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Design of power drive for electric vehicle with solar charging

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Abstract

Solar chargers are simple, portable and ready to use devices which can be used by anyone, especially in remote areas. Solar panels don't supply regulated voltage while batteries need the same for charging. Usually dc converters are one-way, energy can only flow in one way. In order to realize the two-way flow of energy, we generally use two one-way dc converters in parallel. A dc converter control from the input energy to the output transmission, while another control energy transmission in the opposite direction. And bi-directional dc converter can not only adjust energy output but can also control the direction of energy flow in one machine. It is, therefore, important to design a power drive considering the various variables that come into play. In this paper, we analyze the various design considerations and constraints when designing a power drive. Further, we look at various use cases of an electric vehicles and the conditions for maximum power extraction with the help of various algorithms. Lastly, with the advancement in solar technology, we design a system which charges the battery through solar panels and, thereby, integrate it with the rest of the power drive.

Keywords: Electric Vehicle, Converter, MPPT, Solar.

1. Introduction

Development of an alternative vehicle technology the transport sector is heavily dependent on the internal combustion engine because of its good driving range and short refueling time. However, due to the growing environmental awareness, alternatives which are not dependent on fossil fuel are being investigated. The battery-powered electric vehicle (EV) has been proposed as an alternative since it can recharge its batteries from renewable energy sources (such as wind power or solar cells). Solar energy is one of the most important renewable energy sources available that has been gaining increased traction in recent years. Electric vehicle can be called a hybrid if it uses two sources. In this case, one is battery and the other is solar. The energy from battery can be charged by the charging circuit and the energy from solar. The main objective of this project was to design and develop a proof of concept Solar Charging capable of delivering power to Motor. A custom maximum power point tracker (MPPT) will be designed to extract the maximum amount of power available from the solar panels. This MPPT samples the voltage and current output of the solar panels. Regenerative braking is a most excellent way for electric vehicle to expand their driving capabilities. The regenerative braking plays a vital part to maintain the vehicle's strength and getting better energy.

1.1 Background

Recent electric vehicles run mostly on batteries. So, introducing use of solar energy we can make an efficient system which can run for long periods of time. Recently, research and development of low cost flat-panel solar panels, thin-film devices, concentrator systems and many other innovative concepts have advanced. Soon, the costs of small solar powered modular units and solar power plants will be economically feasible for large- scale production and use of solar energy. We have presented the photovoltaic solar panel's operation. The foremost way to increase the efficiency of a solar panel is to use a Maximum Power Point Tracker (MPPT), a power electronic device that significantly increases the system efficiency. By using it, the system operates at the Maximum Power Point (MPP) and produces its maximum power output. Thus, an MPPT maximizes the array efficiency, thereby reducing the overall system cost.

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1.2 Scope

Solar energy is one of the most important renewable energy sources that have been gaining increased attention in recent years. Solar energy is plentiful; it has the greatest availability compared to other energy sources. Recent electric vehicles run mostly on batteries. Introducing the use of solar energy, we can make efficient system and can run for long period of time.

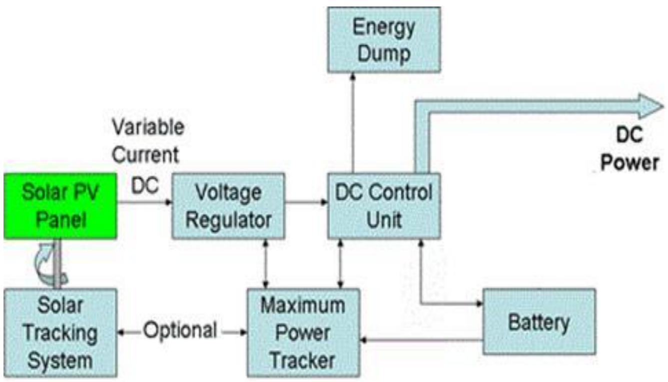

Figure 1: System Block Diagram [5]

2. Literature Review

2.1 DC-DC Converter

A DC-to-DC converter is an electronic circuit or electro-mechanical device that converts a source of direct current (DC) from one voltage level to another [1]. It is a type of electric power converter. Power levels range from very low (small batteries) to very high (high-voltage power transmission). There are different types of DC-to-DC converters available depending on the requirement of power level. The converter topologies are classified as

- Buck Converter: The buck converter is step down converter and produces a lower average output voltage than the dc input voltage.
- Boost converter: The output voltage is always greater than the input voltage.
- Buck-Boost converter: The output voltage can be either higher or lower than the input voltage.

