CAREER EPISODE 1

EFFICIENT SOLAR POWER GENERATION USING A P&O ALGORITHM-BASED MPPT TECHNIQUE

INTRODUCTION

CE 1.1

The project mentioned in this career episode happened when I was student of BS Electrical Engineering at [redacted]. This was a semester project under the title "Efficient solar power generation using a P&O algorithm based MPPT technique". I worked on this project in seventh semester of my degree for one of my courses on Renewable Energy Systems (EL408). After acquiring enough knowledge in this subject, I began working on this project in [redacted] and completed it in [redacted] under the direction of my professor.

BACKGROUND

CE 1.2.1

Considering the increase in electricity demand and changes in the atmospheric conditions like global warming, there was a need of an alternating source of energy which is low in cost and practical. RE refers to the type of energy derived from resources which are naturally replenished like sun, wind, rain and other inherent resources. These resources have ability to naturally recharge; thus, they are considered as infinite. One of RE source is Photovoltaic (PV) effect which is most important due to its easy and abundant availability. Solar energy is dependent on the weather conditions that is why it varies continuously. The output from the PV modules are dependent on the solar radiation and the temperature of the cell. In this project I implemented a PV system with generalized PV panel. I have considered MATLB/Simulink for the implementation of the design.

CE 1.2.2

I started this project by first searching for the comparable projects and research papers on the topic. I also read books with detail of this topic. This was a very vast topic; however, I was able to extract all the useful information as per my requirement which also saved time as it was a semester project and I had very less time to complete this project. It was difficult to work on this project without having complete information that is why I divided the most part of my

project for literature review. This helped me as things seemed simpler and easier due to my knowledge on the topic. I organized my project which helped me in managing my time more effectively and I achieved my goals.

CE 1.2.3

I had detailed discussions with my professor to get feedback on my ideas and work which was in progress. This helped me in maximizing my productivity, achieving my goal, and developing my skills and expertise. I did this project in a group of two members and learned to share responsibilities, work through conflicts, and communicate with each other. I divided and assigned tasks to my group member for effective and timely completion of the project. I also did documentation related to my project. I began with writing a project proposal for giving my professor idea of my work. Later, I also prepared a project report with defined objectives of my project, project plan, literature review and results. At the end of my semester, I presented my project to my fellow students and my professor. I used my expertise in power point for making this presentation in order to make it more effective and engaging.

PROJECT REPORTING HIERARCHY

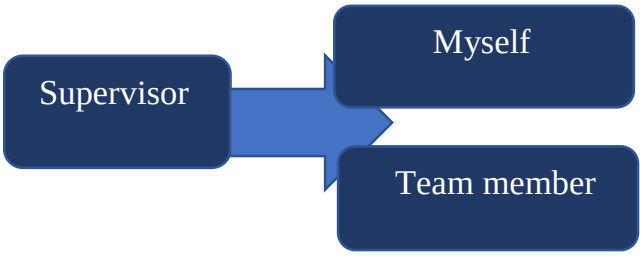

Figure 1 Hierarchy

PERSONAL ENGINEERING ACTIVITY

CE 1.3.1

The continuous increase in electricity demand and the changes in atmospheric conditions required a source of energy which was not only cheaper but practical as well. PV effects is one of the most important RE source due to its abundant and easy availability. PV system consists of PV panel whose parameters can be adjusted according to the choice. In this project I implemented a DC to DC converter using MPPT controller to improve the PV panel system performance. According to the results I obtained it was concluded that performance of a PV array can be significantly improved by implementing MPPT techniques for the case of sudden fluctuations in solar radiation, temperature, and fluctuating power demand. I analyzed different loads connected to PV system and then synchronized the output form a 3-phae inverter to the grid with the help of the feedback system.

CE 1.3.2

After conducting a cost analysis and evaluating the market prices, I determined that using solar power was the most viable option. As, solar power was RE source and sunlight is available abundantly. I used PV array which is a device used for conversion of solar energy to electricity using PV effect. This PV cell converted solar energy to voltage and current, and delivered it to the load. Each cell produced 0.5V. I used a combination of both parallel and series connected cells to produce a PV module. And then combined these PV modules to form a PV array. For high voltage demand PV modules were arranged in series and for high current demands they were arranged in parallel.

CE 1.3.3

I used MPPT algorithm for extraction of best amount of power from the PV module. I used P&O techniques in this project for getting max power from the PV array. Output of this controller was given in form of input to DC to DC converter by means of a duty cycle. DC to DC converter was used to transform one level of voltage to the other. DC to DC converter works by storing the energy for short time and then releasing it in different values of voltage and current for output. I also used an inverter for transforming the DC power to AC power. I adjusted frequency of AC power by using transistor switching, gates and timers.

