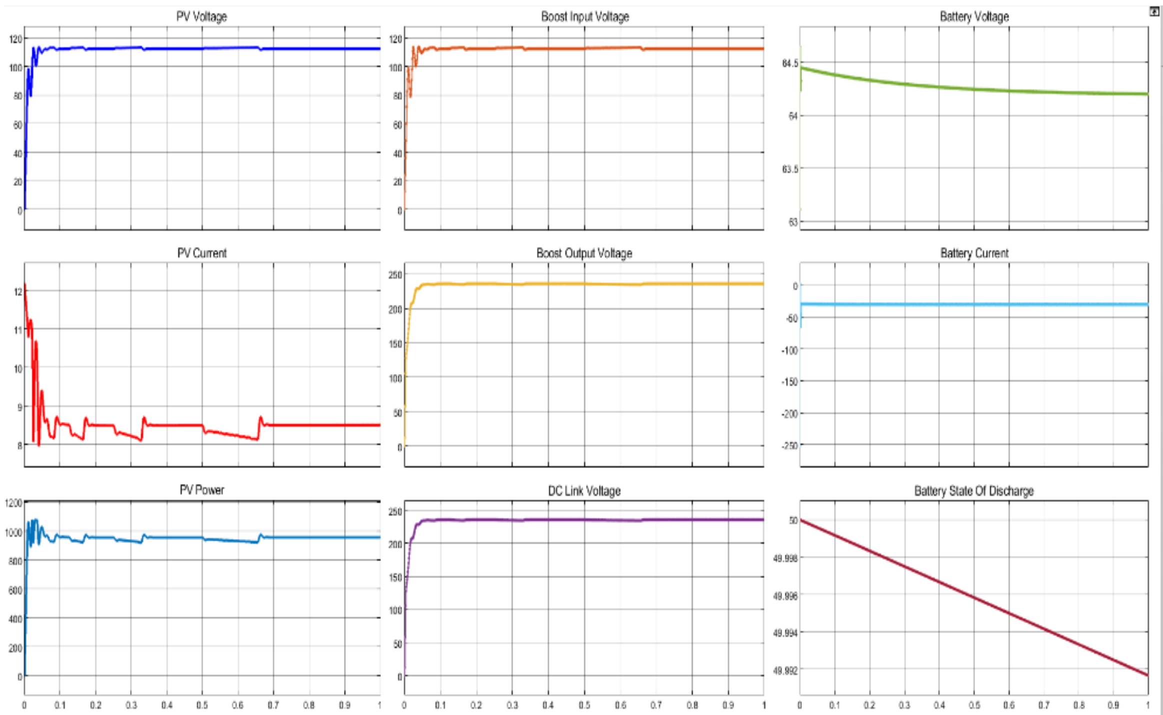

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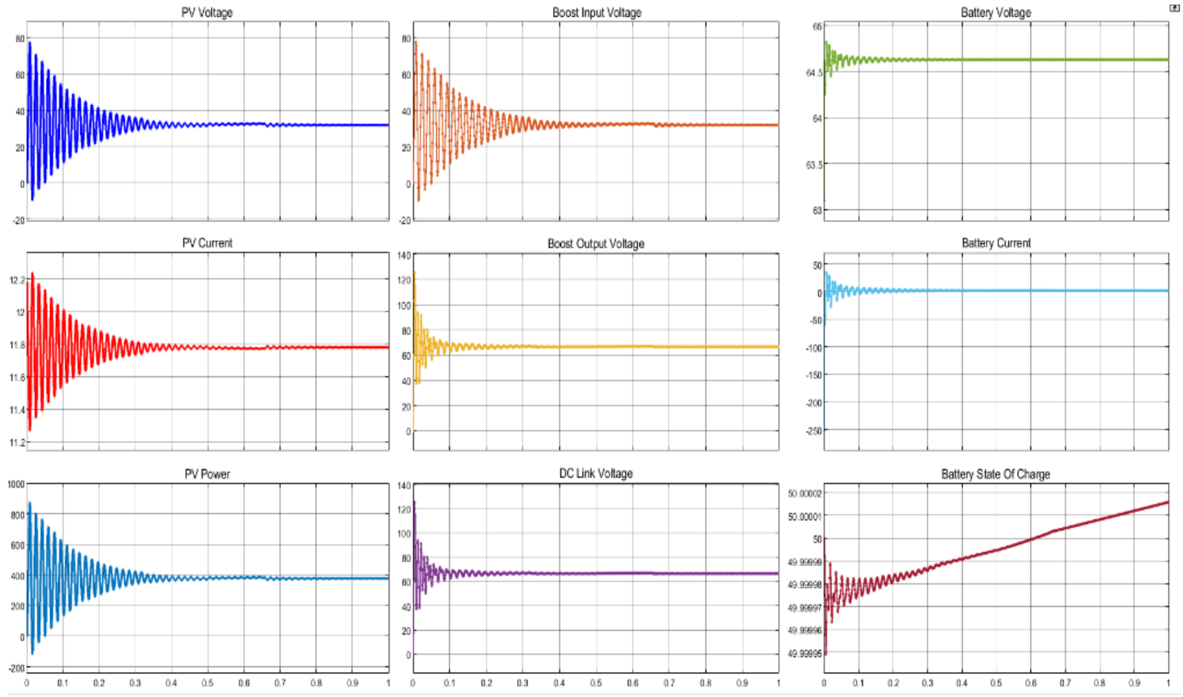

