

# COMPUTER AIDED DESIGN FOR A PV SYSTEM AND INVESTIGATION OF 3 PHASE THYRISTOR CONVERTER

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**ABSTRACT-** In order to deal with this project we must clearly be cognizant of photovoltaic systems and thyristor converter of three phases. The photovoltaic cell is a device which converts sunlight into direct electricity with the help of semiconductor materials. The output efficiency of photovoltaic cell is tremendously growing to its peak and the sun's radiation consists of tiny particles called photons. These photons strike directly on the photovoltaic (PV) cell as they are incident on the surface and as a result the free electrons get excited and generate electricity directly. Most of the photovoltaic systems follow maximum power point tracking (MPPT) principle whereas this principle is used to obtain maximum power from solar inverters and also converts power from dc to ac. It's time to know about the thyristor where this term is derived from the words 'thyatron and transistor'.

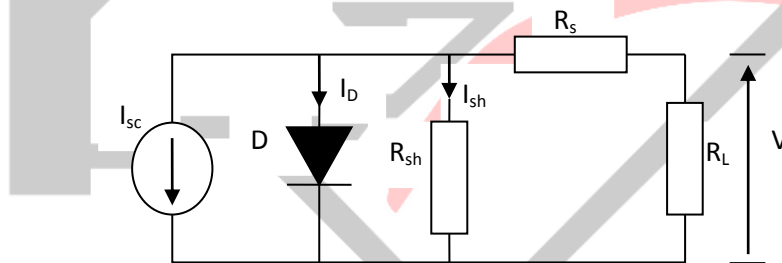
**Keywords – PV SYSTEM, BOOST CONVERTER, THYSTORS.**

## 1. INTRODUCTION

### PV System and Principle of operation

A photovoltaic cell converts energy from the sunlight into electricity. The radiation from the sun is made up of tiny particles of energy called photons. As these photons impact on the cell, some of them are absorbed into the cell. The energy from the photons on impact causes electrons to be free [2]. The movement of the free electrons is what generates electricity.

A PV system is made up of a combination of many cells. Since a PV module is made up of cells combined in series and parallel, the equivalent circuit can be obtained by first doing an analysis on a single cell. The equivalent circuit for a PV cell is given below.



**Figure 1: Equivalent Circuit of PV cell**

The circuit comprises of a Current source which delivers short circuit current  $I_{sc}$ , A shunt diode connected across the current source with current  $I_d$  representing diffusion current across the P-n junction and internal series and parallel resistances  $R_s$  and  $R_{SH}$  respectively

### Mathematical Representation

Using Shockley's diode equation

$$I_d = I_s \left( \exp\left[\frac{q(V + IR_s)}{AkT_c}\right] - 1 \right) \dots \dots (1)$$

Where  $I_s$  is reverse saturation current,  $q$  is charge of one electron,  $T_c$  is the cell temperature in Kelvin,  $V$  is output voltage,  $A$  is junction power factor which determines diode deviation from ideal p-n junction

The photocurrent  $I_{sc}$  is given by

$$I_{SC} = \{I_{SCR} + k_i(T_c - T_r)\} \frac{G}{100} \dots\dots(2)$$

Where  $T_r$  is the reference temperature,  $I_{SCR}$  is the short circuit current at reference temperature,  $k_i$  is temperature coefficient and  $G$  is irradiance in  $mW/cm^2$ .

Reverse saturation current is given by

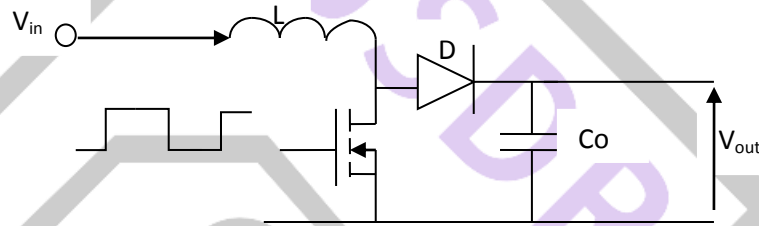
$$I_s = I_{OR} \left(\frac{T_c}{T_r}\right)^3 \exp\left\{\frac{qE_g}{KA} \left[\frac{1}{T_r} - \frac{1}{T_c}\right]\right\} \dots\dots(3)$$

From figure 1 the cell current can be expressed as

$$I = I_{SC} - I_S \left(\exp\left[\frac{q(V + IR_S)}{AkT_c}\right] - 1\right) - \frac{V + IR_S}{R_P} \dots\dots(4)$$

