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Design of Battery Charging from Solar Panel by Using Step-Down Converter with MPPT Technique

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Abstract:

Solar cell power generation system provides an effective usage of solar energy, but the conversion efficiency is very low and it has problem in maintaining of its dc power output from the solar panel as constant. There are some factors that effect the output power are irradiation and temperature. In this data it is shown that for charging lead acid batteries from solar panel MPPT can be attain by observe algorithm. To regulate the photovoltaic output array, MPPT system is used. A charge controller is operated to match the solar panel impedance and battery to get maximum power. Voltage and current rating are noted from the solar panel. Duty cycle of gating signal is changed based on the MPPT algorithm to obtain maximum power transfer.

***Keywords*:** Buch converter, MPPT, Battery, MATLAB, Photovoltaic array (PV).

Introduction:

The increase in demand for clean and sustainable energy sources have led to the development of various methods for harnessing solar power one of the methods is the use of solar panels to convert sunlight into electricity then the output of solar panels can vary significantly depending on factors like intensity of sunlight and temperature. Utilizing a maximum power point tracking is useful for improving the system efficiency. So, the primary goal of the project was to design and build a battery charging system that used an MPPT-equipped buck converter. In this case, the buck converter is essentially a DC-DC converter that lowers the solar panel's voltage to the voltage needed to charge the battery. The solar panel, uses sunlight to produce electricity. The voltage and current of the panels vary based on temperature and solar radiation. The MPP often known as the point of maximum power production, is a specific operational point. The buck converter (DC-DC converter), also known as chopper that lowers the voltage from the solar panel to the necessary level to charge the battery. It is extremely required since solar panel output is typically higher than battery rating voltage. Whereas. making sure solar energy conversion operates at MPPT in a variety of climatic and environmental circumstances increase its efficiency. The MPPT algorithm continually monitors the voltage and current coming from the solar panel and modifies the buck converter duty cycle. In order to optimize the amount of power supplied to the battery, this check operates at a position that is near the MPP.

The main goal of this project is to create a solar-powered battery charging system that is dependable and effective. This technique attempts to encourage sustainability and lessen dependency on conventional energy sources by utilizing solar power. So, with the help of MPPT and buck converter, this project aims to provide a workable method of using solar energy to charge batteries. Numerous applications including off-grid power systems, portable solar chargers, and distant battery-powered gadgets, are possible with this approach.

List of Components

A. Software used:

1. MATLAB (To analyze & design systems)

2. SIMULATION (It is used for continuous test and verification of embedded systems.)

About MATLAB

MATLAB is a programming environment created especially to study, analyze, and create products & systems that change the world. The MATLAB language, a matrix-based language that enables the most natural expression of computer mathematics, lies at the core of MATLAB. Through deployment to embedded devices and enterprise applications, as well as integration with Simulink and Model-based design, MATLAB enables you to take your ideas from research to production.

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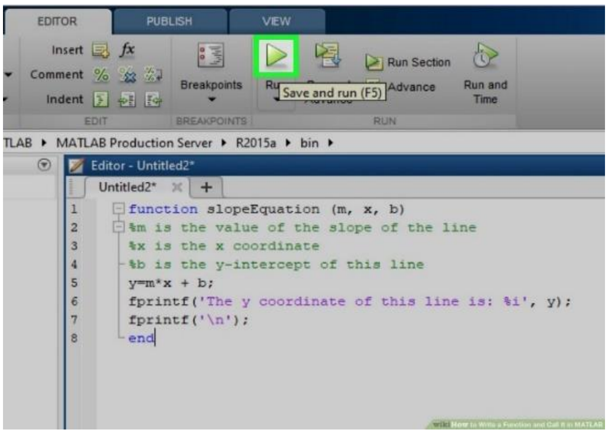


Fig.1. MATLAB software

About SIMULINK in MATLAB

Simulink is a graphical programming environment based on MATLAB that allows you to model, analyze, and simulate multidomain dynamical systems. Its primary interface consists of a graph block diagramming tool and a customizable set of block libraries. It integrates tightly with the rest of the MATLAB environment and may either drive or be written from within it. Simulink is commonly used in automatic control, digital signal processing, multidomain simulation, and model-based design.