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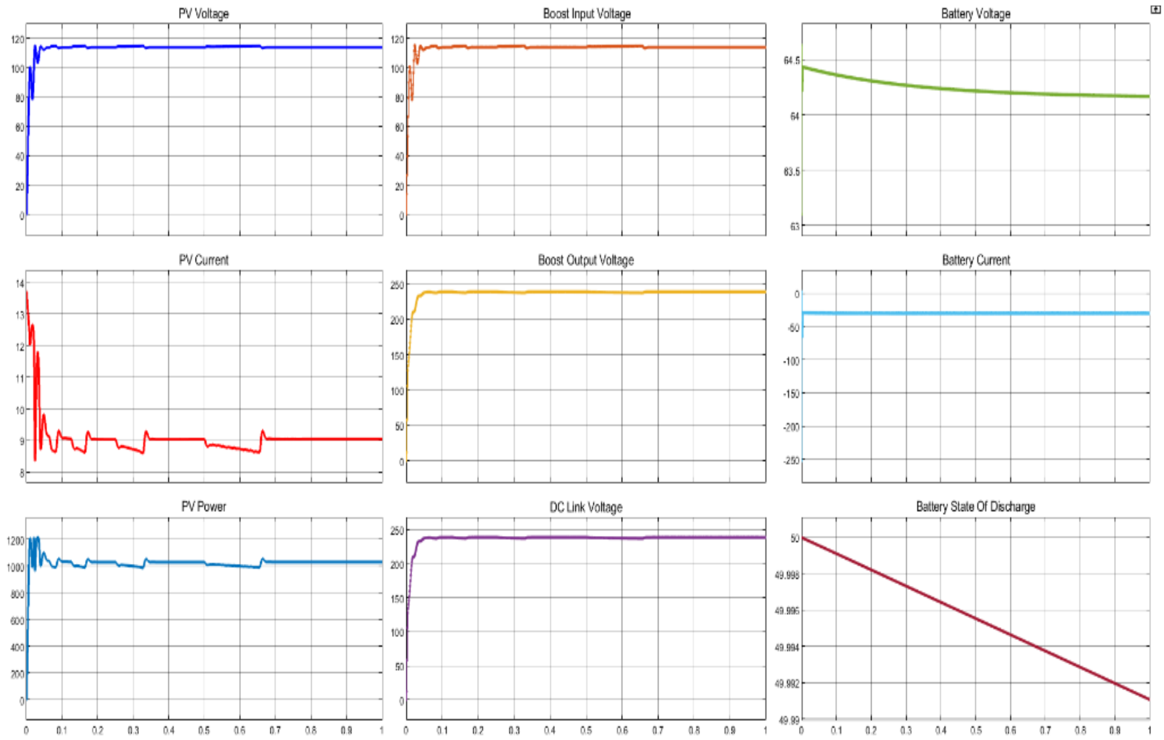