CE 1.3.4

I also included synchronization of grid and 3-phase inverter via feedback system with the help of PLL and SVPWM techniques. I did all this literature before starting my project to have better understanding of the concepts involved. On the basis of that I chose and applied my techniques. There are many methods used for connecting the solar panels, but it was important to choose the suitable type of converter interface for PV system. This selection was based on many factors including cost, converter configuration and efficiency. For selection purpose two approaches are used; Single stage which involves connection of PV array to grid using DC to DC inverter. The other is dual stage which involves transformation from DC to DC converter and from DC to AC inverter for interfacing the PV to grid. However, in this project I used dual stage configuration.

CE 1.3.5

I connected PV to DC to DC converter and linked it to the load. The output from the MPPT controller was the converter's input. Afterwards, I used DC to AC inverter which is 3-phase inverter for injecting AC current to the load. Modelling of PV array in this project included Curves current- voltage characteristics of PV panel which were nonlinear curves and were totally dependent on the temperature and solar radiance. Next was the modelling of the PV cell, which consisted of current source which I then connected parallelly to diode, parallel and a series resistor. I used these resistors to show the leakage current. Series resistor I used showed the internal losses which occurred due to the current flow.

CE 1.3.6

The two main factors responsible for the performance of PV cells were temperature and solar radiance. Here I calculated the final output current by subtracting the current from diode from the photo current. I included the behavior of PV with the help of equation.

$$I = I_{PV} - I_D$$

I also calculated the V-I characteristics of a diode. I modified the equation by using an ideality factor A, which represented the various mechanisms responsible in moving the charge carriers across the junction.

CE 1.3.7

Next goal was to model the PV array, I used BPMSX120 in this project for modelling of PV. This module was consisted of 72 PV cells which were connected in series and generated an optimal power of around 120 Watt. I took general parameter values of BPMSX120 from a datasheet. I also calculated the number of modules that were linked in series and parallel with the help of a formula. After this I calculated Current & voltage of PV.

CE 1.3.8

DC to DC converter was a main part of MPPT system. There are two types of DC to DC converter available; one is buck converter where input voltage has higher value than the voltage value of output and the other one is a boost converter where input voltage has value less than voltage value of output. From equation of buck-converter which relates the input and output voltage it was noted that when duty cycle was varied the output voltage also varied with it resulting in change in input current. Similarly, change in duty cycle also changed the output current. It was also seen that the impedance varied with the duty cycle as well.

CE 1.3.9

I used this property of converter of impedance changing in MPPT. I used buck converter for this case as output voltage was required to be less than the input voltage. The second type which is boost converter, adjusting the duty cycle resulted in a change in the output voltage, ensuring that it always remained higher than the input voltage. Here I found out that boost converter was better than the buck converter. In boost converter both input and output currents were continuous whereas in buck converter input current was inconsistent.

CE 1.3.10

From the current-voltage and voltage-power characteristic curve of PV, I observed that there existed a point where solar power was max. Voltage and current at this point were also max. I concluded that for a PV system to get max efficiency it must be operated at this point. I used MPPT algorithm for max extraction of power. There were various MPPT methods based on cost, complexity, speed etc. The most common techniques I read during my literature review were, FSCC method and FOCV method. These approaches were cheap and easy in implementation, however, there was excessive loss of power. Another technique was perturb & observe algorithm (P&O) it was basically a trial and error technique. When operating point was on left pf the MPP, increase in voltage increased the power and when the power decreased

the voltage decreased with it. Whereas, when operating point on the right of MPP the case was reverse.

CE 1.3.11

Here, I concluded that the next change must be in same direction when power increases in order to achieve MPP. However, if power is decreasing next change have to be reversed. I realized this procedure in MPPT controller for obtaining optimal power from PV. I plotted the output power against the PV voltage at given radiance. This procedure was unsuccessful when the radiations were changing rapidly. When the radiance increased quickly, the system moved away from the MPP. In order to avoid this, I used an upgraded P&O method by reducing perturbation size, step size and improving sampling rate.