**A. Boost converter**

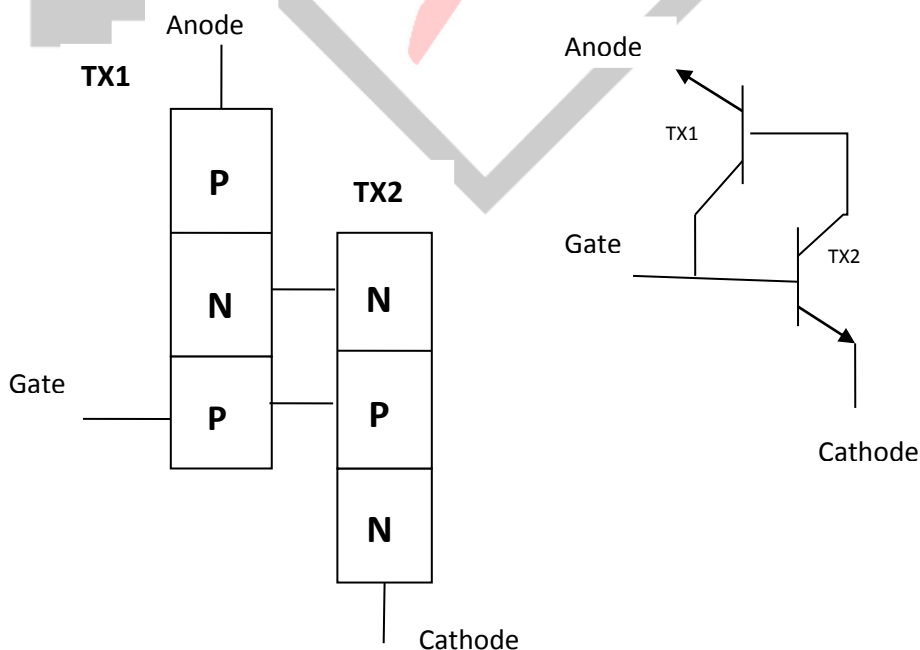
A boost converter is a DC/DC switching converter which is normally used where a higher output voltage than what is supplied by the source is needed by the load [3]. The efficiency of the boost converter is usually very high [3]. A typical boost converter circuit is shown in figure (2) below.



**Figure 2: Boost Converter**

**B. Brief discription of a thyristor**

A thyristor is a switching semiconductor device that is unidirectional, that is to say it can only conduct in a single direction [7]. It is also referred to a silicon controlled rectifier whose principle of operation could be described using the circuit below



**Figure 3: Symbol and Schematic diagram of thyristor**

The physical and schematic diagrams of thyristor are shown Figure 1a and 1b respectively.. It can be seen that a thyristor is basically a combination of PNP and NPN bipolar transistors. To make the thyristor conduct a voltage is applied at the gate which turns on the NPN transistor which in turn makes the PNP to start conducting. Once both transistors are ON, they remain ON until turned OFF. The thyristor could also be turned ON by applying sufficient voltage between the anode and cathode to make one of the transistors break down and begin to conduct . Once one of the internal transistors starts conducting there would be sufficient amount of base current at the second transistor to make it conduct .[6]

The thyristor can turn off by reducing the current flowing in the internal transistors until one of them stops conducting. This can be achieved by applying a negative voltage to the gate [6].

C. 3 phase thyristor rectifier

Due the mode of operation and behaviour as described earlier, thyristors are used in 3 phase rectified circuits. This type of rectifier using thyristors is referred to as line commutated controlled rectifier. An example of a 3 phase thyristor converter is shown below.