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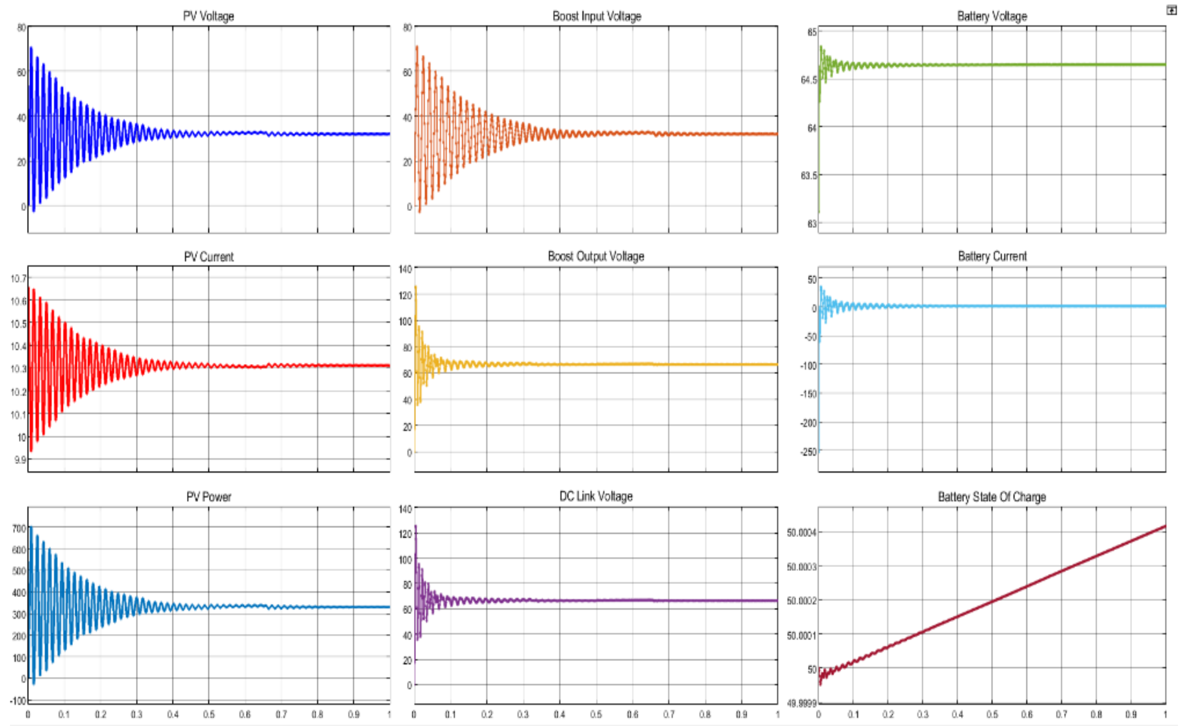
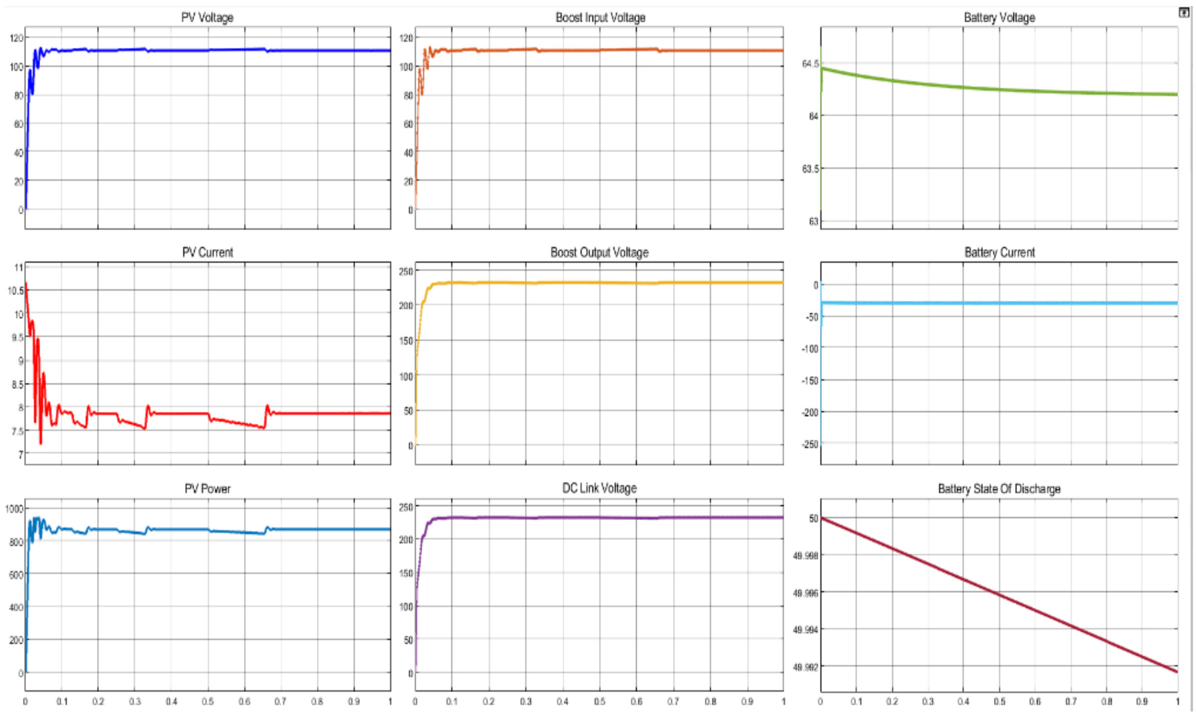
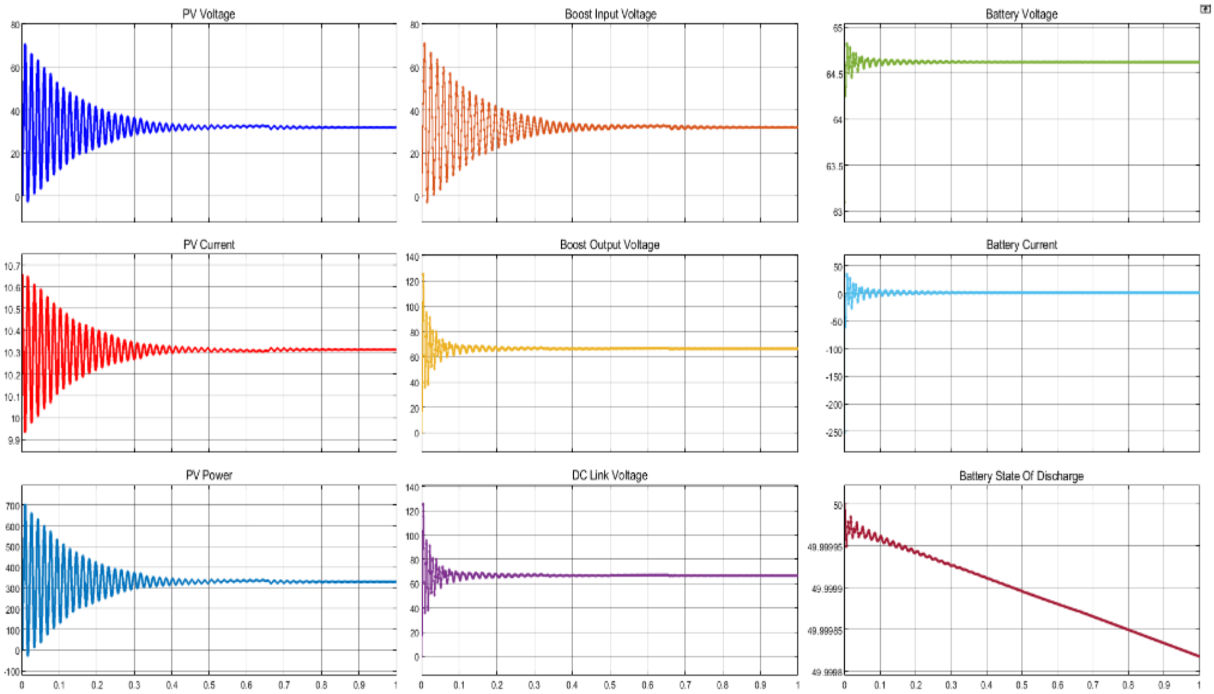
Figure 12: Irradiance 800w/m² & Temperature 25°C (a) Charging operation without load (b) Discharging operation without load (c) Charging operation with resistive load (d) discharging operation with resistive load


PV Voltage
Boost Input Voltage
Battery Voltage
PV Current
Boost Output Voltage
Battery Current
PV Power
DC Link Voltage
Battery State Of Charge

(a)


PV Voltage
Boost Input Voltage
Battery Voltage
PV Current
Boost Output Voltage
Battery Current
PV Power
DC Link Voltage
Battery State Of Discharge

(b)



