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Solar PV-based electric vehicle battery charger using current control technique

[1]Siddiqui Sufeeyan Muzaffar, [2]Prof. Seema Narayan Kharat, [3]Prof. Chandra Obula Reddy

[1]Mtech Electrical Power System, [2]Assistant Professor, [3]HOD & Prof, Department of Electrical Engineering
[1]Electrical Power System,
[1]M.S.S College of Engineering, Jalna, India

Abstract: In this project, current controlled technique is used in Maximum power point tracking (MPPT) of the solar photovoltaic array to charge batteries of EV, within the safety limits and supported rating of batteries so that EV battery does not get damaged and can also increase the life of the battery. The battery is charged within the rated charging limit, under variable solar irradiance on MATLAB simulation. Charging batteries using solar photovoltaic has problems of its own as if a high output solar PV array is operating on MPPT conditions output of the solar PV is kept at the maximum power possible and when one EV battery is kept for charging it can damage the battery with very high charging current. The MPPT is used to operate the solar PV array so that maximum power can be extracted while it is in operation for these different algorithms such as NHS (Normal Harmonic Search) etc. is used. The proposed algorithm is highly robust and has good dynamic response. MATLAB/ SIMULINK based simulation study was conducted and subsequently, an experimental setup was developed to verify the effectiveness of the proposed method, and the results were compared with conventional PSO based MPPT algorithm, as well as the Perturb and Observe (P&O) MPPT method.

***Index Terms* – PV, NHS, MPPT, EV.**

I. INTRODUCTION

Following are the problems that are there in current Battery charging system and power generation system:

- Current power supply system is dependent on fossil fuels and is a major cause of pollution.
- Integrated Chargers have got AC supply. There is growing interest in low cost integrated supply which can be interfaced directly with DC power outlets.
- If we directly charge battery from the output of PV array then due to the varying charging current the life of battery is reduced and the efficiency is also compromised.

For the above-mentioned problems, this paper shows current controlled solar based battery charging system which nullifies these problems that are as follows:

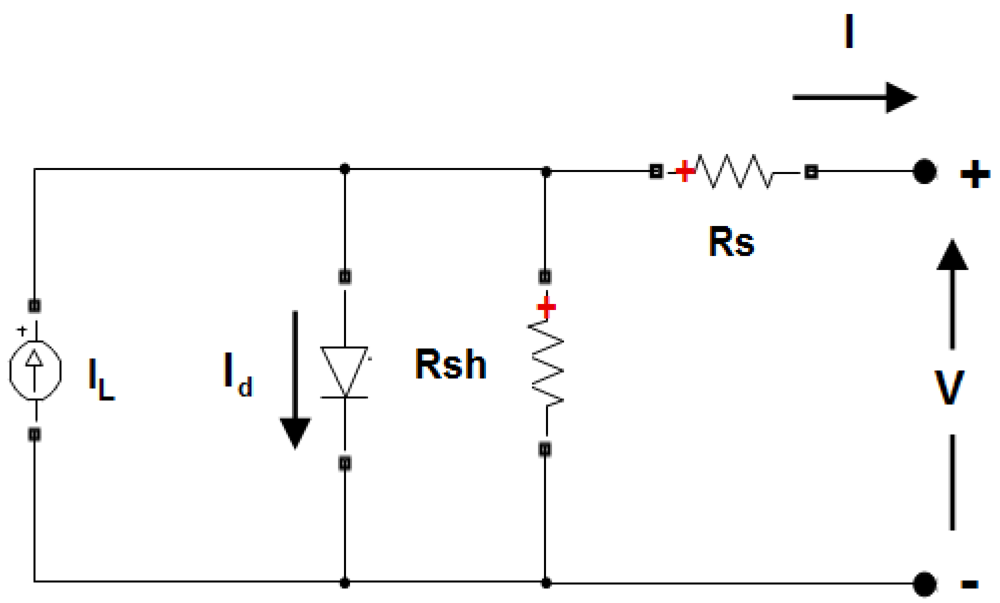
- This project considers PV panel because it is a clean source of energy and is not responsible for emission of carbon dioxide.
- This project considers electric vehicles to be charged from PV panel which provides DC output.

- This project shows a method to charge batteries with the help of current controlled device which will not only improve the battery life but also increase its efficiency.

1.1.PV Energy Generating Systems: Solar energy is radiation from the Sun having ability of producing heat, resulting in chemical reactions and generation of electricity. The total amount of solar energy incident on Earth is huge and capable of fulfilling the world's current and anticipated energy requirements. If efficiently harnessed, this highly available source has the potential to satisfy all future energy needs. Hence, we can utilize the potential of solar energy by studying it's essential character tics and properties.