Block diagram:

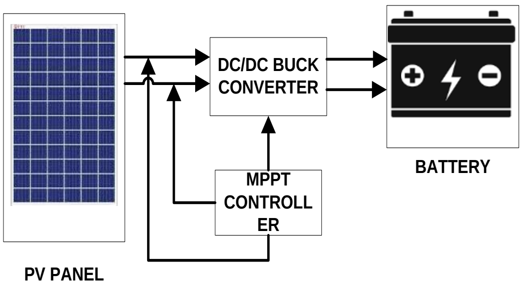


Fig.2. Outline of the system

Fig. 2 shows the procedure embrace in this report to charge batteries by recognizing the battery charging current. MPP tracking systems are used to maximize the power output from the PV panel. Even though many characteristics like temperature, irradiance and the load vary but it helps by keeping output of the solar PV panel constant. And for finer efficiency output from the solar PV panel buck converter is used for power transmission (DC-DC). In standalone / off-grid solar PV systems are effectual in DC-DC step down or buck converter working and battery storing operations. For battery charging application buck converter gives better efficiency, tracking power (solar) form PV panel many MPPT methodologies are applicable such as perturb and observe (P&O), incremental conductance algorithm etc. Among all P&O algorithm is extensively used and more productive with simple control algorithm.

Many characteristics like temperature problems and insolation can get control of by using P&O algorithm, this is effective, malleable and earliest control algorithm. Insolation (incoming solar radiation) is to estimate the solar radiation energy on a specified surface area and take down during a given time. Irradiation expressed in Watts per square meter (W/m2). In photovoltaic a proportion of radiation reflected or absorbed depends on the object's reflectivity. The insolation decreases in proportion to the cosine of the angle as the angle grows between the direction of the sun's beam at a right angle to the surface and that direction. The buck converter uses buck operation, which steps down the voltage and is useful for charging batteries and low power applications.

Characteristics of PV panel

Large-area semiconductor diodes, which are the individual cells that make up a solar panel, are designed to allow light to enter the p-n junction region. The junction that forms between the p- type surface layer and the n-type silicon wafer controls both the photovoltaic effect and the diode properties. When light is absorbed by silicon, more holes and electrons produced. Power can be generated by allowing these extra charges to pass via an external circuit.

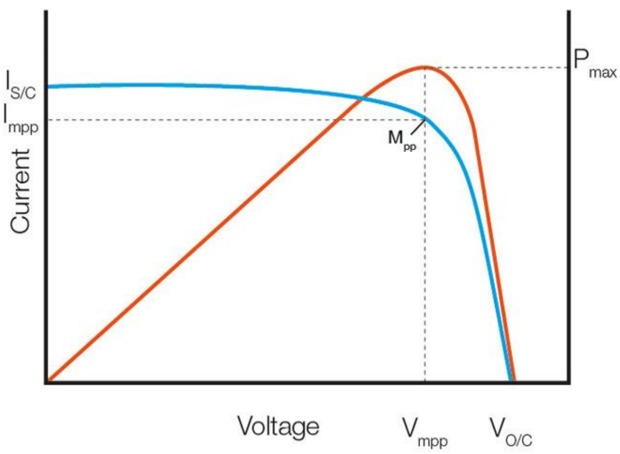


Fig.3. I-V curve

PV panels are not a linear power source. The output current and voltage (I-V curve) for a specific light intensity falling on the PV panel is displayed in Fig. 3. The output Power Eventually, PM is the product. P_o= Vm* The goal of MPPT is to locate the maximum power output point. Usually, this happens at the curve's knee. The I-V curves variations with the amount of light falling on the panel are depicted in Fig. 4.

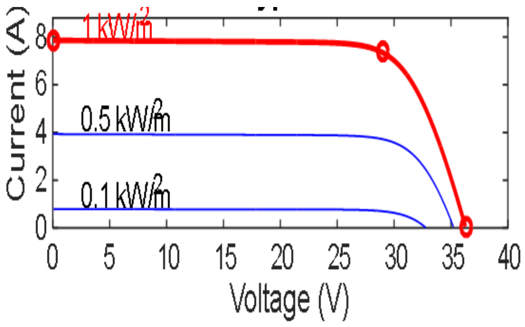


Fig.4. Variations in I-V curve

A DC-DC converter is necessary to regulate the load that the solar panel perceives and maintain the panel at its maximum power since the operating point of the solar cell is dependent on the applied load and the solar panel's I-V curve. One can create a P-V characteristic curve from the solar panel's I-V curves. The P-V curve for various irradiation levels is displayed below. The operation is maintained at the apex of this curve and followed by the MPPT method.