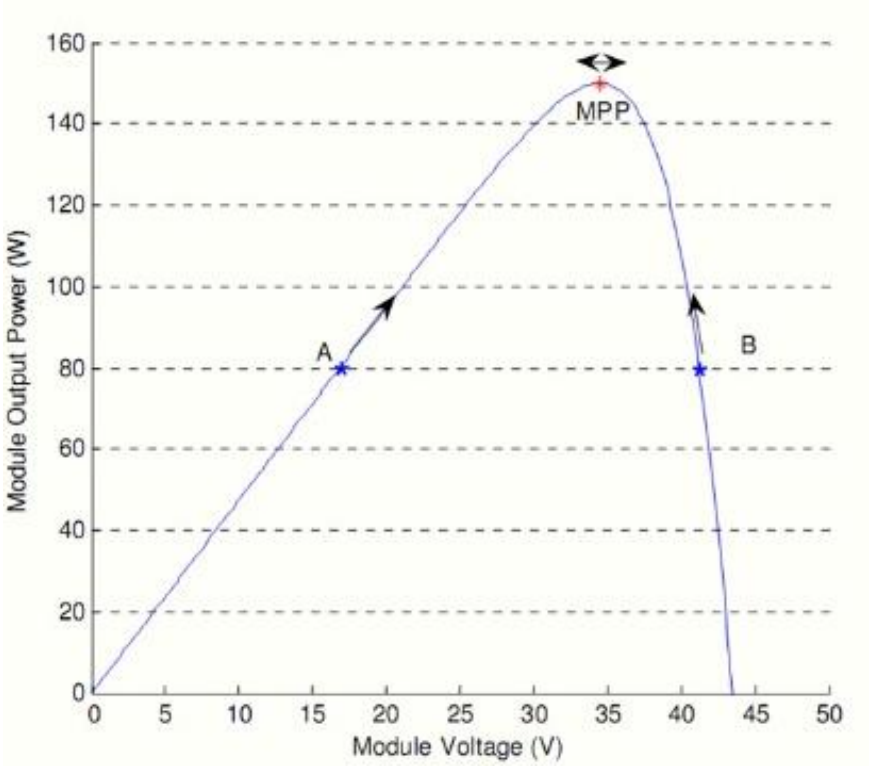

Figure 2 Graph Power versus Voltage for P&O Algorithm

CE 1.3.12

This algorithm started by reading values of current and voltages of PV. Then I calculated power from these measured values. MPP controller's output which was duty cycle was calculated by sign of power. In simulation, used control variable of DC to DC converter was the duty ratio. At first, I measured current and voltage values of PV array and after that calculated power. I related this value of power then with the preceding power value. I increased the duty cycle when difference between these was positive.

CE 1.3.13

I used MATLAB for modelling of PV system. The inputs of solar PV panel were temperature and solar radiance. I created a mask to make a generalized model of PV. I used boost converter along with the PV model to find the MPP. This modelling of PV enabled me to have different characteristics graphs including current- voltage and power-voltage curves for different values of temperature and solar radiance. I used PV current as input for this model. The output voltage changed with change in PV current. For simulation of MPPT system, I implemented DC to DC buck-boost converter. PV voltage was given as input to this converter. The controller I used provided the switching commands for IGBT block.