1.2.Batteries: Batteries are the devices which are used to produce electrons through electrochemical reactions. Batteries contain positive (+) and negative (-) terminals. This device has one or more electrochemical cells used to transform stored chemical energy directly into electrical energy. There are two major classes of batteries, one is primary batteries and the other is secondary batteries. The first ones are non-rechargeable which are used only ones and then abandoned because they cannot be recharged again. The secondary type can be recharged after they have been used. The main purpose of batteries is to store electrical energy and supply it whenever required.

1.3.MPPT: It is a device which is used to maximize the power output of a solar photovoltaic system abbreviated as maximum power point tracker. Basically, it is a DC-DC converter which efficiently utilizes simulation logic and produces one of the most efficient ways of PV generating system. The working principle of an MPPT is rather simple. As the amount of sunlight (Irradiance) incident on a solar panel is varying throughout the day making the panel voltage and current fluctuating. So we need to get the maximum power out of the PV array, for this we need an MPPT which sweeps through the panel voltage to find the percussion center or the best amalgamation of PV voltage and PV current to generate the maximum power.



1.1 PV Array Circuit

II. LITERATURE SURVEY:

In 1749, "Benjamin Franklin" a polymath and founding father of united states was the first to use the term "BATTERY" to describe a set of linked capacitors he used for his experiments with electricity. However, in 1800, "Alessandro Volta" an Italian physicist and chemist has invented the first true battery which came to be known as "Voltaic pile "In 1836, "John Frederic Daniell" a British chemist invented the "Daniell cell" and it became the first practical source of electricity. In 1859, "Gaston Planté" a french physicist invented the lead acid battery, the first ever battery that could be recharged by passing a reverse current through it. In 1899, "Waldemar Jungner" a Swedish scientist invented the "nickel–cadmium battery". The nickel–hydrogen battery entered the market as an energy-storage subsystem for commercial communication satellites. The first consumer grade "nickel–metal hydride" batteries (NiMH) for smaller applications appeared on the market in 1989 as a variation of the 1970s nickel–hydrogen battery. In 1981, a chemists team from japan were the first who invented the lithium ion battery.

III. SYSTEM DEVELOPMENT:

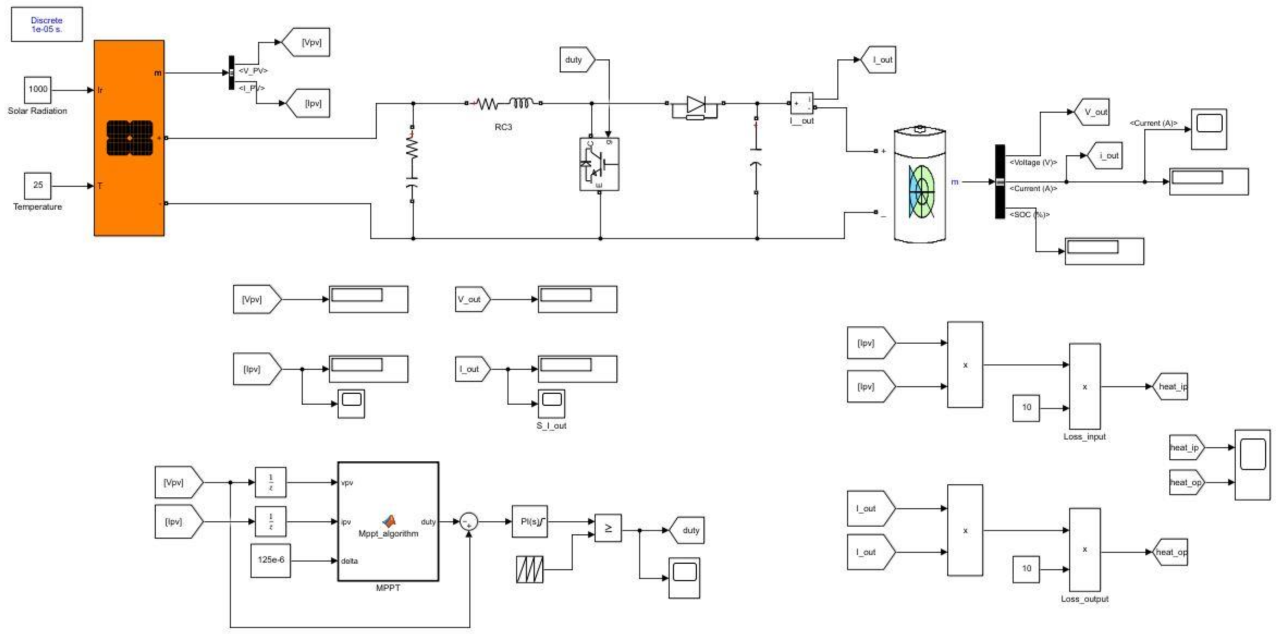


Fig 3.1: MATLAB Simulation of Whole System

The Figure 3.1 shows the complete simulation diagram of the system in MATLAB. It can be divided into following blocks:

1. PV Solar Generating System
2. Battery system
3. MPPT

1. PV Solar Generating System:

Whole PV system was developed and simulated in MATLAB as shown in Figure 3.1. Firstly, it has PV array block which simulates PV panels and we can provide values such as irradiance and temperature to simulate its behavior. Photovoltaic solar panels are of individual PV cells connected all together, then this Solar Photovoltaic Array is also known as a Solar Array is a system. In MATLAB the photo voltaic array block can be found out at Simscape / Electrical / Specialized Power Systems / Sources library. The photo voltaic array implements an array of PV modules. This is made up of strings of modules connected in parallel, each string consists of modules in series. This block will allow you to model PV modules from the National Renewable Energy Laboratory (NREL) System Advisor Model (2018) as well as modules that you define. The PV Array block is having five-parameter model current source (I_L), diode, series resistance (Rs), and shunt resistance (Rsh) to represent the irradiance- and temperature-dependent I-V characteristics of the modules.

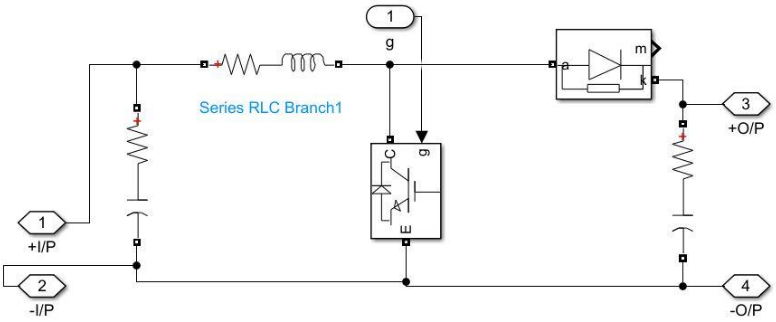


Figure 3.2: Boost converter

As seen in Figure 3.2, the boost converter is having IGBT in parallel to which gate signal is given through MPPT. MPPT is used to track the maximum point thus maximizing the power output of the system. Perturb and Observe Method is implemented in MPPT through code given in Figure 3.3.

```
function duty = Mppt_algorithm (vpv,ipv,delta)
duty_init = 0.05;
duty_min = 0;
duty_max = 0.75;
persistent Vold Pold duty_old;
if isempty(Vold)
    Vold = 0;
    Pold = 0;
    duty_old=duty_init;
end
P= vpv*ipv;
dV= vpv - Vold;
dP= P - Pold;
if dP ~=0 && vpv>60
    if dP<0
        if dV < 0
            duty = duty_old - delta;
        else
            duty = duty_old + delta;
        end
    else
        if dV < 0
            duty = duty_old + delta;
        else
            duty = duty_old - delta;
        end
    end
else
    duty = duty_old;
end
```