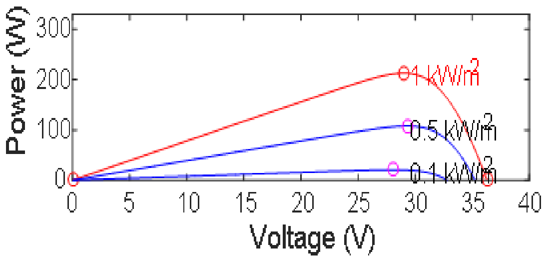
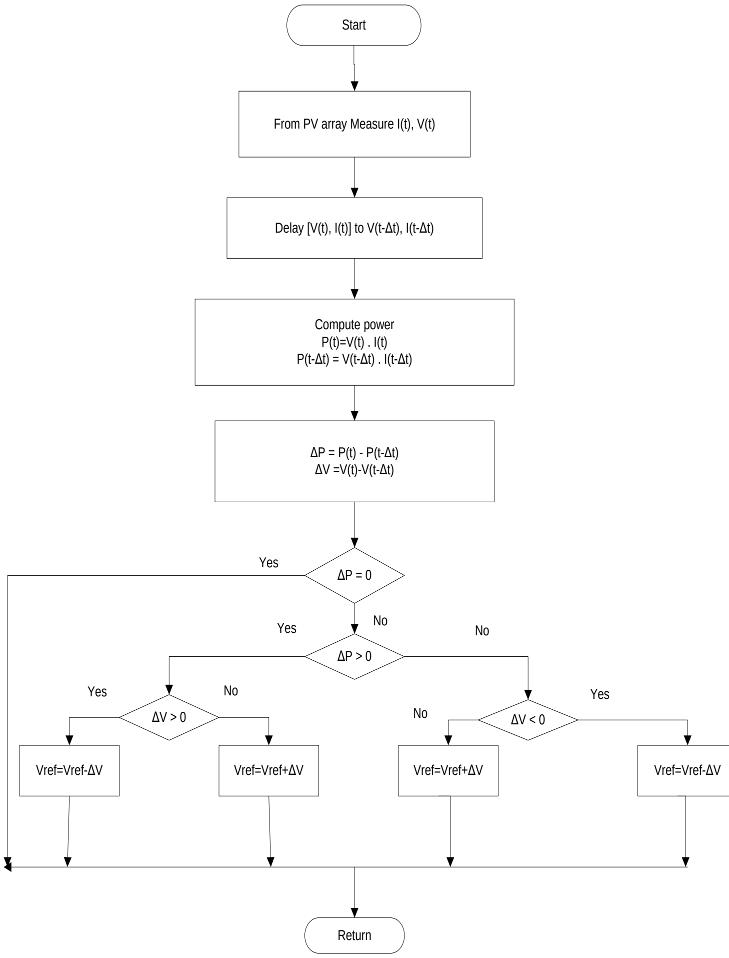


Fig.5. Variations in P-V curves

MPPT Algorithm

When controlling the MPPT method for a PV generator, the Two Point Power Comparison approach is typically used the most. Its easy to use, affordable, and basic construction. To implement, fewer characteristics to consider, potential for enhancements, and potential for maximum efficiency. This approach relies on examining the relationship between the voltage and output power of a photovoltaic module. The way a solar panel behaves to indicate MPPT and operational principle is depicted in Fig4, which shows that the following is observed as a result of the change in PV power: The PV module voltage should be perturbed in the direction of the MPPT when the PV module operating point is on the left side of the curve (ΔP/ΔV is positive), indicating an increase in PV module output power. The PV module voltage disturbance should be reduced in the direction of the MPPT if the module's operating point was on the right side of the curve (ΔP/ΔV is negative).

FLOW CHART for P&O algorithm:



First, measurements are made of the PV array's voltage and current, the real power of the PV module is then determined by multiplying the voltage by the current. After that, it will verify status regardless of whether ΔP=0. The operating point is at the MPPT if this condition is met. It will verify another state where ΔP>0 if it is not satisfactory. It will verify that ΔV>0 if this condition is met. In the event that it is satisfied, the operational point is shown to be on the left side of the MPP. The operational point is at the right side of the MPPT if the condition is not satisfied ΔV>0. This procedure is kept on repeating till the MPPT is reached. Thus, there is always a compromise between the increments and sampling rate in the two point power comparison method.

