Department of Electrical & Electronic Engineering

Brac University

Fall-2022

Course Code: EEE422

Course Title: Power Electronics Laboratory Project

Project Title: Designing a novel battery regulation system for photovoltaic applications

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Date of Submission: 23 th December, 2022

Introduction

We needed to design a converter for charging the battery with a PV panel. A synchronous buck converter was used and with the help of the Maximum Power Point Tracking (MPPT) algorithm it extracts maximum power from the PV panel and charges the battery through the DC-DC converter.

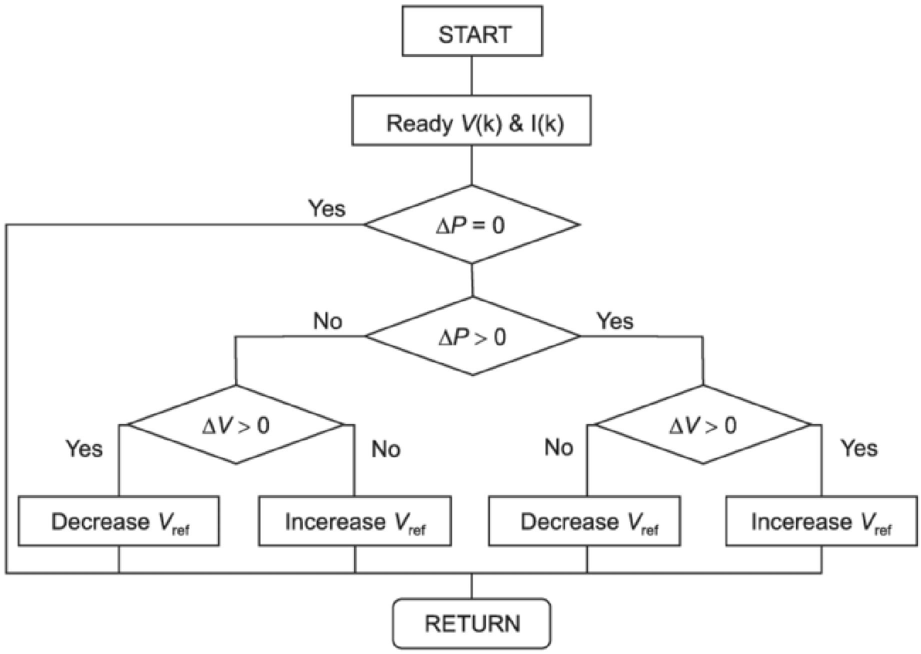


Fig: MPPT Algorithm

Then we used a buck converter here because it is a step-down converter which means its Vin>Vout. We chose this because the output voltage of the solar panel is higher than that of the battery, hence the voltage needed to be stepped down.

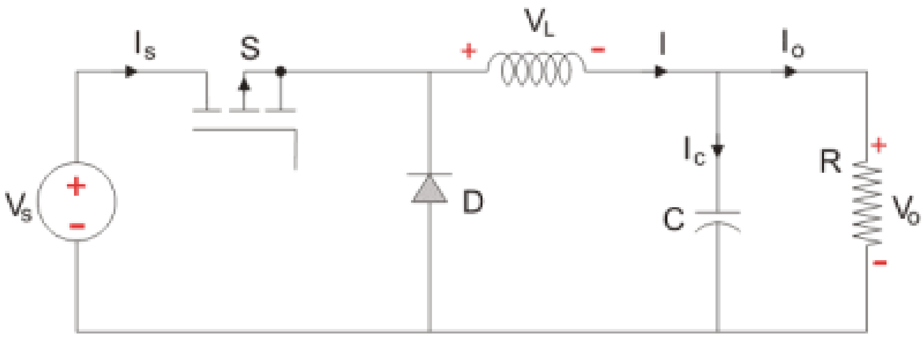


Fig: Circuit diagram of buck converter

We need to design the buck converter in such a way so that it provides us the required voltage. To do so, we have to use definite values for the inductor and the capacitor. To design the inductor, we derived the following equation:

$$\Delta i_L = \frac{V_i - V_o}{L} DT \qquad \Delta i_L = +\frac{V_o}{L}(1-D)T$$

we consider only magnitude.