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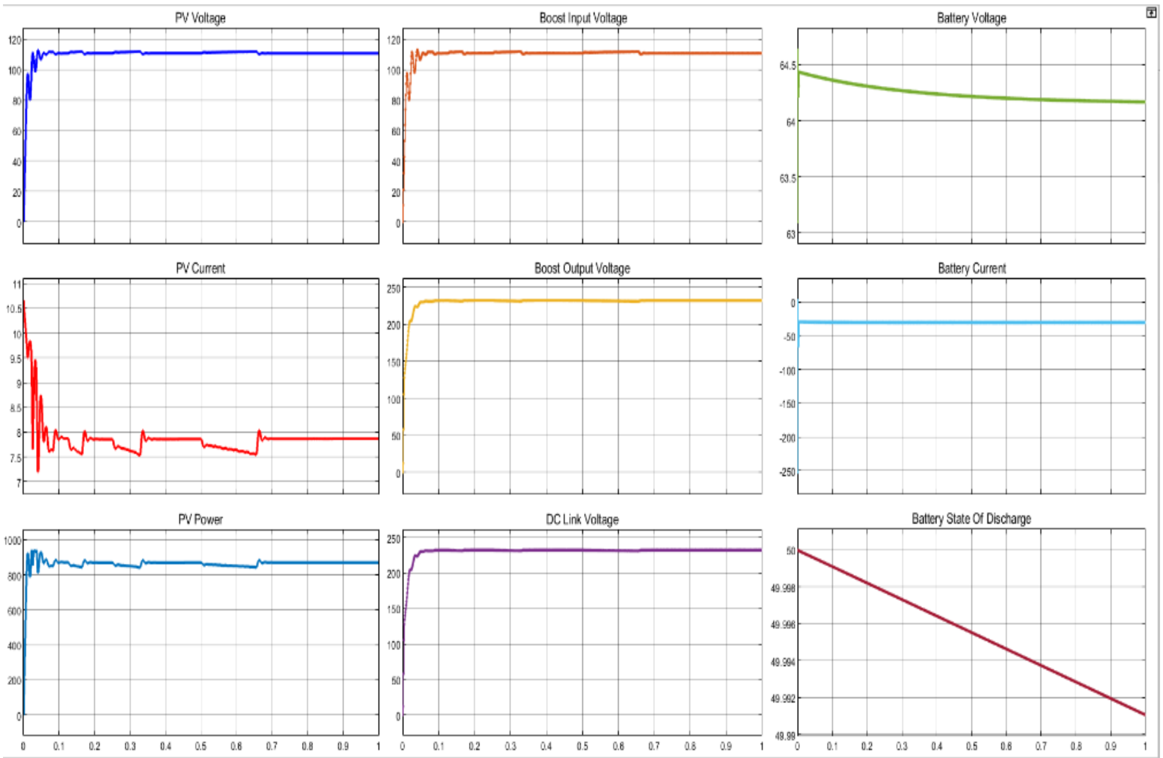

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Figure 13: Irradiance 700w/m² & Temperature 25°C (a) Charging operation without load (b) Discharging operation without load (c) Charging operation with resistive load (d) discharging operation with resistive load

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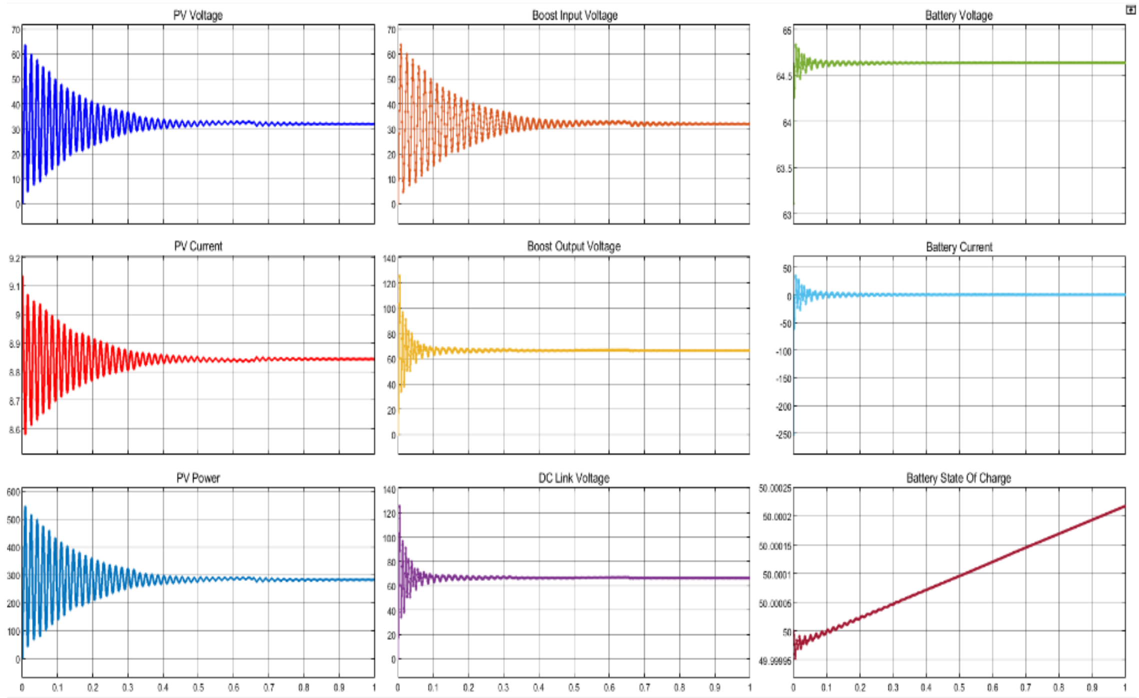