Figure 3.3: MPPT Code in MATLAB

2. Battery System:

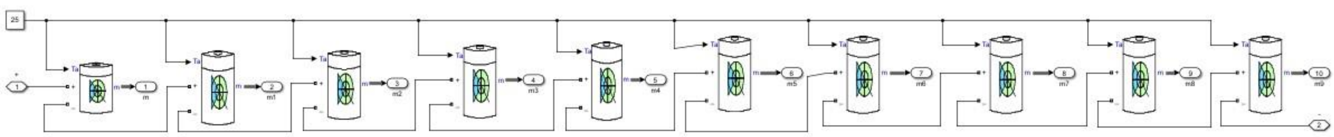


Figure 3.4: Series battery connection in MATLAB

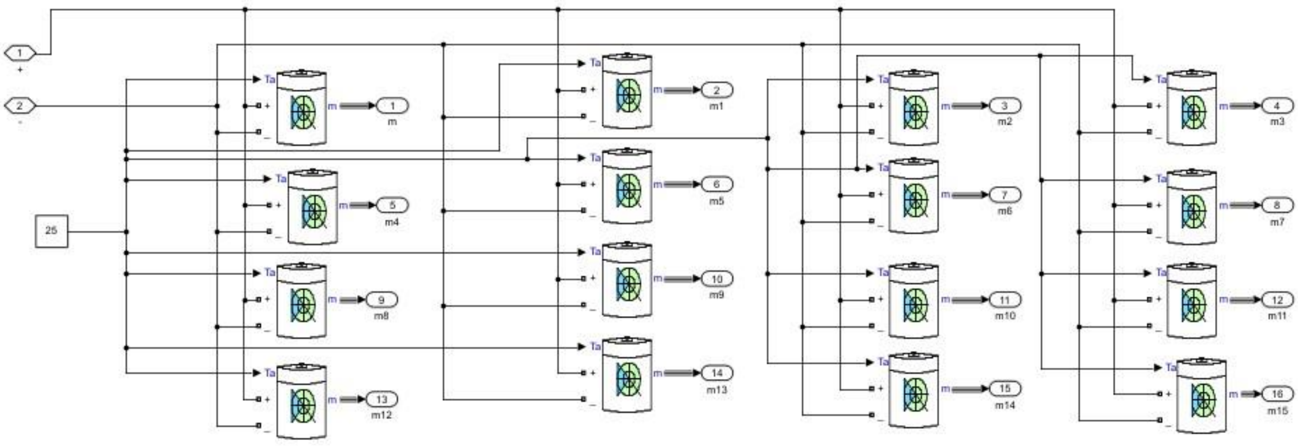


Figure 3.5: Parallel battery connection in MATLAB

There are two types of connections possible in forming battery packs, series connection and parallel connection. Both methods of connecting have their own advantages and disadvantages that's why some global organizations prefer series and some prefer parallel. But nowadays there is new trend evolving which utilizes the advantages of both the connection strategies. So we will use both the connections in this simulation.

The output of PV system will be given to battery packs connected in series and parallel, for the series connection of batteries the overall emf will be given by,

$$E = E_1 + E_2 + E_3 + E_4 + \dots\dots\dots + E_n$$

If the emf of each cell is identical, then the emf of the battery combined by n numbers of cells connected in parallel is equal to the emf of each cell. The properties of the battery are taken as follows,

Type: Lithium-Ion

Nominal voltage (V): 12.6

Rated capacity (Ah): 40

Initial state-of-charge (%): 45

Battery response time (s): 1

IV. MATLAB RESULTS AND DISCUSSION:

A photovoltaic array is the complete power-generating unit, consisting of any number of PV modules and panels. In this proposed system we have used 1 Parallel strings having 12 series connected module per string. The Module data has been kept as user defined with following properties.

- Maximum Power (W): 213.15
- Cells per module (Ncell): 60
- Open circuit voltage Voc (V): 36.3
- Short-Circuit Current Isc (A): 7.84
- Voltage at maximum power point Vmm (V): 29
- Current at maximum power point Imp (A): 7.35
- Temperature coefficient of Voc (%/deg.C): -0.36099
- Temperature coefficient of Isc (%/deg.C): 0.102

The above values are taken as per the current business standards and trends. Because this will make the simulation more relevant to current market scenario and this ultimately serve the purpose of this project.