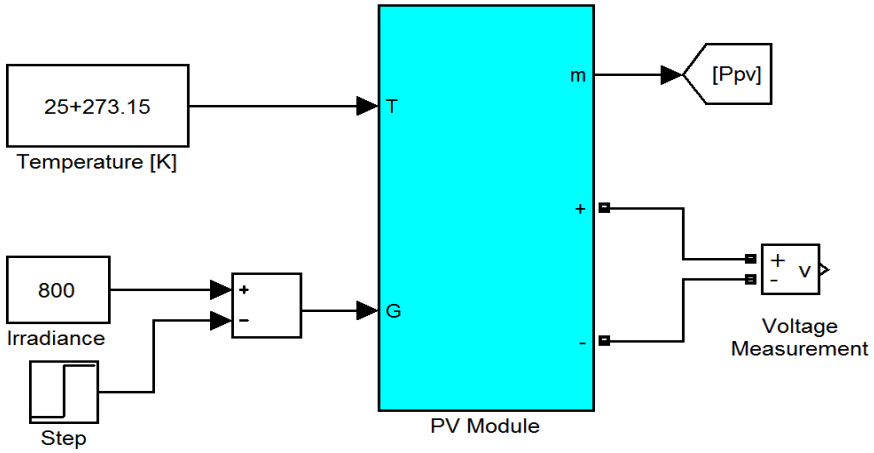

Figure 3 Block diagram of PV module

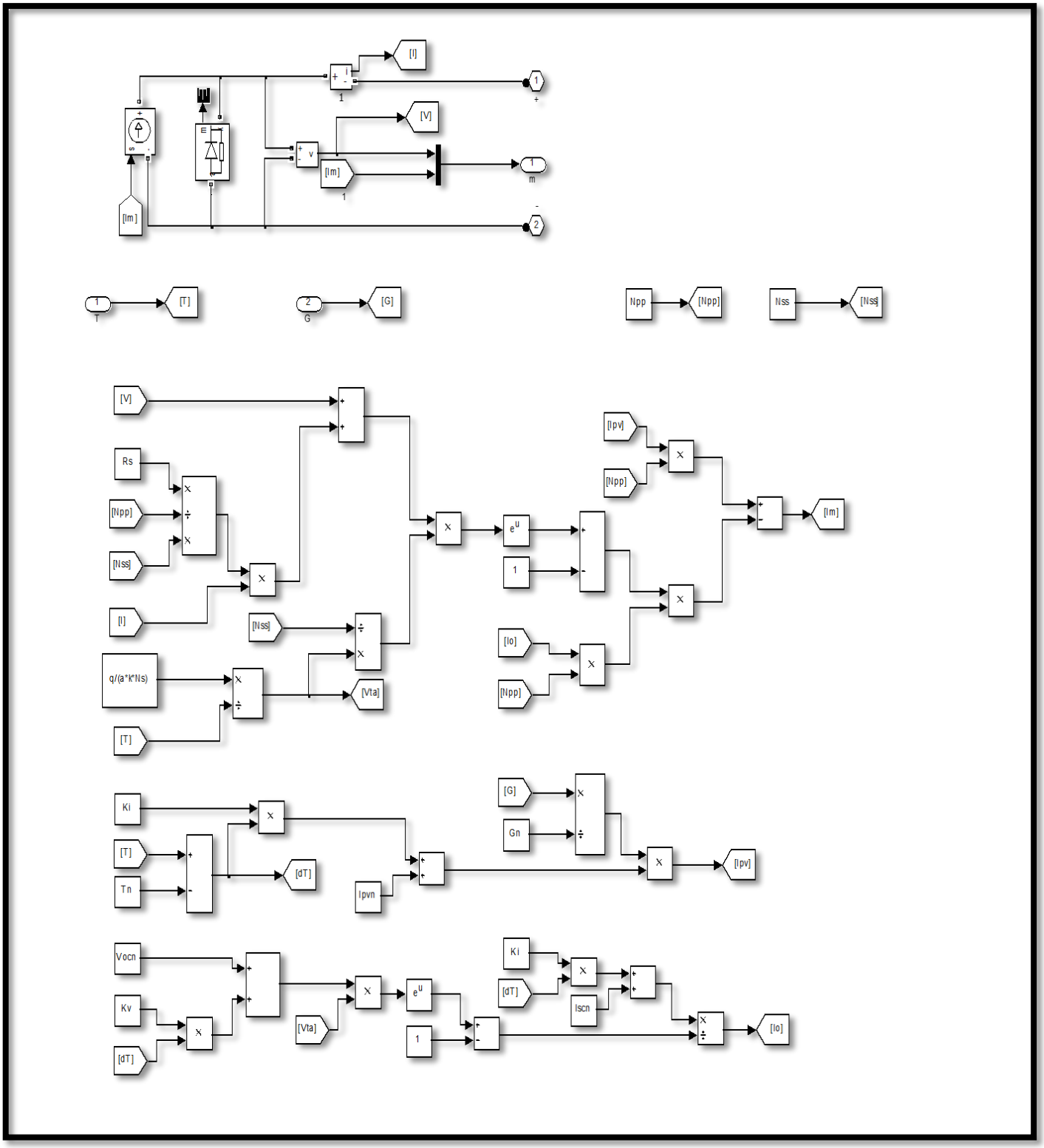

Figure 4 model under the mask of PV array

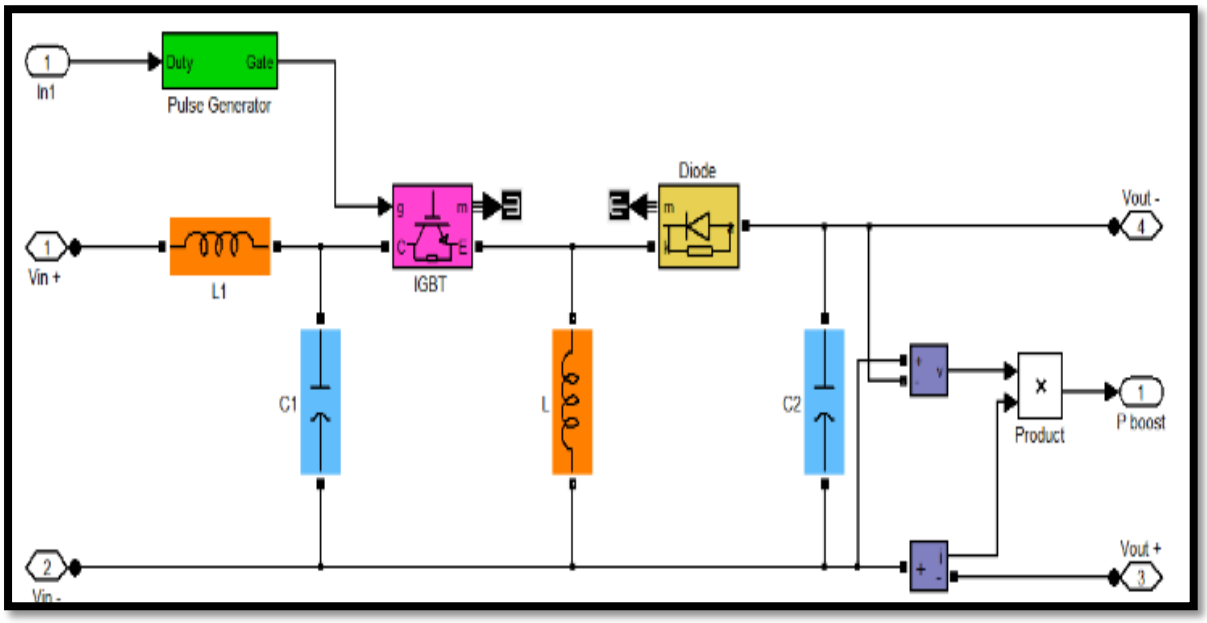

Figure 5 DC to DC converter

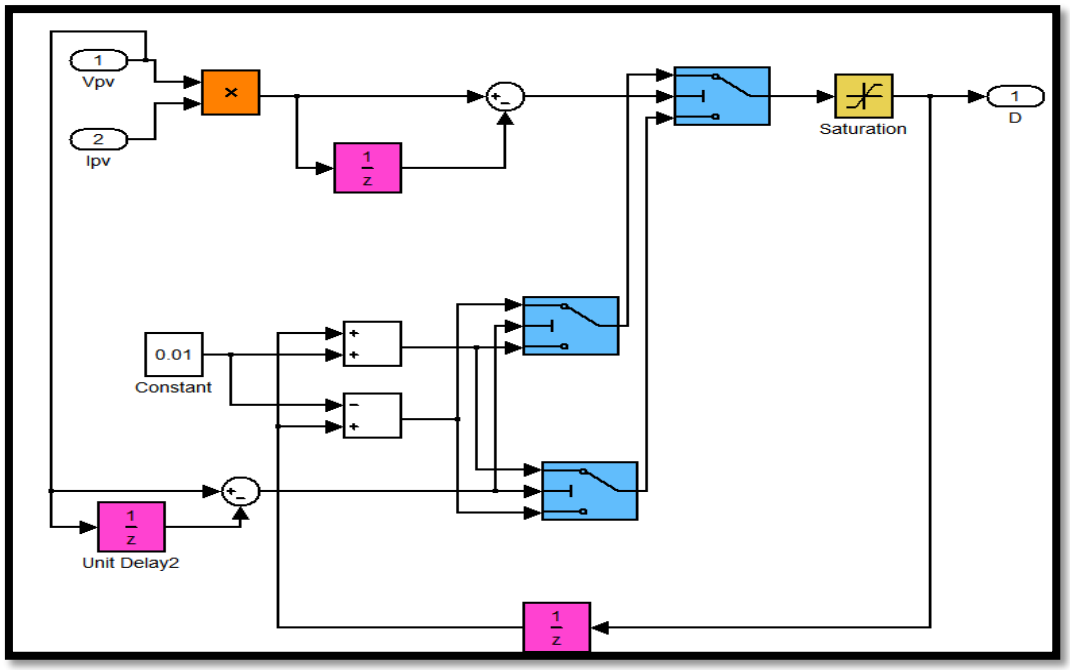

Figure 6 P&O controller mode

CE 1.3.14

I used MPPT block whose input was the output from PV which were current and voltage. Duty cycle was the output of this MPPT block which I used further to provided switching frequency for the converter. Duty cycle was used to determine the efficiency and accuracy of the P&O

controller. I also included simulation model of 3-phase inverter. I used pulse generator block from Simulink in order to generate the PWM signal. This simulated model I implemented was accurate as the characteristics of both current and voltage were same as in the data sheet.