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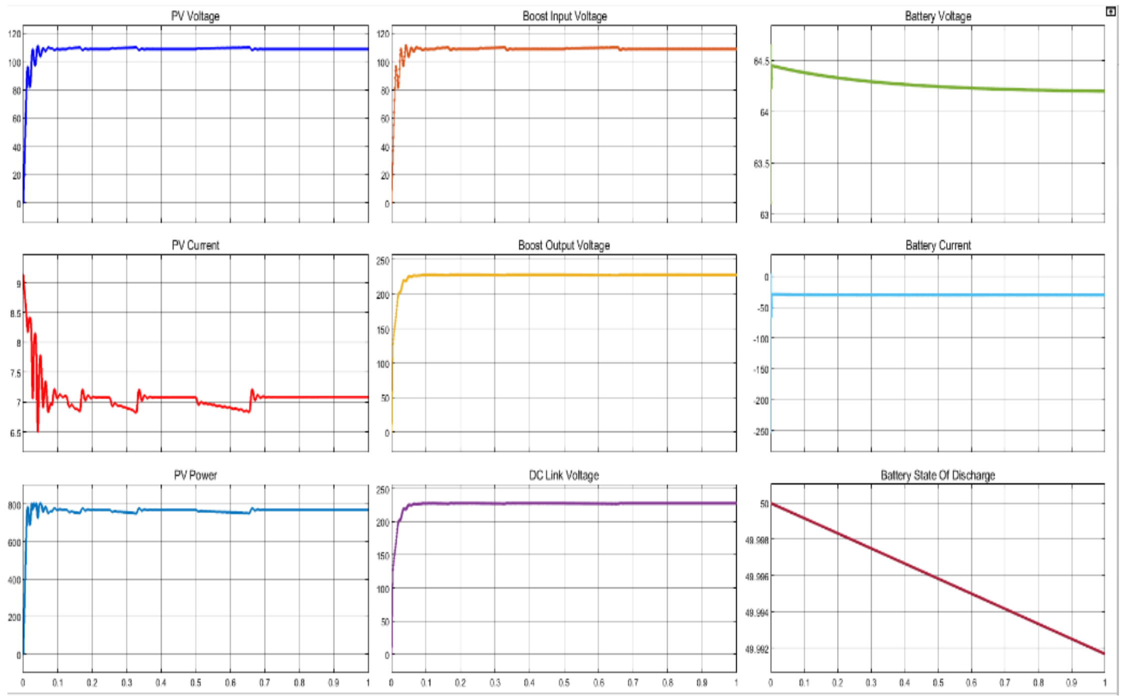

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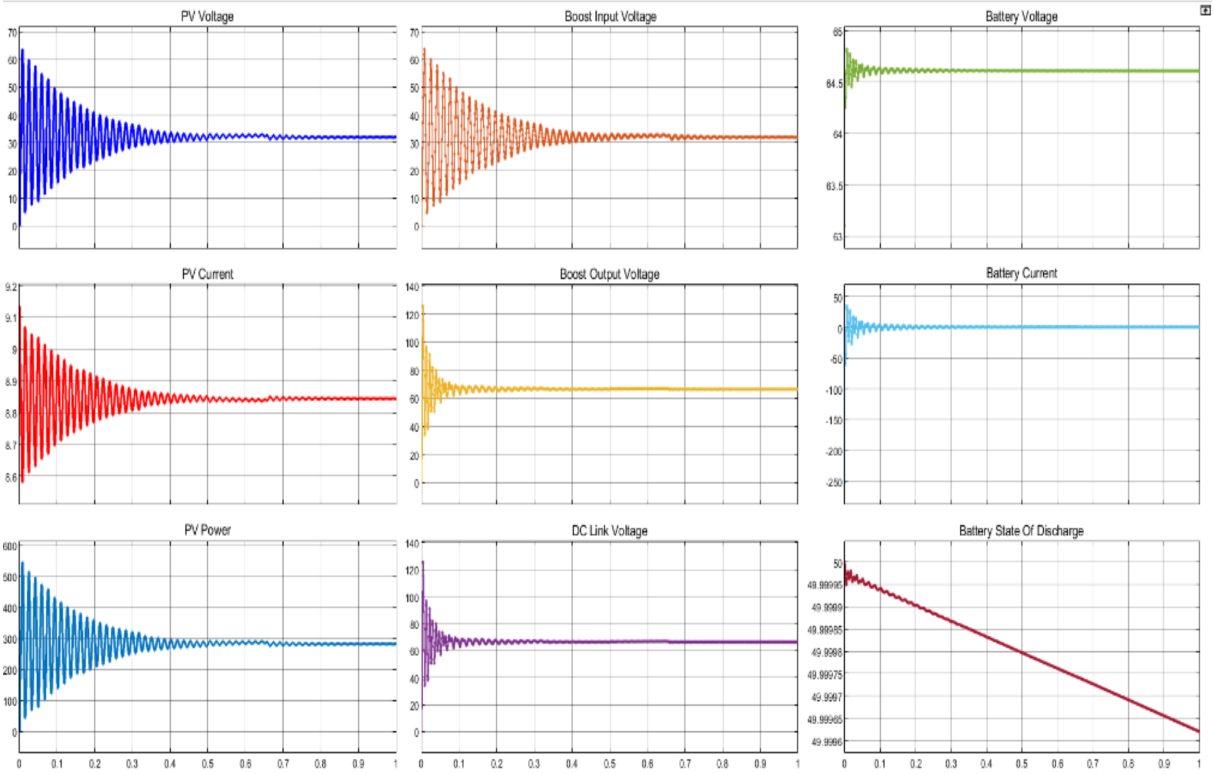

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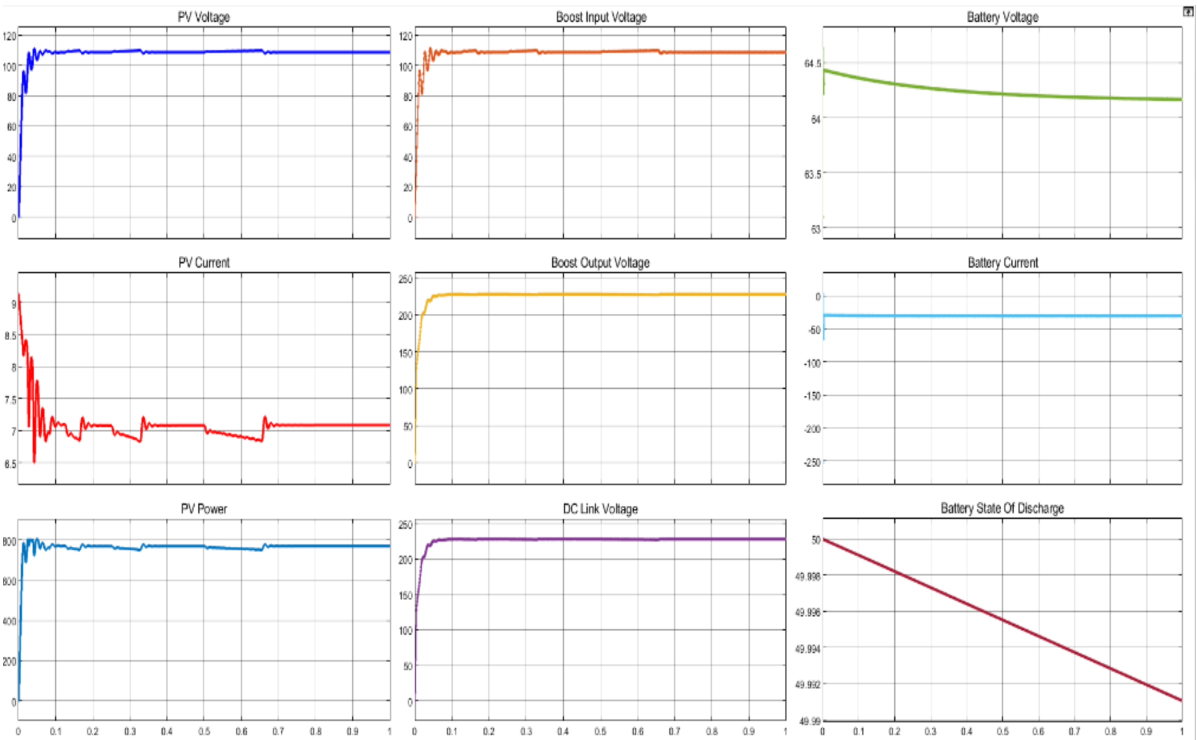