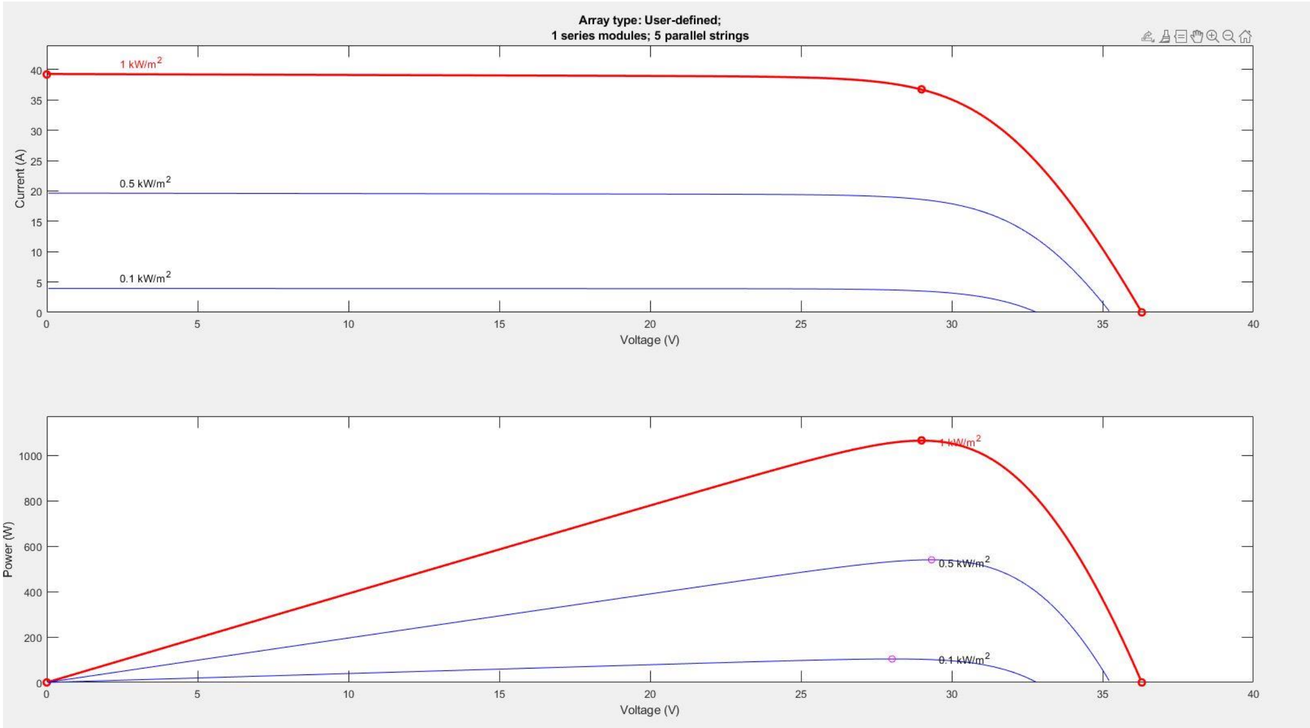


Figure 4.1: PV array plot from MATLAB

After taking the shown values we have got the PV array plot from MATLAB as shown in fig 4.1, We have got this plot for different values of irradiances and for our user defined configuration of 12 series module with 1 parallel strings. With the help of the PV array plot we can easily understand what will be the maximum power for a particular value of irradiance. To Understand this more easily we can look at fig 4.1. and derive that what will be the maximum power value for different values of irradiances and the values that we have obtained are as shown in table 4.1.

Table 4.1: Irradiance Power Table

Value of Irradiance (W/m2)	Maximum Power (W)
1000	1065
500	539
100	103

The table 4.1 shows different power values for different irradiances. With the help of this we can easily predict the value of maximum power obtained for a particular irradiance. In this simulation we have kept the value of irradiance constant at 1000 for which we will try to achieve the power around 1000 W with the help of current control