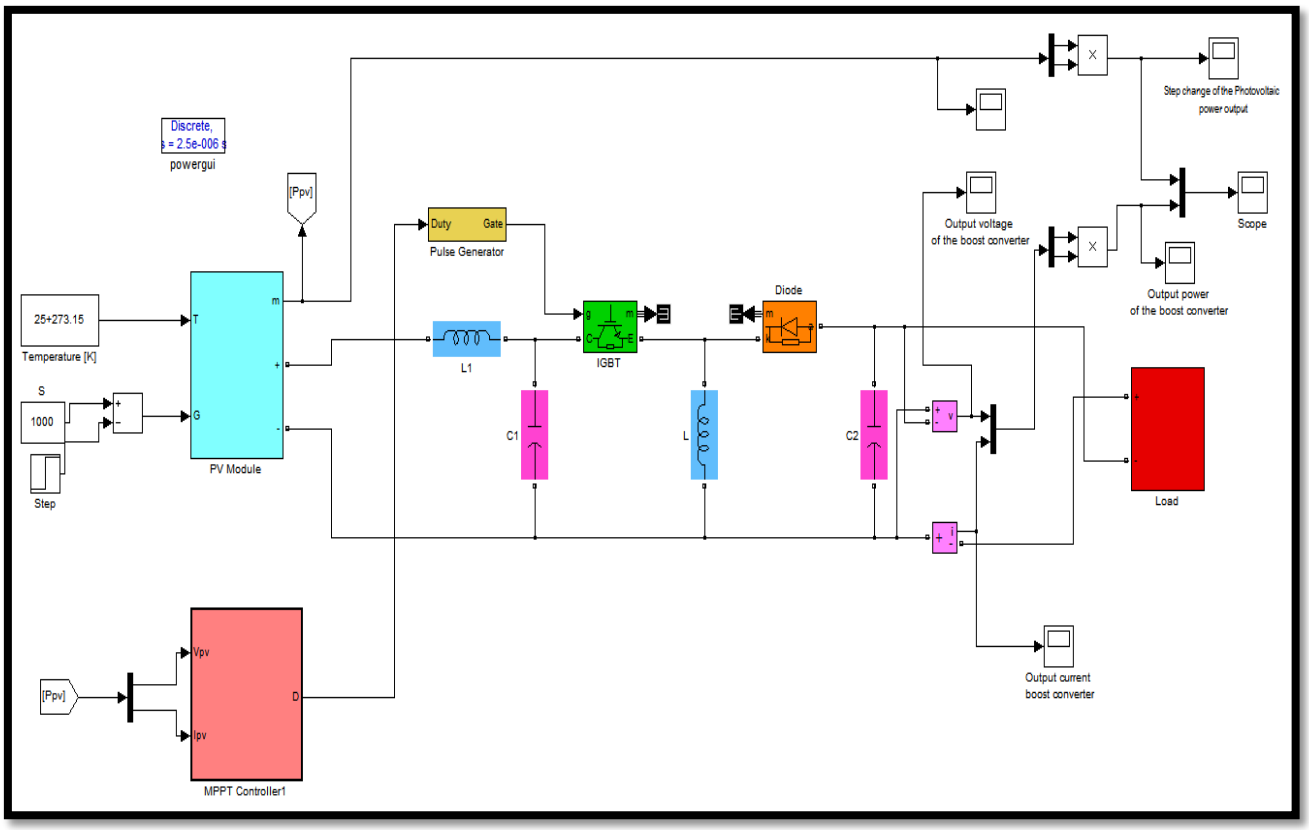

Figure 7 PV system and P&O controller

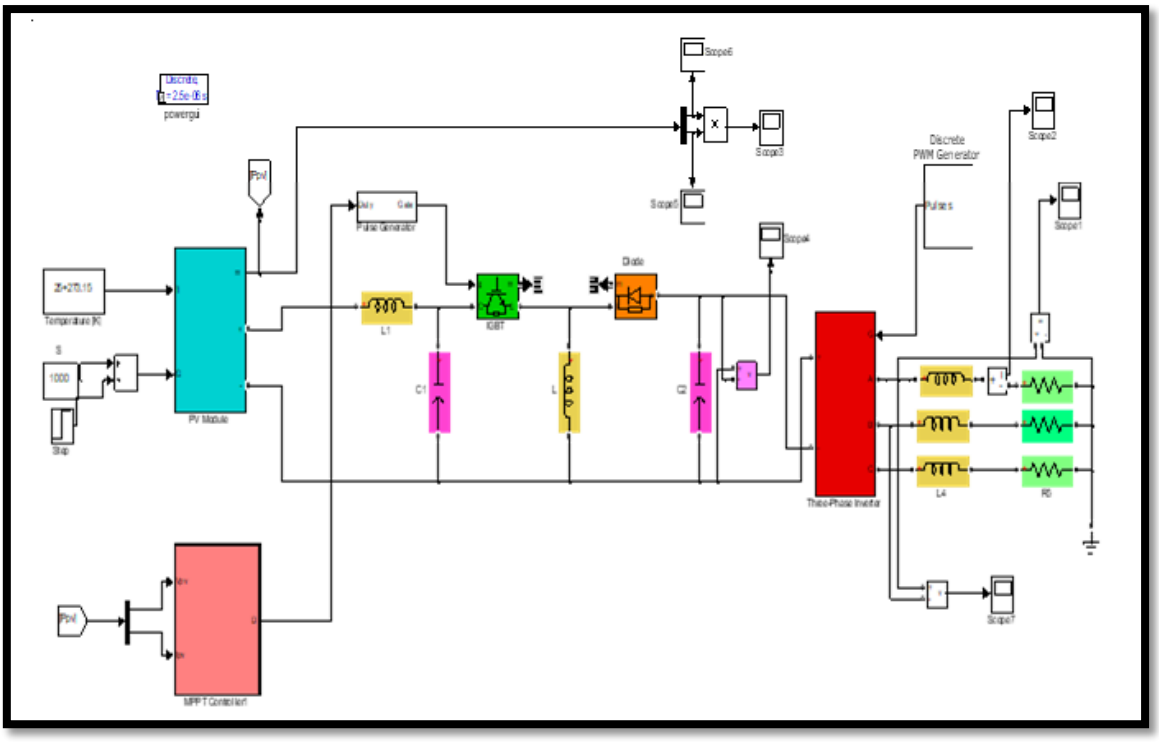

Figure 8 PV system model with 3-phase inverter

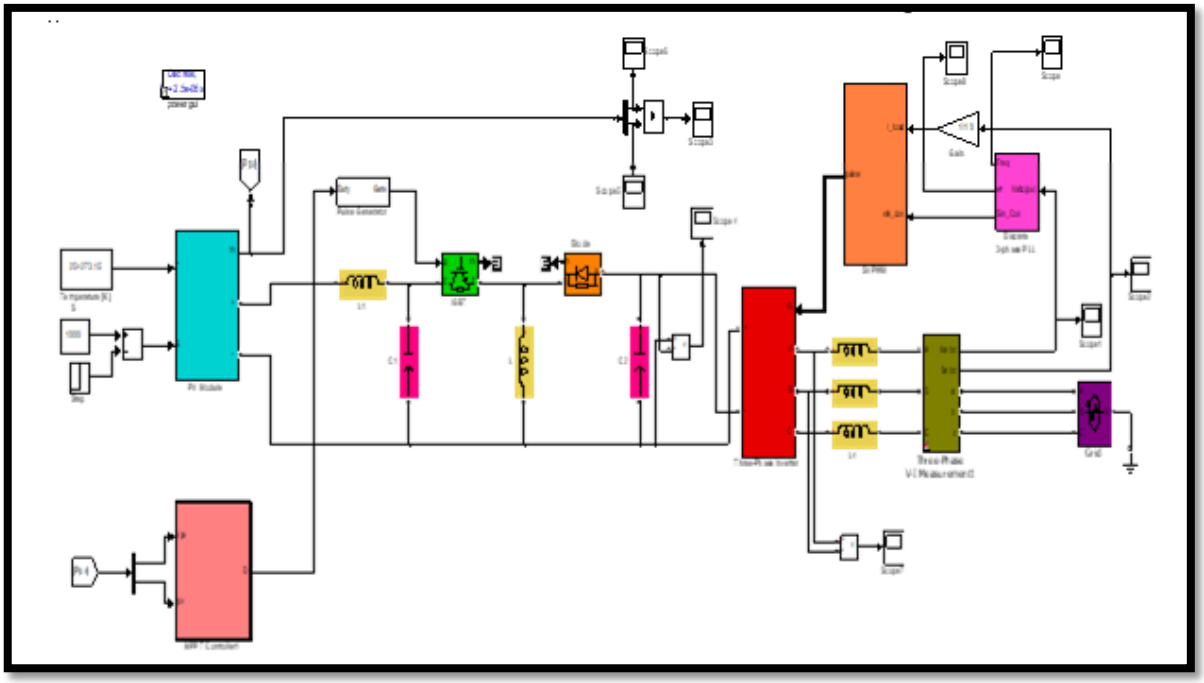

Figure 9 PV system model synchronization circuit

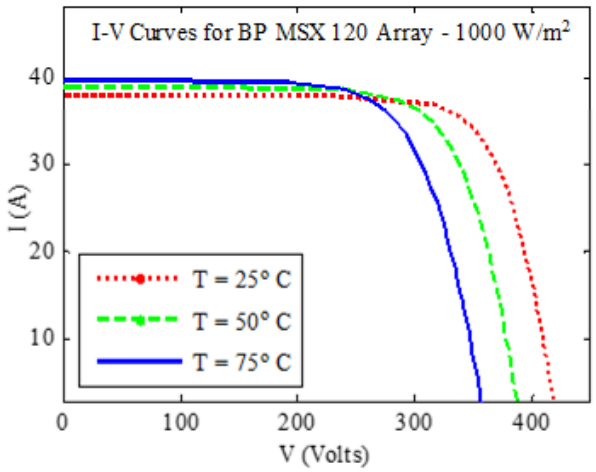