$$i_o = i_L$$

$$I_L - \frac{1}{2}\Delta i_L \geq 0$$

$$I_o - \frac{1}{2} \times \frac{V_o}{L}(1-D)T \geq 0 \qquad T = 1/f$$

$$I_o \geq \frac{1}{2}\frac{V_o}{L}(1-D)T$$

$$I_o \geq \frac{1}{2} \times \frac{I_o R}{L}(1-D)T$$

$$L \geq \frac{\frac{1}{2} R(1-D)}{f}$$

The capacitance of the capacitor was determined by the following equation:

$$C\,dV_o = \frac{1}{2} \times \frac{T}{2} \times \frac{1}{2}\Delta I_L$$

$$C\,dV_o = \frac{1}{2} \times \frac{1}{2f} \times \frac{1}{2} \times \frac{V_o}{L}(1-D)T$$

$$\frac{dV_o}{V_o} = \frac{(1-D)}{8f^2 CL}$$

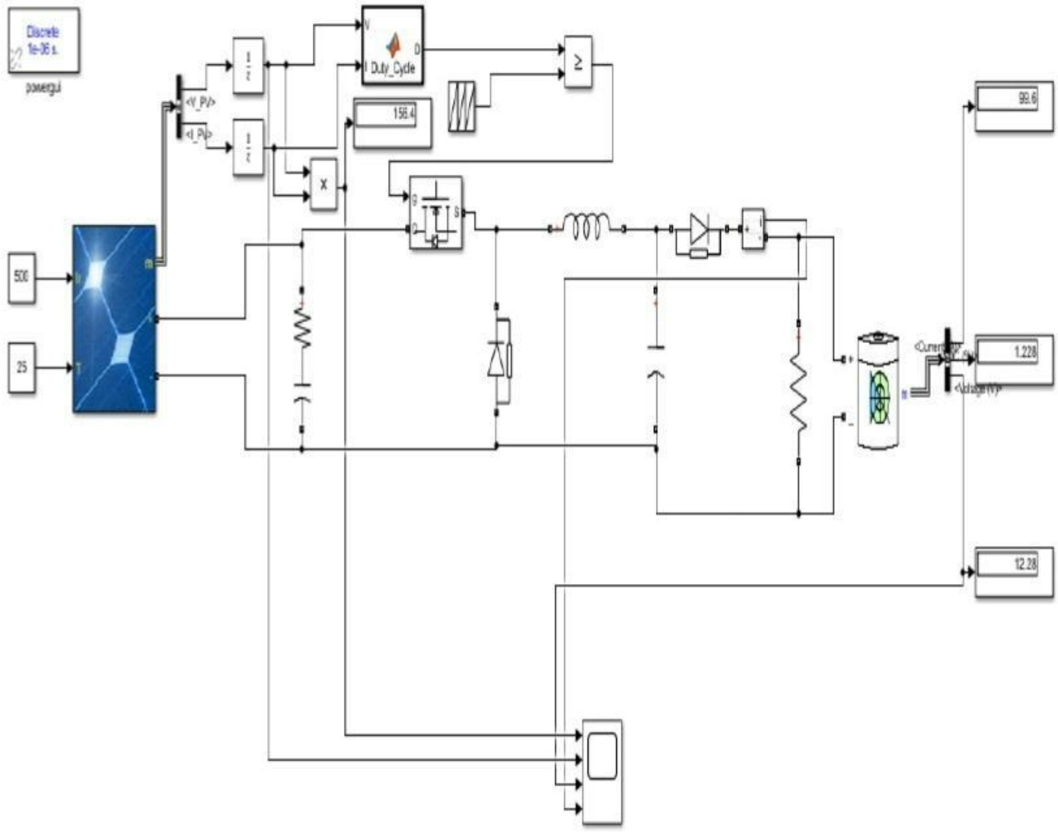
→ Voltage ripple → 1% → $\frac{dV_o}{V_o} = 0.01$

Software Requirements

To model and simulate our system, we utilized the following software tools:

-MATLAB
-MATLAB Simulink

Circuit Diagram



Design

Rated Power = 310 W $V_{oc} = 44.97$

$V_{in} = 36 - 45$

$V_{out} = 12V$

$$\text{Output current} = \frac{\text{Rated Power}}{V\ \text{output}} = \frac{310}{12} = 25.833$$