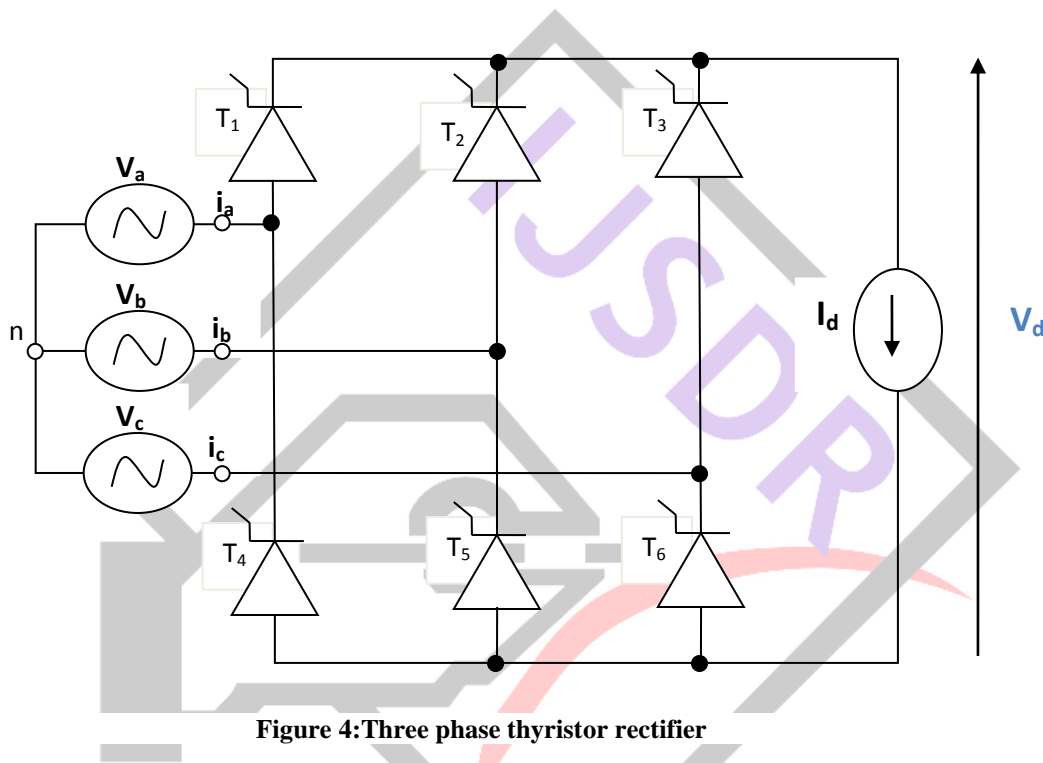


Figure 4: Three phase thyristor rectifier

The 3 phase rectifier shown in figure (4) above has 6 thyristors connected in two groups of 3 each. The first group has a common cathode connection and the second group have a common anode connection. The thyristors are fired at an interval of 120°. The firing sequence for the thyristors is 1,6,2,4,3,5 and 6. Each thyristor is fired after 60° of the previous thyristor being fired. This means at point  $\omega t = \pi/6$  (because its 3 phase starting point is not  $\omega t = 0$  ) T1 is triggered while T6 is still conducting and between 60° and 120° both T1 and T6 would conduct together and the line to line voltage  $V_{ab}=V_{an} - V_{bn}$  would appear across the load. At 180° thyristor T6 is fired and thyristor T6 is reversed biased thereby switching off. At 240° T2 is triggered and T1 is switched off. The process continues for the rest of the sequence with the triggering action of one thyristor switching off the previous thyristor.[4]

D. PI Controller

A PI controller is a combination of a proportional controller and integral controller. By combining both controllers, the setbacks in one is corrected by the other. For example a proportional controller has non zero steady state error while a proportional integrator forces the steady state error to zero by accumulating all the errors