DC-DC Buck Converter

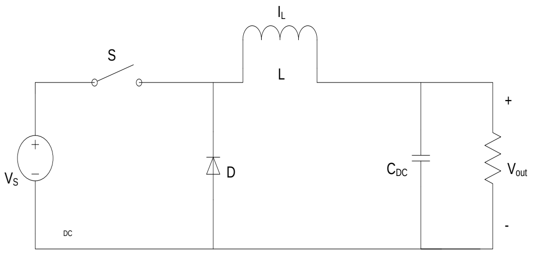


Fig.6.Buck Converter

The DC-DC converter changes the DC output voltage to a higher or lower value from the DC input voltage source. Given that the voltage of the PV array is higher than that of the battery, a buck. Typically, topology is selected for solar PV charge controller applications. The buck converter operates as a regulator to step down the input voltage from the PV array while maintaining its power delivery to charge the battery. This is achieved by stepping down the input voltage and increasing the output current delivered to the battery.

SIMULATION AND RESULTS

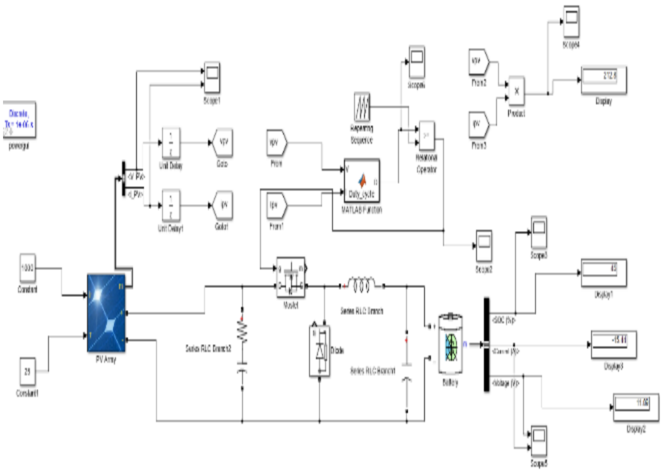


Fig.7. Simulation and designing a battery charging from Solar PV panel by using Step down converter and MPPT technique