Figure 10 (I-V characteristics with temperature variation)

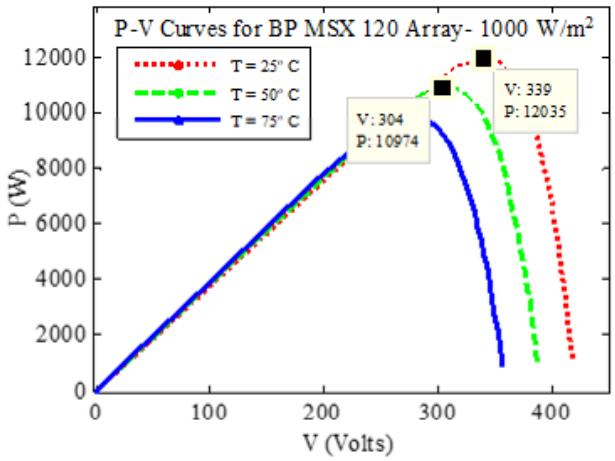

Figure 11 (P-V characteristics with temperature variation)

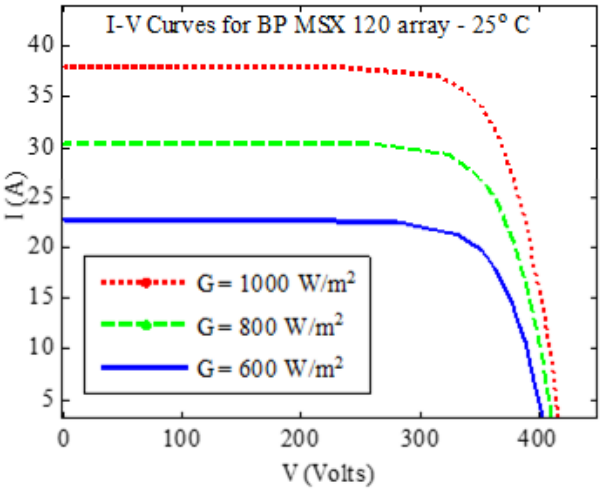

Figure 12 I-V characteristics of PV (at various irradiance)