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Figure 14: Irradiance 600w/m² & Temperature 25°C (a) Charging operation without load (b) Discharging operation without load (c) Charging operation with resistive load (d) discharging operation with resistive load

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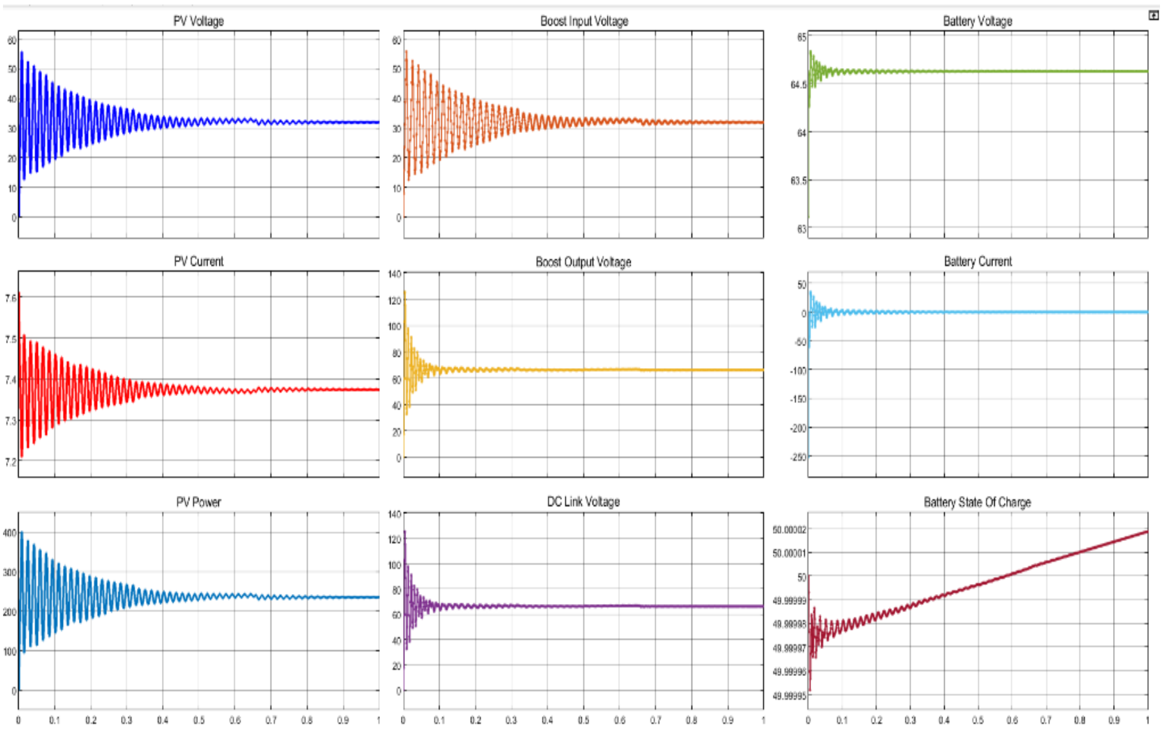

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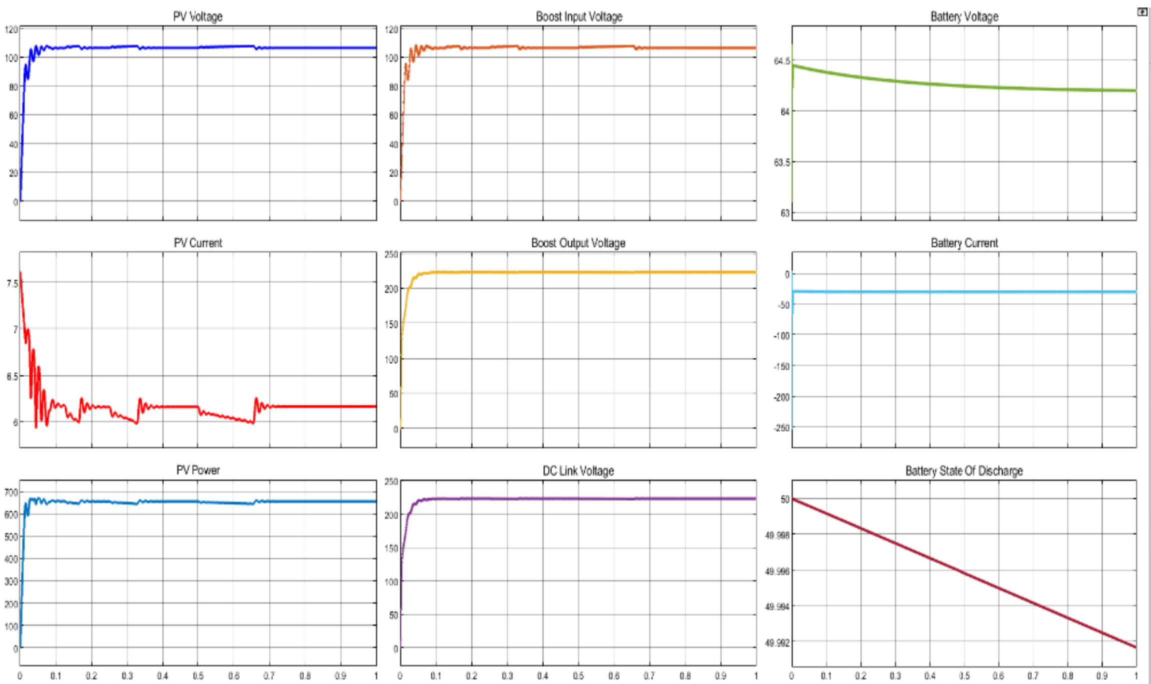