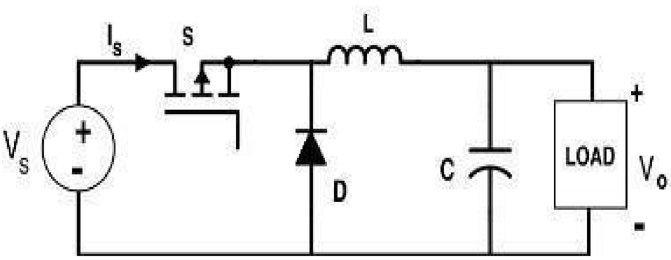

Figure 2: Buck Converter [6]

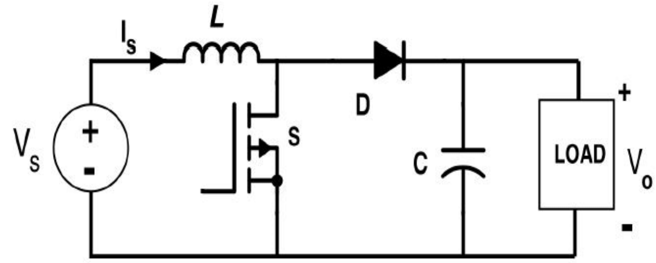

Figure 3: Boost Converter [6]

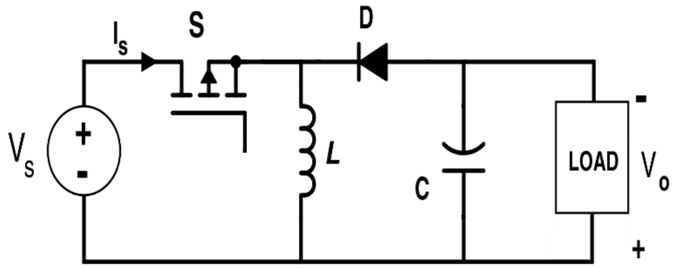

Figure 4: Buck-Boost Converter [6]

2.2 MPPT Algorithm

In a (Power-Voltage or current-voltage) curve of a solar panel, there is an optimum operating point such that the PV delivers the maximum possible power to the load. This unique point is the maximum power point (MPP) of solar panel. Because of the photovoltaic nature of solar panels, their current-voltage, or IV, curves depend on temperature and irradiance levels. Therefore, the operating current and voltage which maximize power output will change with environmental conditions. As the optimum point changes with the natural conditions so it is very important to track the maximum power point (MPP) for a successful PV system. So, in PV systems a maximum power point tracker (MPPT) is very much needed. In most PV systems a control algorithm, namely maximum power point tracking algorithm is utilized to have the full advantage of the PV systems. For any given set of operational conditions, cells have a single operating point where the values of the current (I) and voltage (V) of the cell result in a maximum power output. These values correspond to a load resistance, as specified by Ohm's Law. From basic circuit theory, the power delivered from or to a device is optimized where the derivative of the I-V curve is equal and opposite the I/V ratio. This is known as the maximum power point (MPP) and corresponds to the "knee" of the curve.