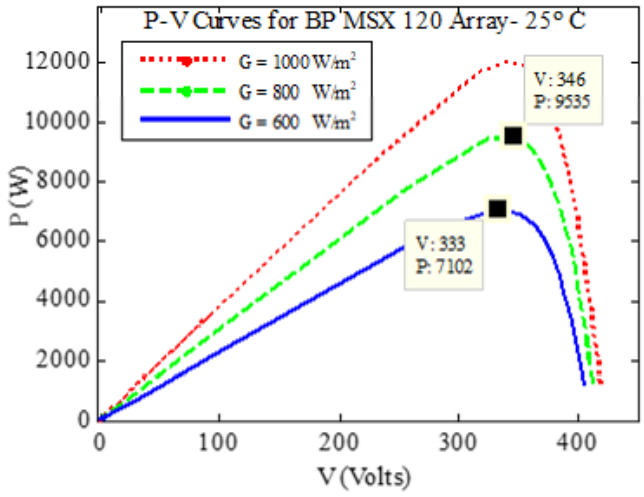

Figure 13 P-V characteristics of PV (at various irradiance).

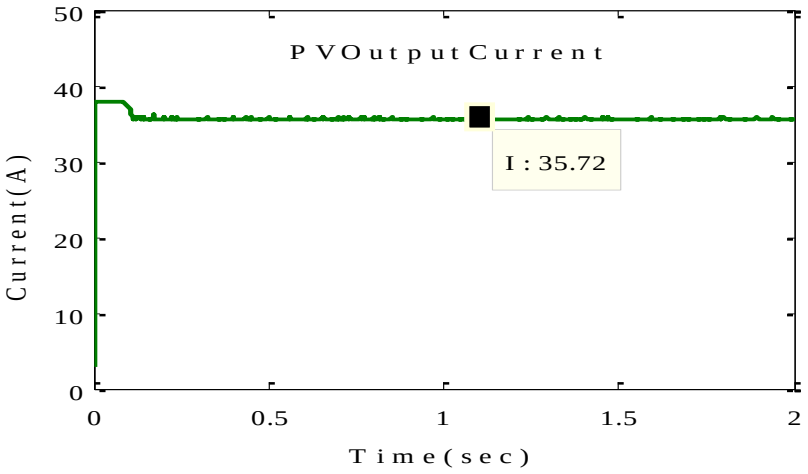

Figure 14 PV output current

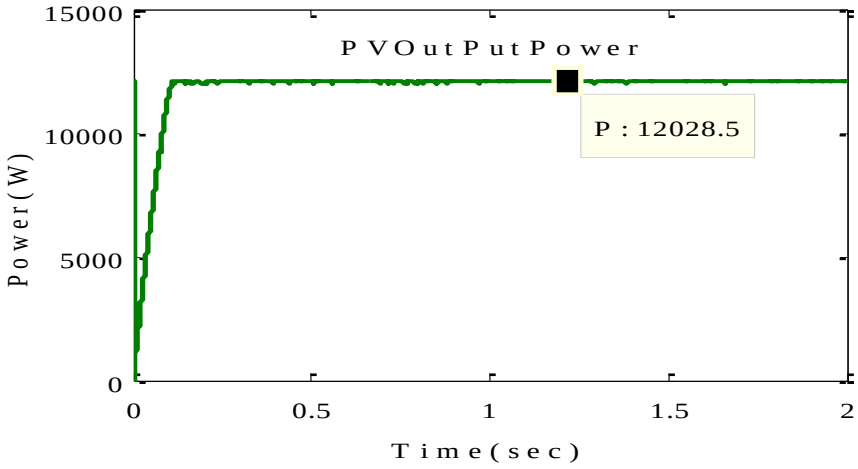

Figure 15 PV output power

SUMMARY

CE 1.4.1

I deigned a generalized PV panel system having MPPT, DC to DC converter and a pure resistive load. The system I proposed was simulated using Simulink. I also developed a mathematical model of PV system. The simulation of PV array BPMSX120 array showed that simulation was accurate. Then I conducted analysis of PV array using a boost converter subject to frequent variations in temperature as well as solar radiance. Simulation results showed that output power, voltage and current of PV panel varries with the variation in temperature as well as solar radiance. This variation in load did not impact the PV array output. This deigned P&O system based on MPPT algorithm was able to track the MPP of the PV under varying weather conditions. This model I proposed was successful in synchronizing the grid with PV model. At the end after successful completion of my project, I was able to understand various solar energy systems, MPPT techniques and experience of both hardware and software.