2. RESULTS AND DISCUSSION

1) Boost converter model

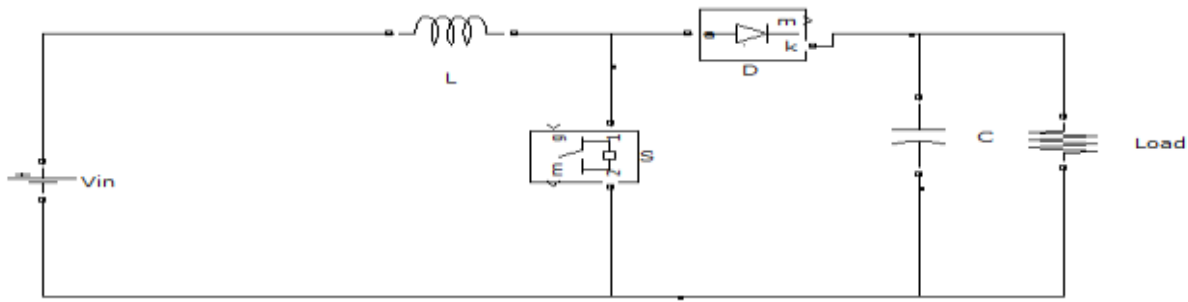


Figure 5: Model of Boost Converter

A dynamic PWM generator

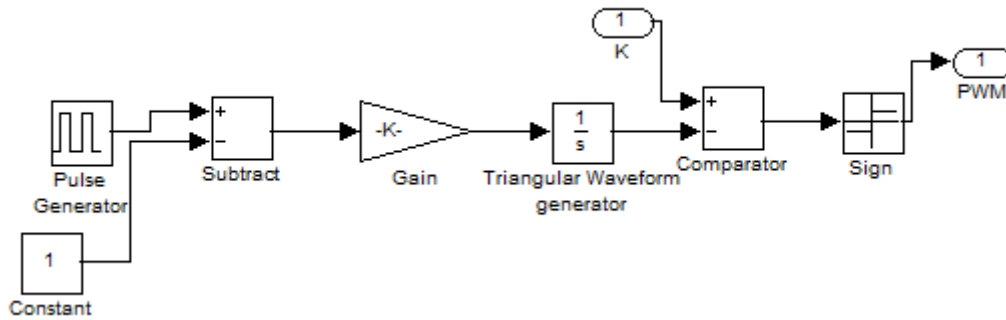


Figure 6: PWM generator

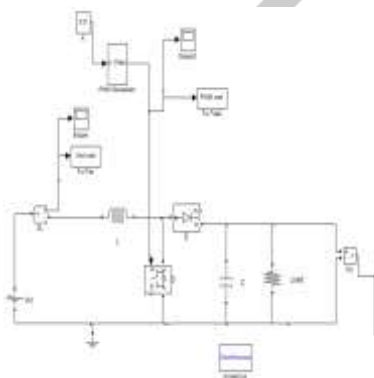


Figure 7: Boost Converter with PWM generator

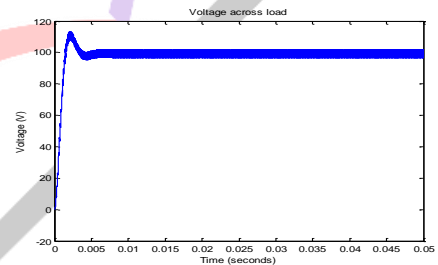


Figure 8: PV voltage of Boost Converter

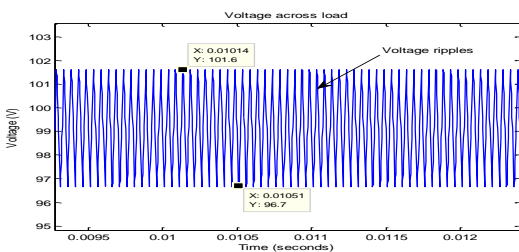


Figure 9: Amount of ripple

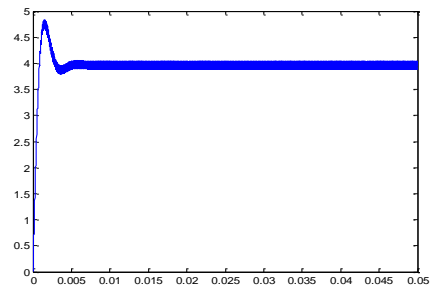


Figure 10: Inductor current of boost converter

### S function for pv model

The S-function processes input signals as states and generate outputs from these signals. Both the input and output signals are in vector form. The S-function is made of several call functions which are used by simulink during simulation.

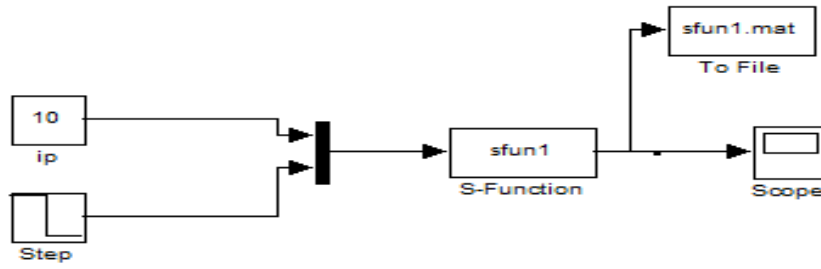


Figure 11: S function

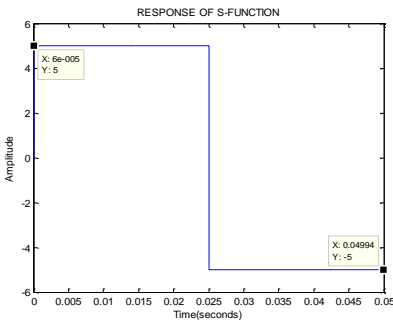


Figure 12: S -function output step and constant block inputs.