$$\text{Current ripple} = 1\% \times 25.833 = 0.25833$$

$$\cancel{\min = 0.25833 \times 100}$$
$$\cancel{= 25.833}$$

$$\text{Voltage ripple} = 10\% \times 12 = 1.2\ \cancel{\times 100}$$

$$\cancel{\min = 1.2 \times 100}$$
$$\cancel{= 120V}$$

$$L = \frac{12(36-12)}{5000 \times 0.25833 \times 36}$$

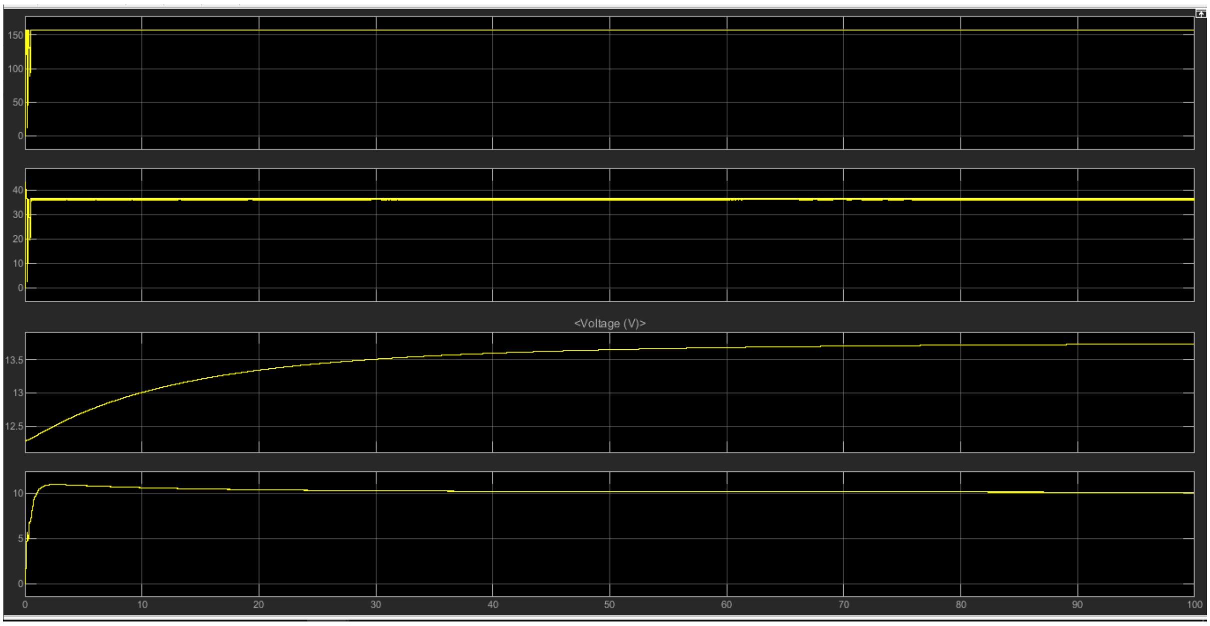
$$= 6.19 \times 10^{-3} \qquad 100 \times \min = 100 \times 6.19 \times 10^{-3}$$
$$= 0.619\ H$$

$$C = \frac{0.25833}{8 \times 5000 \times 1.2} = 5.38 \times 10^{-6}$$

$$100 \times \min = 100 \times 5.38 \times 10^{-6}$$
$$= 5.38 \times 10^{-4}\ F$$

The minimum value of inductance and capacitance was found out from the formula and we had to use a value 100 times that. We chose these values to step down the Vin the right amount for the battery to get charged up.

Results and Observations



To visually represent the behavior of our system over time, we generated four distinct graphs. These graphs were obtained after running the simulation for 100 seconds:

1. Supply Power: The first graph illustrates the supply power over the 100-second simulation period. It shows the power generated by the PV panel and supplied to the system.

2. Power Voltage: The second graph represents the voltage levels in the power circuit. This graph details how voltage changes throughout the simulation, providing insight into the dynamic behavior of the system.

3. Battery Voltage: In the third graph, we monitor the battery voltage over time. This graph shows the voltage levels within the battery, indicating how well the system is charging it.

4. Battery Current: The fourth graph tracks the current flowing into and out of the battery during the simulation. It reveals the charging and discharging behavior, which is essential for understanding the battery's status.

These timing diagrams serve as crucial visual aids for assessing the system's performance and its ability to efficiently manage power and maintain battery health over the 100-second simulation period.

The MPPT algorithm effectively optimizes power extraction from the PV array, ensuring that the battery receives the maximum available power. However, it's crucial to provide quantitative results, such as specific power outputs and efficiencies, to demonstrate the success of the system in meeting the design objectives.

Discussion

One intriguing observation was the inability to discharge the battery, even after connecting a resistor parallel to it. This issue may be attributed to various factors related to circuit design, software settings, or component selection. Further exploration and analysis are required to address this challenge and enable bidirectional power flow from the battery.

Conclusion

In conclusion, our project successfully designed a battery regulation system for PV applications, integrating a buck converter with the MPPT algorithm. While we achieved efficient power transfer from the PV array to the battery, the challenge of battery discharge remains a subject for further investigation and improvement. This project highlights the significance of designing robust battery regulation systems for renewable energy applications and sets the stage for future enhancements in this field.