technique. Similarly, we can also confirm the authenticity of this PV array plot by changing the value of irradiance to 500. As seen in the table 4.1, the value of maximum power for 500 irradiance will be almost half of the previous value of power which was 1065 W and now it is 539 W. Exactly identical to this we will have the value of power at irradiance 100, for this the power will be 103 W.

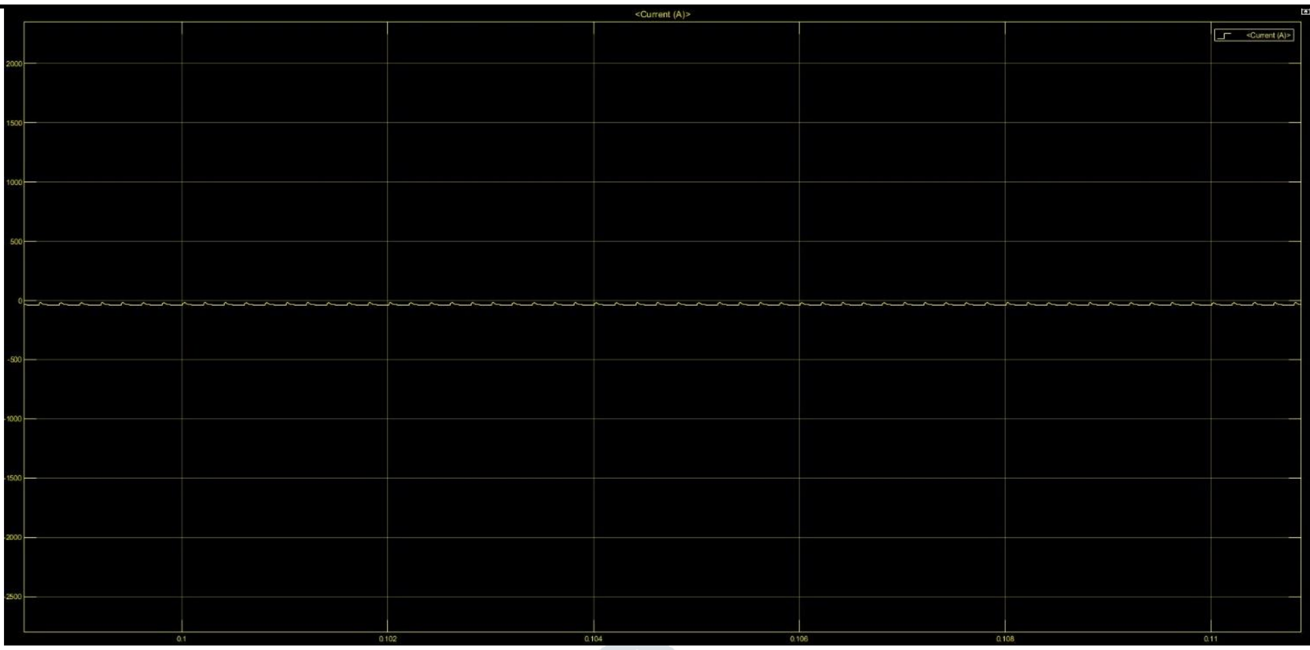


Figure 4.2: Battery Current

The main purpose of the project is to control the current of the PV output and give it to battery. So as described above the configuration of the PV array, this PV array is given a constant irradiance of 1000 w/m2 and temperature of 25 deg.C. The figure 5.5 shows the output of PV array which is given to a boost converter. DC-DC converters are also known as Choppers. A Step-Up Chopper or Boost converter which increases the input DC voltage to a specified DC output voltage. The input voltage source is connected to an inductor. The solid-state device which operates as a switch is connected across the source. The second switch used is a diode.