2.2.1 Methods of MPPT algorithms

Maximum Power Point Tracking (MPPT) is used to obtain the maximum power from these systems. In these applications, the load can demand more power than the PV system can deliver. There are many different approaches to maximizing the power from a PV system, this range from using simple voltage relationships to more complexes multiple sample-based analysis. There are some conventional methods for MPPT. Seven of them are listed here. These methods include:

1. Constant Voltage Method
2. Open Circuit Voltage method
3. Short Circuit Current method
4. Perturb and Observe method
5. Incremental Conductance method
6. Temperature method
7. Temperature Parametric method

2.2.2 Perturb and Observe Method

In this method the controller adjusts the voltage by a small amount from the array and measures power [2], if the power increases, further adjustments in the direction are tried until power no longer increases. This is called P&O method. Due to ease of implementation it is the most commonly used MPPT method.

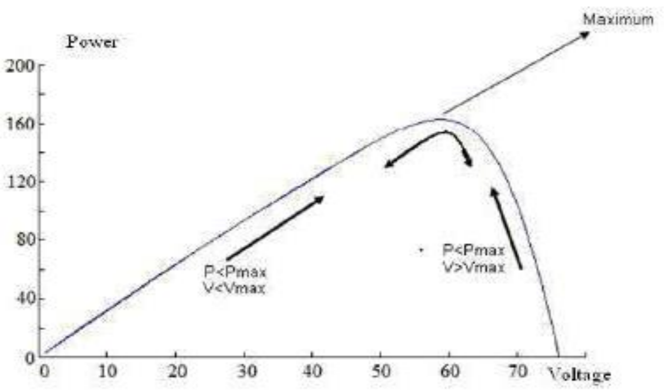

Figure 5: Output power using P&O algorithm [7]

P&O is very popular [3] and most commonly used in practice because of:

1. Its simplicity in algorithm.
2. Ease of implementation.
3. Low cost
4. It is a comparatively an accurate method

For our project we choose the Perturb and observe algorithm as it has more advantages. Here is the chart of P&O method's efficiency during various conditions.

Table 1: Efficiency during several conditions

Sky Conditions	Days of data	MPPT
Clear	20	98.7
Partially Cloudy	14	96.5
Cloudy	9	98.1
Overall	43	97.8
Total		99.3

3. Design Considerations

3.1 Basic Configuration of a Boost Converter

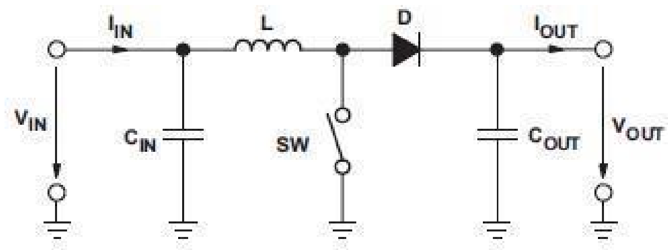

Figure 6: Boost converter [6]

3.1.1 Necessary Parameters of the Power Stage

The following parameters are needed to calculate the power stage:

$V_{IN(min)} = 9V$ and $V_{IN(max)} = 12V$

Nominal Output Voltage: $V_{OUT} = 24V$

Maximum Output Current:

$I_{OUT\,(max)} = \frac{P_{out}}{V_{out}} = 250/24 = 10.416$ A

Table 2: Buck converter output

Parameters	Simulation	Practical
Input Voltage	24 V	24 V
Input Current	3.663 A	2 A
Output Voltage	12.64 V	14.5 V
Output Current	6.32 A	3.5 A
Duty Cycle	55.6%	60%

4. Simulation

4.1 Boost Circuit

A boost converter (step-up converter) is a DC-to-DC power converter that steps up voltage (while stepping down current) from its input (supply) to its output (load). It is a class of switched-mode power supply (SMPS) containing at least two semiconductors (a diode and a transistor) and at least one energy storage element: a capacitor, inductor, or the two in combination. To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are normally added to such a converter's output (load-side filter) and input (supply-side filter).