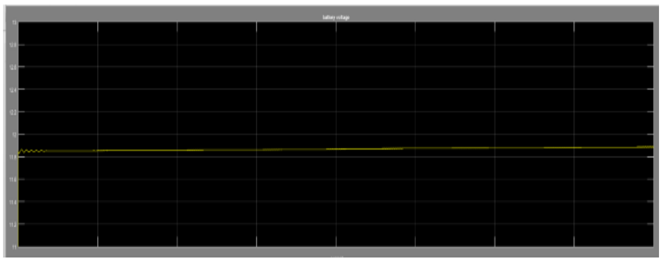


Fig.8.Battery Voltage

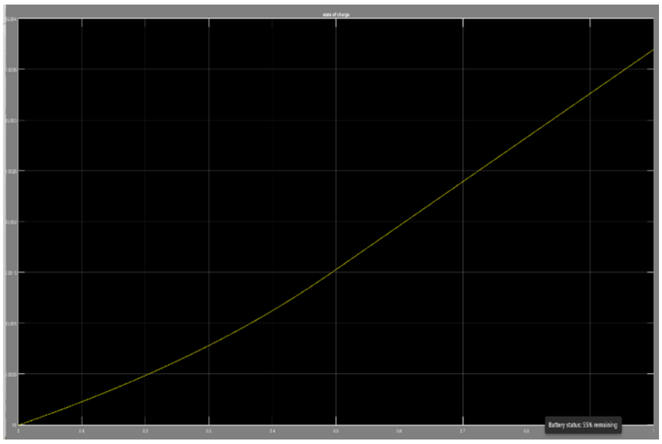


Fig.9.Battery State of Charge

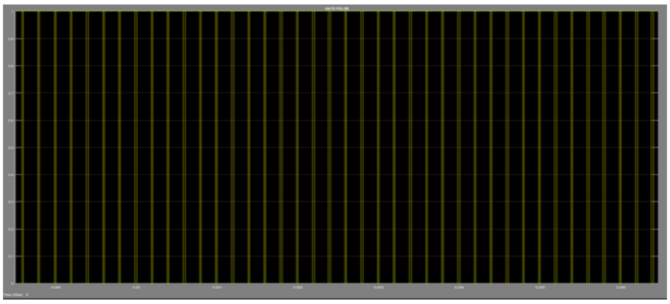


Fig.10.Gate Voltage

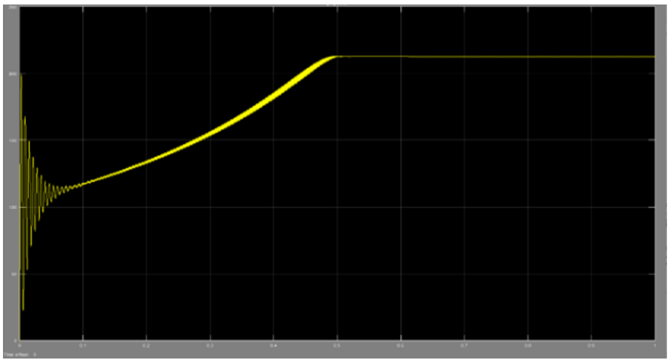


Fig.11.Input PV Power

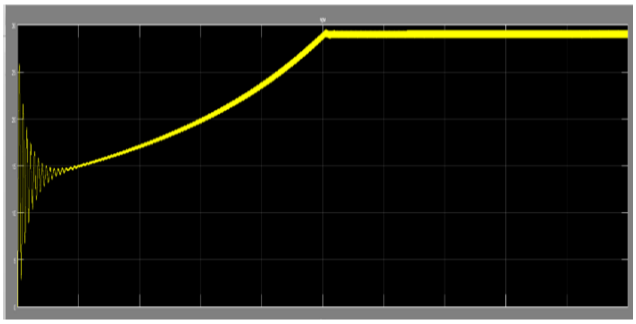


Fig.12. Voltage of PV Panel

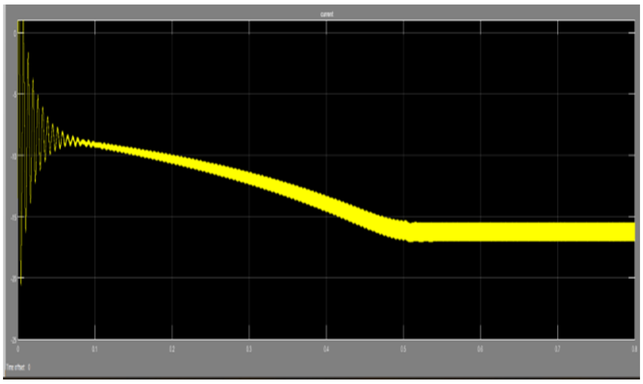


Fig.13.Battery Currents

SIMULATION ANALYSIS

Every aspect of the system is simulated using MATLAB/Simulink. Here, the P&O technique is used to determine the maximum output power from the solar PV system MPPT or Charge controllers employ a technique called highest power point tracking to harvest the highest amount of power that can be extracted from photovoltaics module under specific circumstances. Peak power voltage, often known as the "maximum power point," is the voltage at which photovoltaic modules may generate their greatest power. Solar radiation, outside temperature, and solar cell temperature all effect maximum power. The solar array has a rated power of 213W and a solar input voltage of 29V. Battery voltage is 12 volts, switching frequency is 25khz, output current is equal to (rated power/output voltage) is (213/12)= 17.75 amp, and voltage ripple is 1%. As a result the value of capacitance, C=1.775/(8*5000*0.12)=369.79µF, and the value of inductance, L=12*(29-12)/(5000*1.775*29) = 0.792mH, correspond to the current ripple of 10% of 17.75A, or 1.775A, and voltage ripple of 1% of 12V , or 0.12V. The PV module-based power system that is being simulated here is ultimately capable of generating a maximum power of roughly 210W, as can be seen from the findings above. At a cell temperature of 25C and an irradiation of 1000W/m2, while managing a 12V battery and preserving the MPPT. This model can be used to test any PV module or even any PV array-based powers system under any irradiation and temperature conditions because simulation has been run here for a set of temperature and irradiation levels. When the amount of radiation is reduced, the array's power and output charging current both decreases in tandem, and vice versa.

Once again, as the temperature rises, the array's power will decrease in proportion, as will the output charging current, and vice versa. Additionally, as the number of parallel threads rises, so does the power and charging current. Fig10 illustrates how the battery's SoC changes in a single second, from 45% to 45.004%.