The inductor connected to input source leads to a constant input current, and thus the Boost converter is seen as the constant current input source. And the load can be seen as a constant voltage source. The controlled switch is turned on and off by using Pulse Width Modulation (PWM). PWM can be time-based or frequency based. Frequency-based modulation has disadvantages like a wide range of frequencies to achieve the desired control of the switch which in turn will give the desired output voltage. Time-based Modulation is mostly used for DC-DC converters. It is simple to construct and use. The frequency remains constant in this type of PWM modulation. The Boost converter has two modes of operation. The first mode is when the switch is on and conducting.

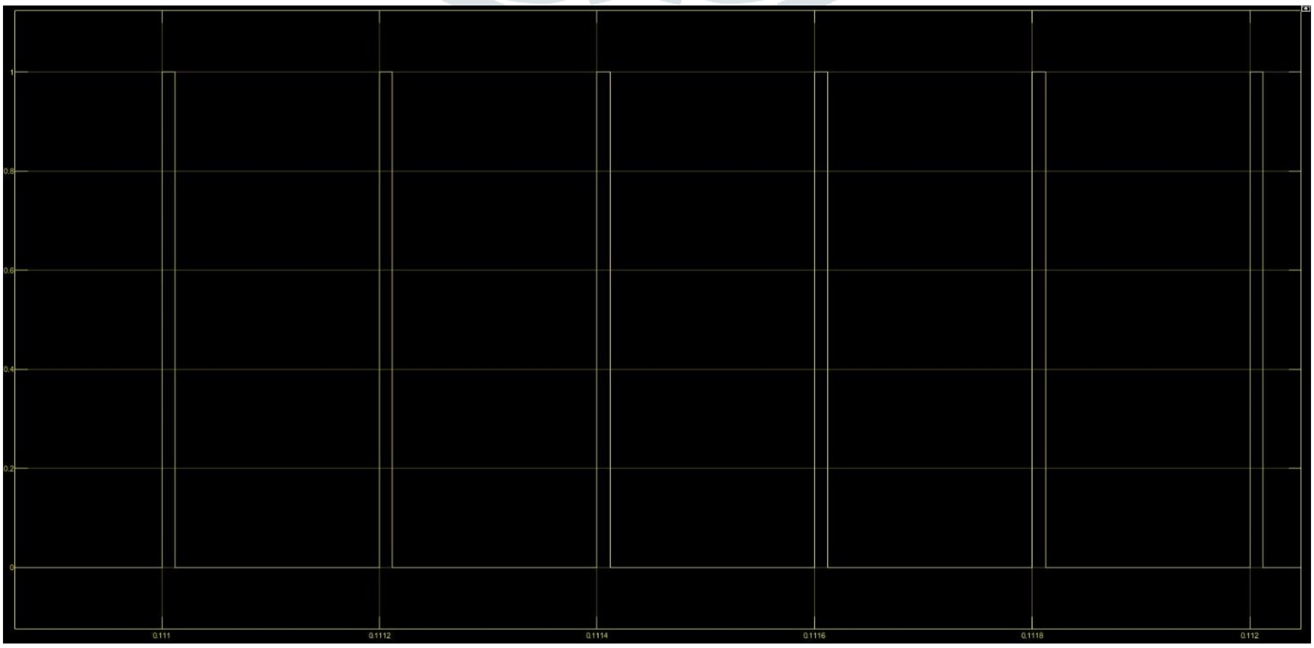


Figure 4.3: Gate Pulse Given To IGBT

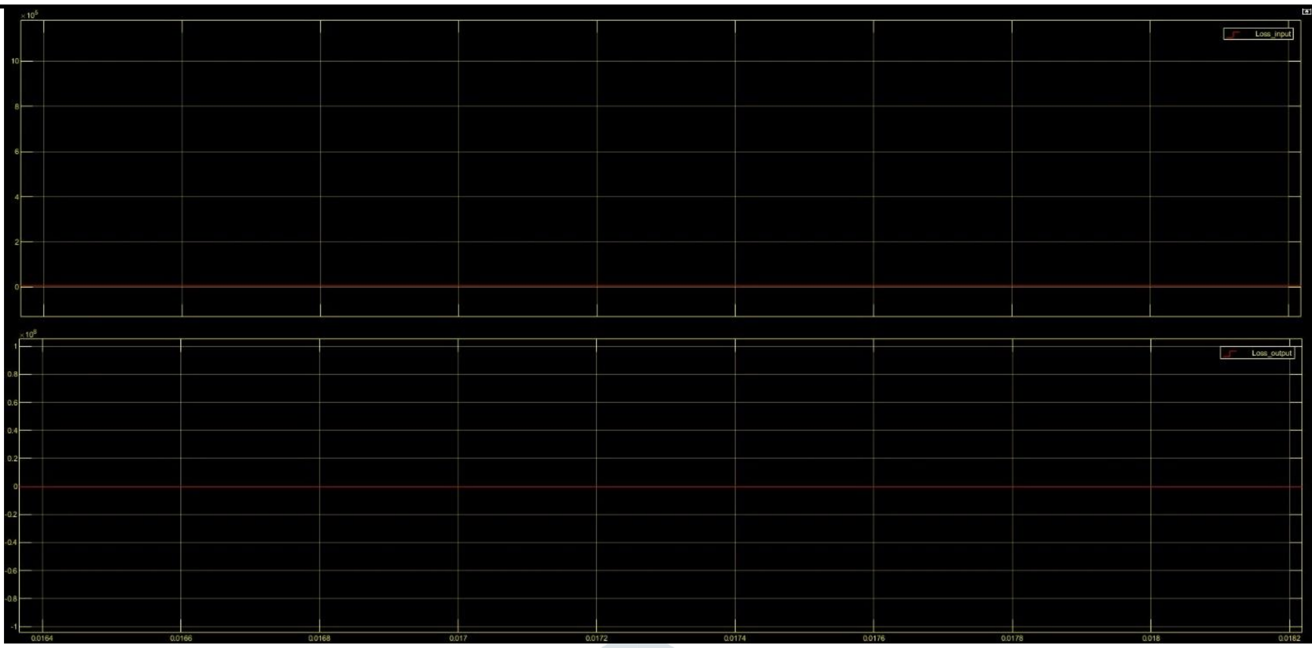


Figure 4.4: Heat

The figure 4.5 shows the output of boost converter obtained with MPPT current control technique which is a rippled DC output. This output is controlled through an MPPT controller which acts as a current controller in this study. An MPPT, or maximum power point tracker is an electronic DC to DC converter that optimizes the match between the solar array (PV panels), and the battery bank or utility grid. To put it simply, they convert a higher voltage DC output from solar panels (and a few wind generators) down to the lower voltage needed to charge batteries. Through MPPT the gate pulse is given to IGBT. The Insulated Gate Bipolar Transistor also called an IGBT for short, is something of a cross between a conventional Bipolar Junction Transistor, (BJT) and a Field Effect Transistor, (MOSFET) making it ideal as a semiconductor switching device.