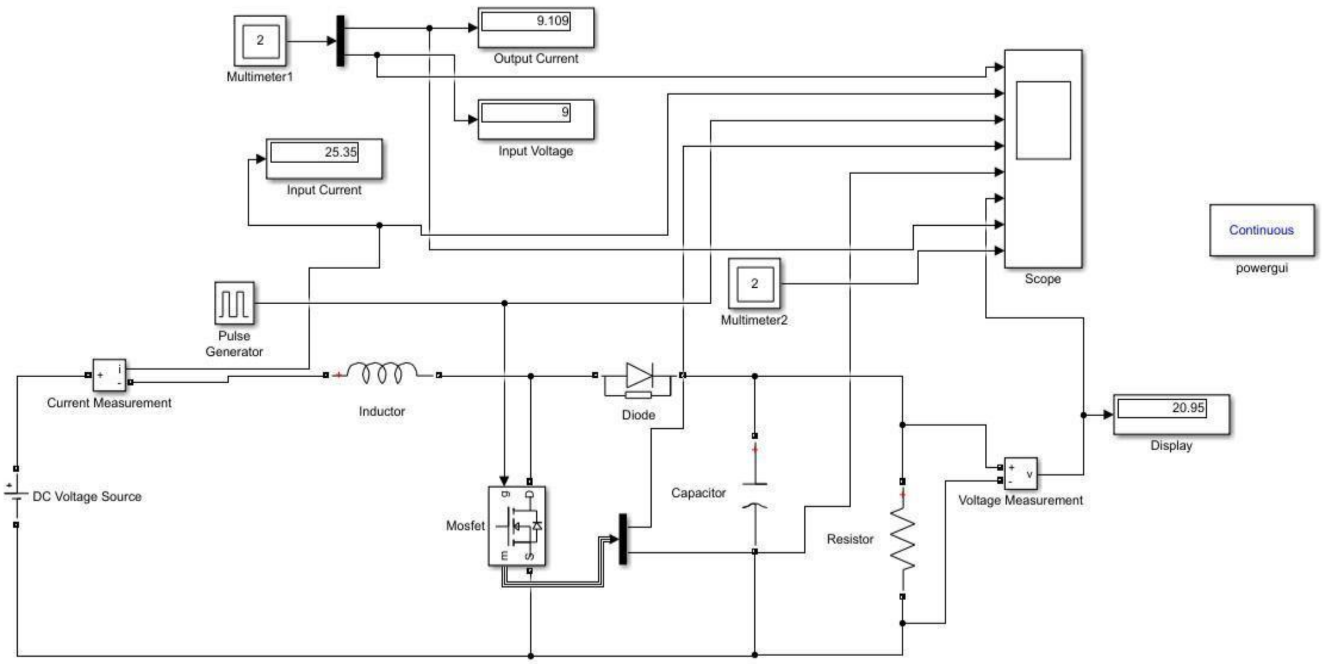

Figure 7: Simulation of Boost Circuit

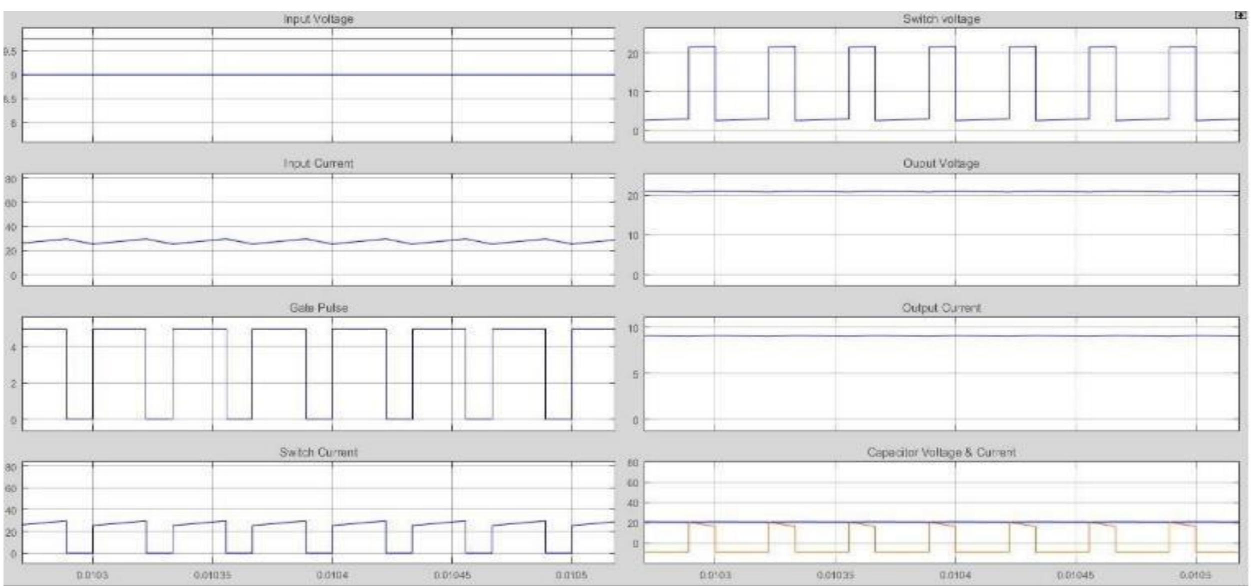

Figure 8: Waveform of the parameters of boost converter

4.2 Buck Circuit

A buck converter is a dc-dc converter. It takes a dc voltage at input. In output, it gives a dc voltage smaller than the input voltage. The magnitude of the output voltage can be controlled by a power semiconductor switch by controlling how much time the switch will be on. This time is called duty cycle, D. The output voltage is determined by = × The range of the value of duty cycle is 0 to 1.