Conclusion:

Our primary goal is to use solar power to properly charge batteries. The Simulink model of a solar PV MPPT battery charge controller is shown in this report. A stepdown converter which supplies the battery for a 12V operation. The buck converter does the power conversion. The amplitude of the reference current, which is used to regulate the switching of buck converter, is coded in MATLAB and is tracked by the maximum power point tracking or Two Point Power Conversion algorithm, which is the perturb and observe algorithm. The current's amplitude varies along with changes in radiation. The method would guarantee the tracking of maximum power points by adjusting the duty cycle of the buck converter's MOSFET. The output power and output current of the solar array are provided by the Simulink model. Variations in temperature and sun radiation also affect output power and output current. Using a buck converter, the battery's charging current is adjusted dependent on the power from the photovoltaic system. The proposed work can be utilized to connect appliances through an inverter circuit or directly to a load. This will prolong battery life, minimize pollution caused by fuel combustion, and ensure that the load receives steady power

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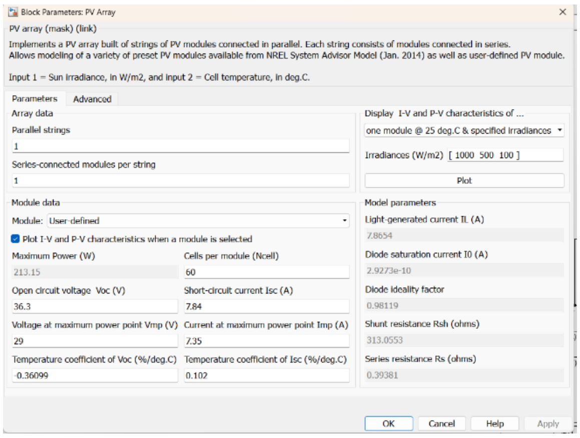
APPENDIX

Code of the P&O algorithm:

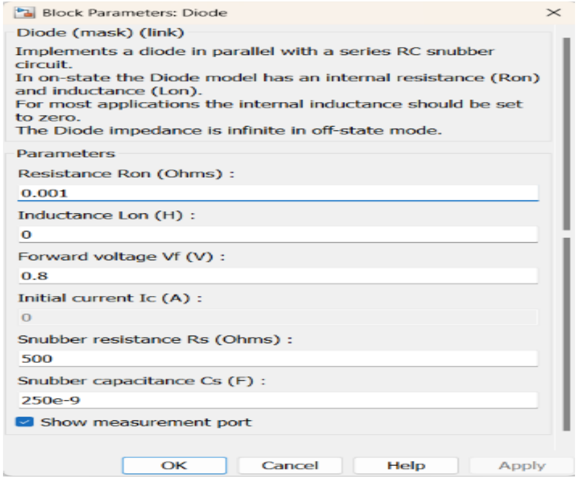
```
Function D= Duty.cycle (V, I)
Dmax = 0.95;
Dmin = 0;
Dinit = 0.95;
Deld = 0.0001;
persistent Vold Pold Dold;

datatype = 'double';
if isempty(Vold)
   Vold=0;
   Pold=0;
   Dold=Dinit;
end
P=V*I;
dV = V-Vold;
dP = P-Pold;
if dP ~=0
  if dP<0
     if dV<0
        D=Dold -Deld;
  else
     D=Dold-Deld;
  end
else
  if dV<0
     D=Dold+Deld;
  else
     D=Dold-Deld;
  end
 end
else D=Dold;
end
if D >= Dmax || D < Dmin
  D=Dold;
end
Dold = D;
Vold = V;
Pold = P;
```

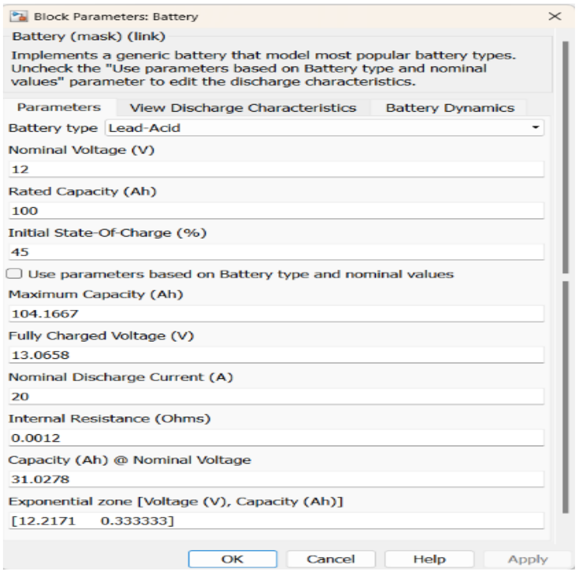
Block parameters of PV array:



Block Parameters of Diode:



Block parameters of Battery:



Buck Converter Specifications:

1.	**Input Voltage**	**29V**
2.	**Output Voltage**	**12V**
3.	**Output Current**	**17.75**
4,	**Voltage& Current ripple**	**1% & 10%**
5.	**Inductance**	**0.792mH**
6.	**Capacitance**	**369.79μf**
7.	**Switching frequency**	**5000**
8.	**Maximum input power**	**213W**