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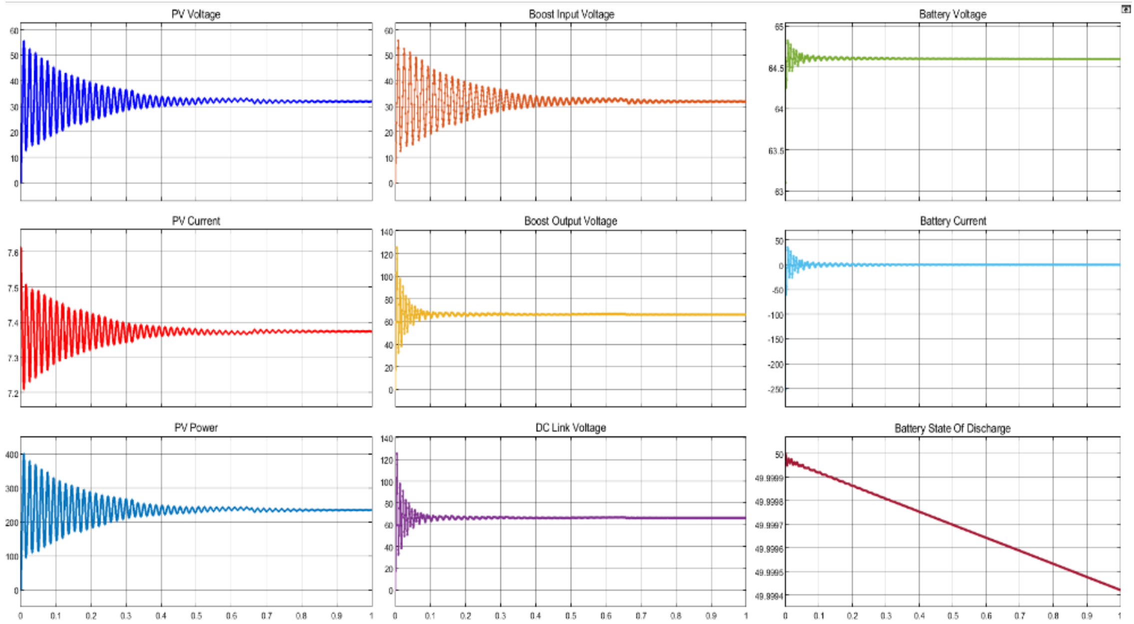

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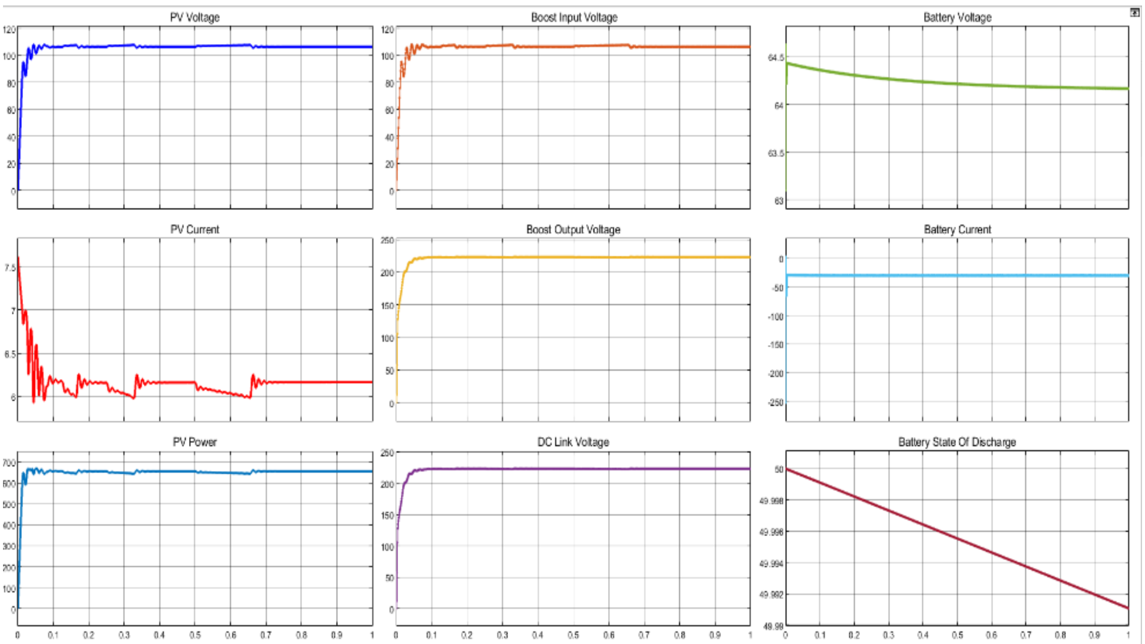

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Figure 15: Irradiance 500w/m² & Temperature 25°C (a) Charging operation without load (b) Discharging operation without load (c) Charging operation with resistive load (d) discharging operation with resistive load

This paper presents a solar photovoltaic system with battery charging and discharging operation using the ANN MPPT technique. The Graph 10 to 15 irradiance 1000w/m², 900w/m², 800w/m², 700w/m², and 600w/m², 500w/m² for charging operation without load. The current will be flow from positive to negative terminal of the battery when total potential difference is greater than electromotive force battery is charged.