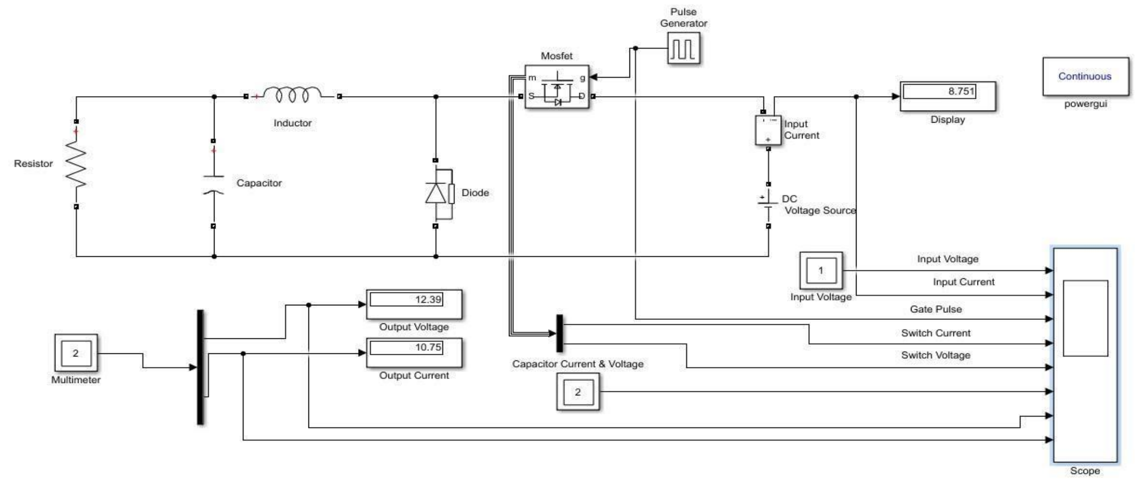

Figure 9: Simulation of Buck Circuit

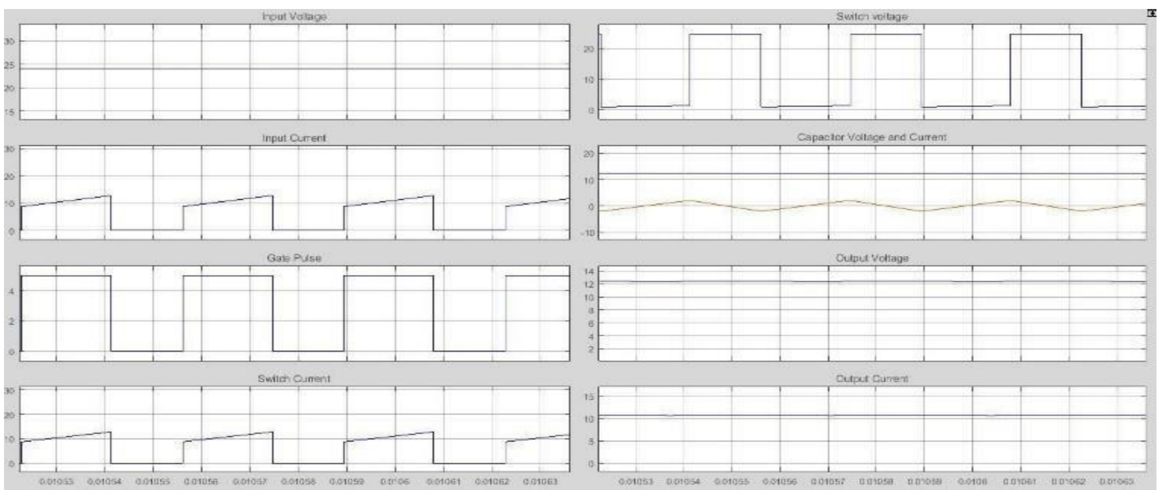

Figure 10: Waveform of the parameters of buck converter

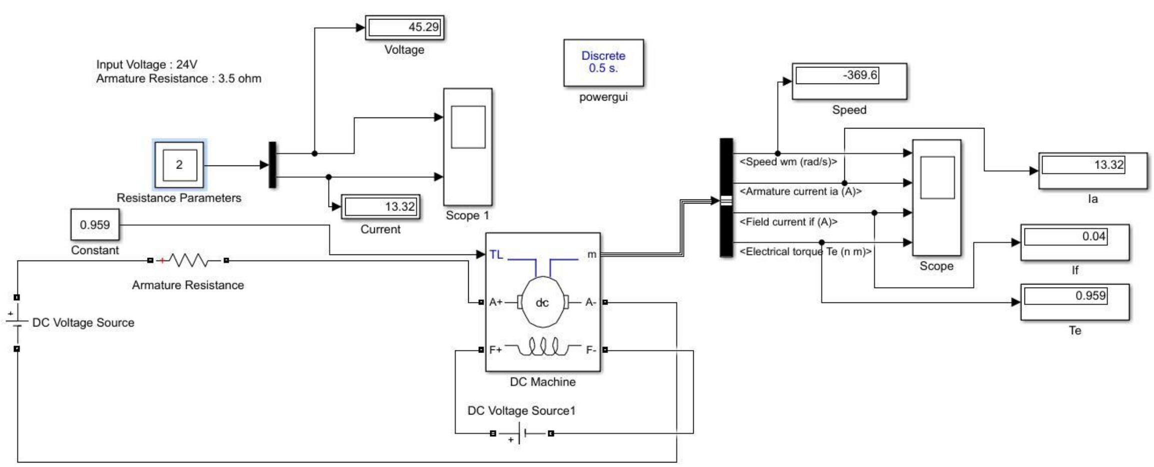

Figure 11: Simulation of DC Machine

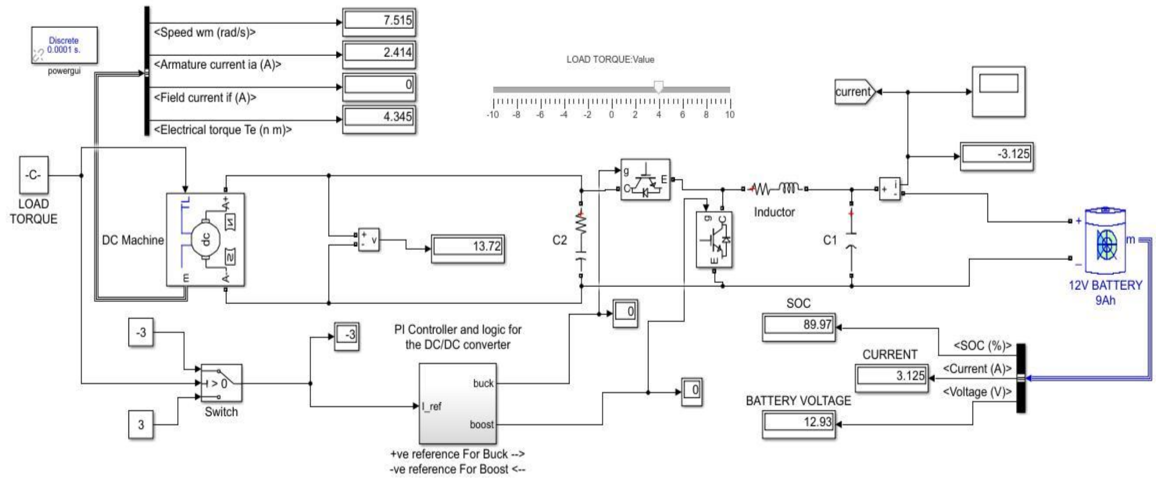

Figure 12: Battery to Motor Simulation

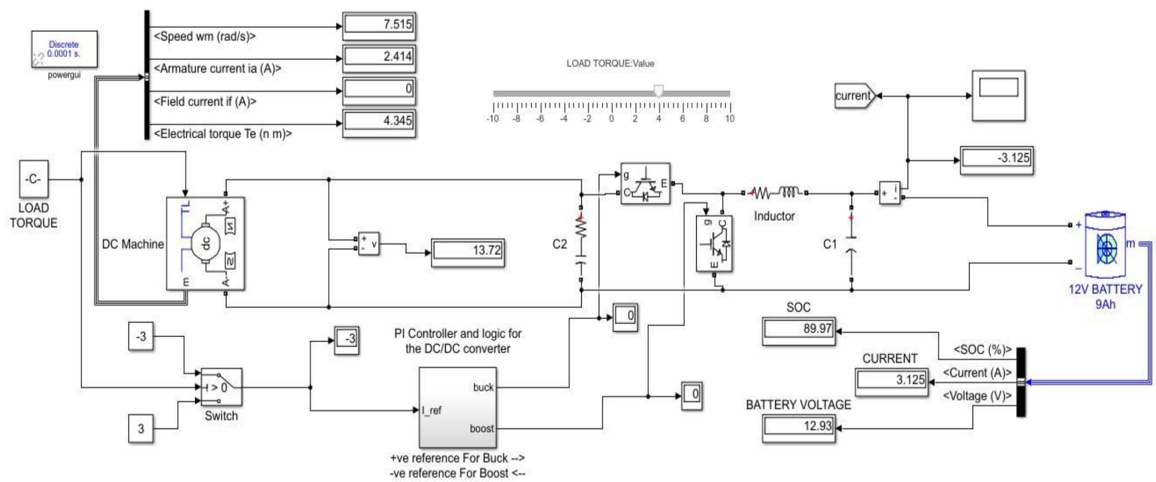

Figure 13: Simulation of Regenerative Braking

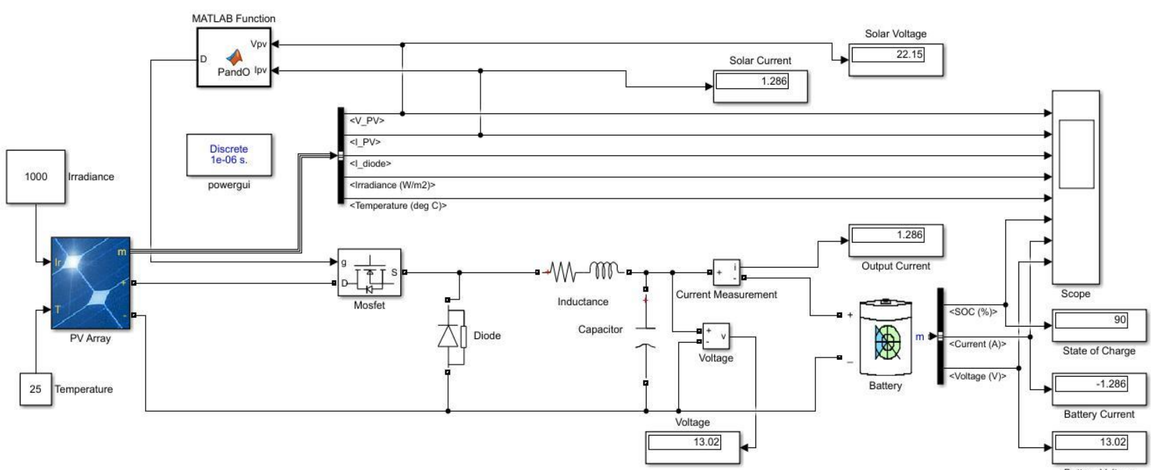

Figure 14: MPPT Simulation

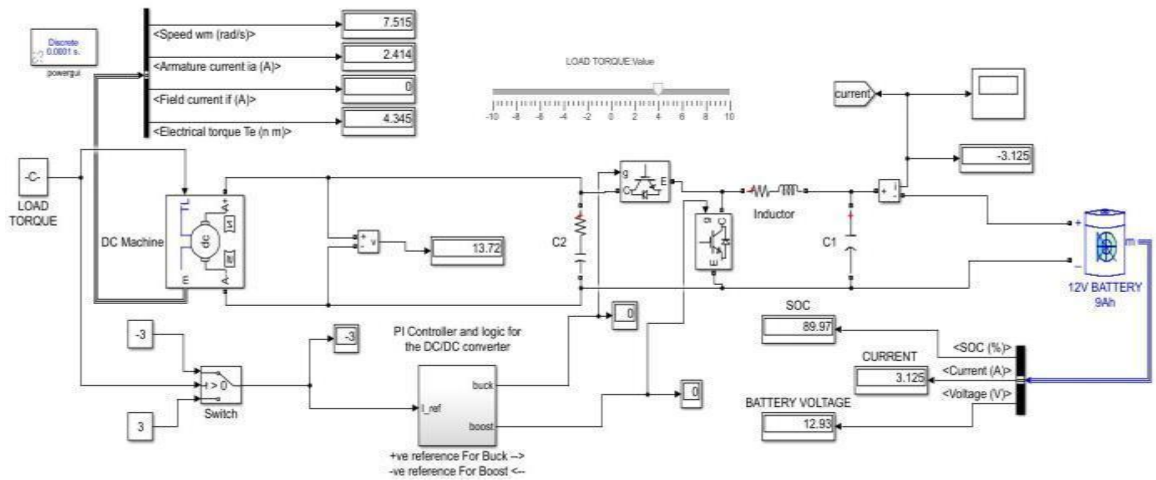

Figure 15: Power Drive Design

5. Conclusion

A maximum power point tracking algorithm that regulates the duty cycle of DC-DC Converter. In this way efficiency is always kept at its maximum during whole charging process. MATLAB Simulation of Bidirectional DC-DC Converter & DC Machine is shown here. As our aim was to design a system which can extract maximum output power, so we explained about maximum power point (MPP) and maximum power point tracker (MPPT). MPPT type of charging performs better even with varied intensity of sunlight and consequently, charge the battery efficiently and minimize the losses that happen in this process.

Bidirectional DC-DC Converter is used in this project to use the concept of regenerative braking while the converter input is battery and load is motor that time it acts as boost converter and during regenerative power flow is reversed from machine to battery the converter acts as a buck converter. So, it is possible by providing gate pulses which will be based on the reversal of armature current of the machine. Mathematical models for the buck and boost modes of the DC-DC converter are derived. Transient performances of the bidirectional DC-DC converter using the derived mathematical models are simulated in a MATLAB Simulink environment. It is observed that the current changes its direction quickly as the mode of operation changes without any overshoot of the values. Hence, the converter's voltage and current are stable in its operation in both directions. It was observed that the duty cycle for buck and boost operation must be greater than 50% to charge or transfer energy from one battery bank to machine.

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