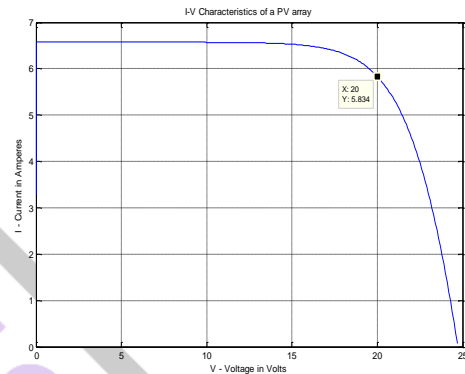


Figure 13: I-V Characteristic of a PV Array

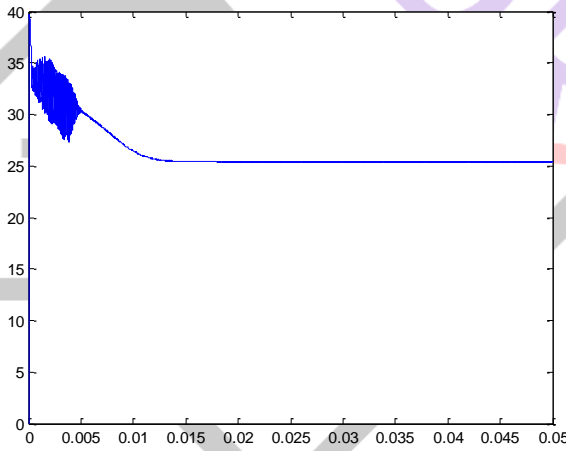


Figure 14: PV voltage

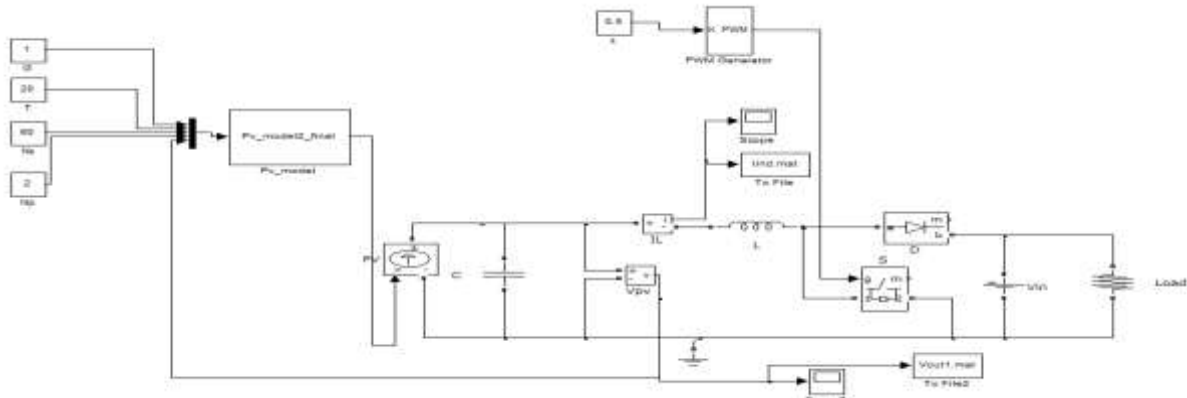


Figure 15 :PV Model with Boost Converter

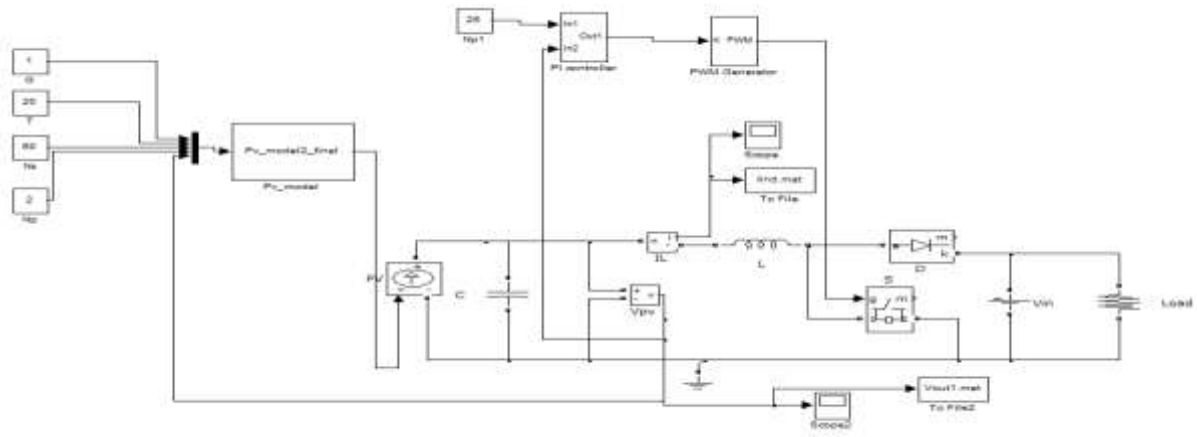


Figure16: PV Model with Boost converter and PI controller