The graph 13 to 15 irradiance 700w/m², and 600w/m², 500w/m² for charging operation with resistive load. The battery is discharging because current will be flow from negative to positive terminal of the battery when electromotive force is greater than total potential difference battery is discharge.

The graph 10 to 15 irradiance 1000w/m², 900w/m², 800w/m², 700w/m², and 600w/m², 500w/m² for discharging operation without load and with resistive load. The current will be flow from negative to positive terminal of the battery when electromotive force is greater than total potential difference battery is discharge.

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Table 4. Solar photovoltaic system with battery charging operation using ANN MPPT technique without load

SN	System	1000w/m² &25°C	900w/m² &25°C	800w/m² &25°C	700w/m² &25°C	600w/m² &25°C	500w/m² &25°C
1.	Solar PV voltage	32.1V	32.07V	32.04V	31.01V	31.98V	31.96V
2.	Solar PV current	14.71A	13.24A	11.78A	10.31A	8.84A	7.37A
3.	Solar PV power	472.1W	424.7W	377.3W	330W	282.8W	235.6W
4.	Boost input voltage	32.1V	32.07V	32.04V	32.01V	31.98V	31.96V
5.	Boost output voltage	66.77V	66.68V	66.6V	66.5V	64.43V	66.34V
6.	DC link voltage	66.77V	66.68V	66.6V	66.5V	64.43V	64.34V
7.	Battery voltage	64.68V	64.67V	64.66V	64.65V	64.64V	64.63V
8.	Battery current	3.69A	2.99A	2.28A	1.56A	0.856A	0.141A
9.	State of charge	50%	50%	50%	50%	50%	50%

Table 5. Solar photovoltaic system with battery discharging operation using ANN MPPT technique without load

SN	System	1000w/m² &25°C	900w/m² &25°C	800w/m² &25°C	700w/m² &25°C	600w/m² &25°C	500w/m² &25°C
1.	Solar PV voltage	115.1V	113.8V	112.4V	110.7V	108.6V	106.3V
2.	Solar PV current	9.49A	9.04A	8.50A	7.862A	7.085A	6.16A
3.	Solar PV power	1093W	1030W	956.2W	870.1W	769.7W	655W
4.	Boost input voltage	115.1V	113.8V	122.4V	110.7V	108.6V	106.3V
5.	Boost output voltage	241.4V	238.9V	235.8V	232.2V	227.9V	222.9V
6.	DC link voltage	241.4V	238.9V	235.8V	232.2V	227.9V	222.9V
7.	Battery voltage	64.2V	64.2V	64.2V	64.2V	64.2V	64.2V
8.	Battery current	-30.28A	-30.26A	-30.31A	-30.24A	30.28A	-30.27A
9.	State of discharge	49.99%	49.99%	49.99%	49.99%	49.99%	49.99%

Table 6. Solar photovoltaic system with battery charging operation using ANN MPPT technique
With resistive load

SN	System	1000w/m² &25°C	900w/m² &25 °C	800w/m² &25°C	700w/m² &25°C	600w/m² &25°C	500w/m² &25 °C
1.	Solar PV voltage	32.09V	32.05V	32.02V	31.99V	31.97V	31.94V
2.	Solar PV current	14.71A	13.24A	11.78A	10.31A	8.84A	7.37A
3.	Solar PV power	472.9W	424.5W	377.2W	329.9W	282.7W	235.5W
4.	Boost input voltage	32.9V	32.05V	32.02V	31.99V	31.97V	31.94V
5.	Boost output voltage	66.74V	66.65V	66.57V	66.48V	64.39V	66.31V
6.	DC link voltage	66.74V	66.65V	66.57V	66.48V	64.39V	64.31V
7.	Battery voltage	64.65V	64.64V	64.63V	64.62V	64.61V	64.6V
8.	Battery current	3.7A	2.99A	2.28A	1.57A	0.858A	0.143A
9.	State of charge	50%	50%	50%	50%	50%	50%

Table 7. Solar PV system using ANN MPPT technique with battery discharging operation With resistive load

SN	System	1000w/m² &25°C	900w/m² &25°C	800w/m² &25°C	700w/m² &25°C	600w/m² &25°C	500w/m² &25°C
1.	Solar PV voltage	115.1V	113.8V	112.4V	110.7V	108.6V	106.2V
2.	Solar PV current	9.50A	9.05A	8.51A	7.865A	7.088A	6.16A
3.	Solar PV power	1093W	1030W	956.6W	870.4W	770W	655.1W
4.	Boost input voltage	115.1V	113.8V	112.4V	110.7V	108.6V	106.2V
5.	Boost output voltage	241.4V	238.8V	235.8V	232.2V	227.9V	222.9V
6.	DC link voltage	241.4V	238.8V	235.8V	232.2V	227.9V	222.9V
7.	Battery voltage	64.17V	64.17V	64.17V	64.17V	64.17V	64.17V
8.	Battery current	-30.31A	-30.28A	-30.35A	-30.34A	-30.35A	-30.29A
9.	State of discharge	49.99%	49.99%	49.99%	49.99%	49.99%	49.99%

VII. CONCLUSION

The paper presents the use of an artificial neural network for maximum power point tracking to extract the maximum power from a solar photovoltaic panel at different irradiance conditions. The boost input, output, and DC link voltage and also change with respect to the irradiance conditions. The bidirectional converter has two modes of operation. (i) When the buck mode is enabled the DC link voltage releases energy and the current will flow from the positive to negative terminals of the battery when the terminal potential difference exceeds electromotive force, in this condition battery is charged. (ii) When boost mode is enabled, DC link voltage stores energy and the current will be flow from the negative to positive terminals of the battery and electromotive force to exceed the terminal potential difference, in this condition battery is discharged.

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