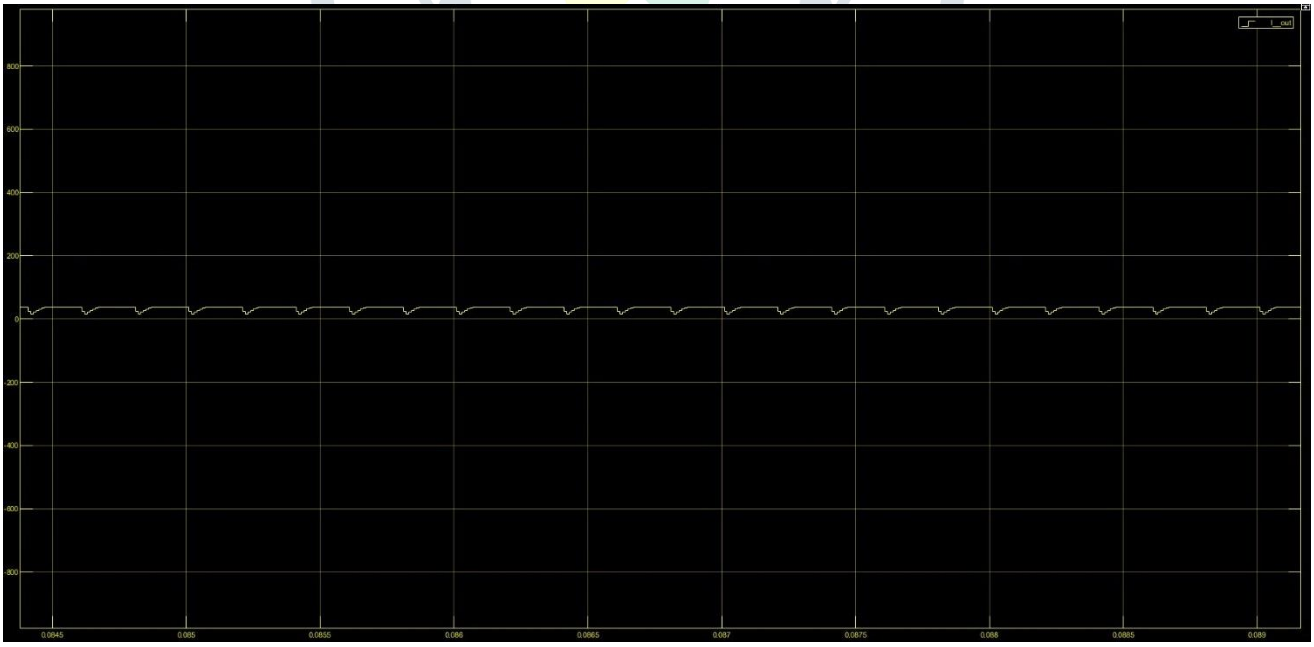


Figure 4.5: Output Current Of Boost Converter

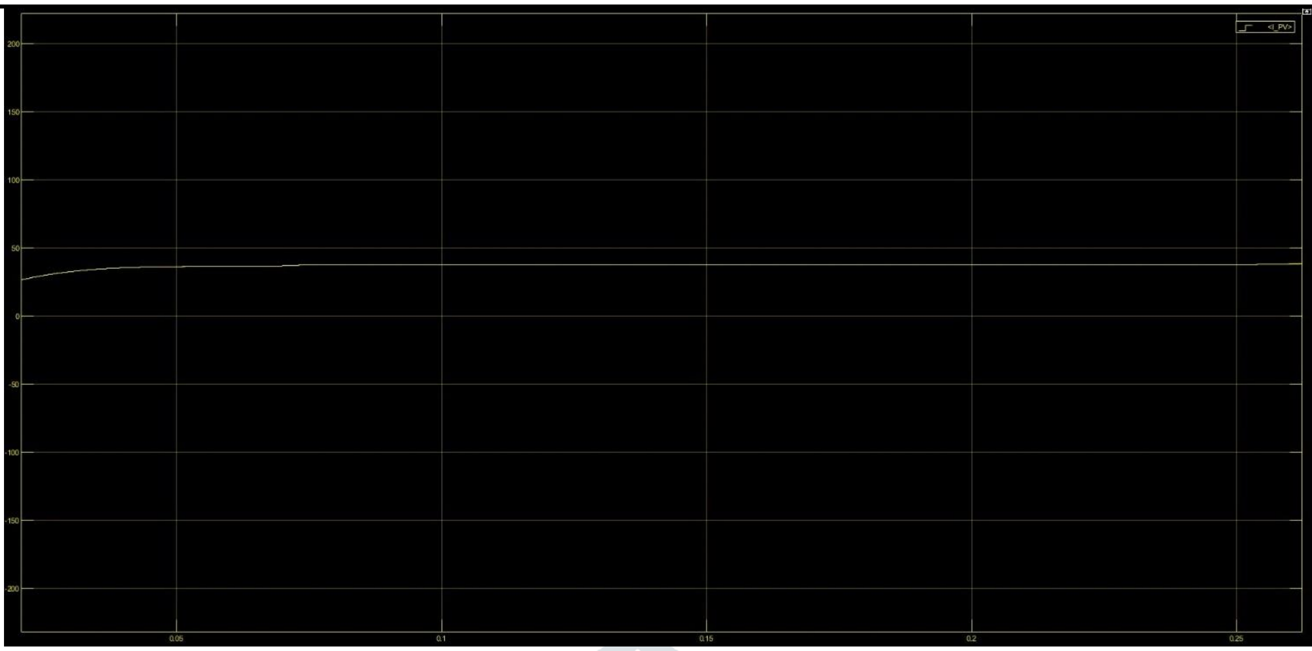


Figure 4.6: Output Current Of PV Array

The IGBT Transistor takes the best parts of these two types of common transistors, the high input impedance and high switching speeds of a MOSFET with the low saturation voltage of a bipolar transistor, and combines them together to produce another type of transistor switching device that is capable of handling large collector-emitter currents with virtually zero gate current drive. The figure 5.2 shows the gate pulse given to IGBT.

V. CONCLUSION

Charging batteries using solar photovoltaic has problems of its own as if a high output solar PV array is operating on MPPT conditions. Output of the solar PV is kept at the maximum power possible and when one EV battery is kept for charging it can damage the battery with very high charging current. Current controlled strategy will be used in Maximum power point tracking (MPPT) of the solar photovoltaic array to charge vehicle lithium-ion batteries within the safety limits and supported rating of batteries so that EV battery does not get damaged and can also increase the life of the battery. The MPPT has been used to operate the solar PV array so that maximum power can be extracted while it is in operation. The proposed method of current-controlled Maximum power point tracking of the solar photovoltaic array for charging batteries has been implemented and simulated using MATLAB Simulink and steady charging current under the specified limit was maintained by proposed strategy during the simulation of the system.

VI. ACKNOWLEDGMENT

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