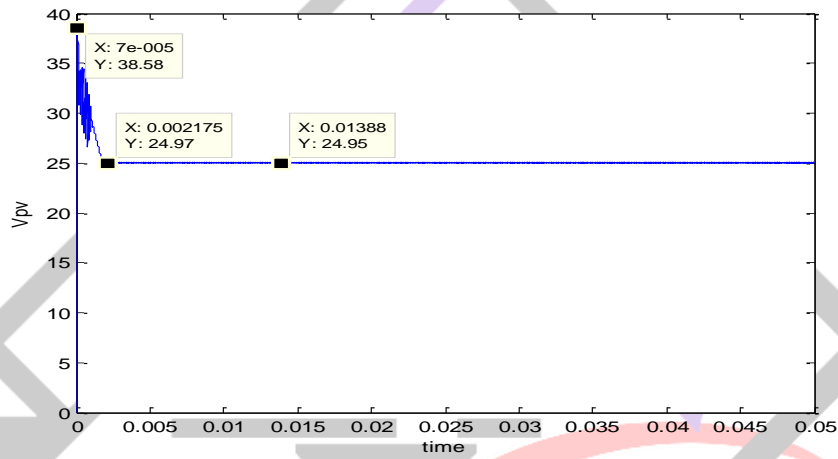


Figure17: Closed loop response with adjusted Ki and Kp

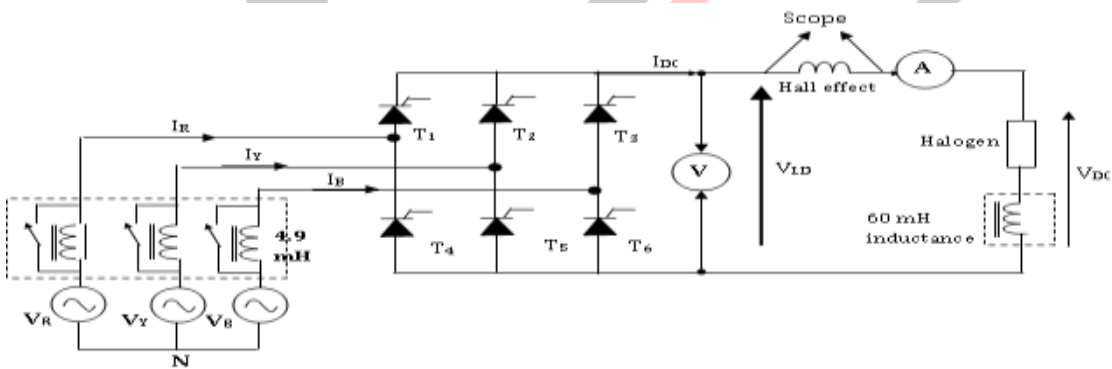


Figure 7: Diagram of experiment connection

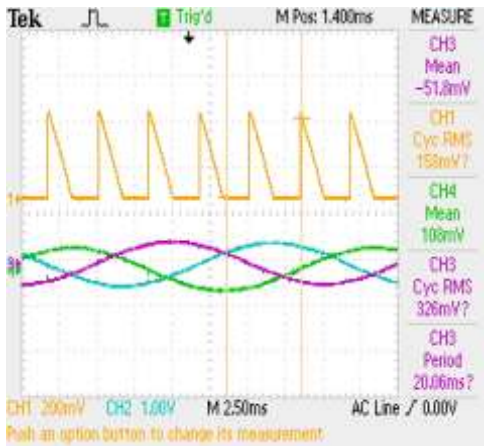


Figure 19: Voltage Waveforms firing angle set  $90^{\circ}$

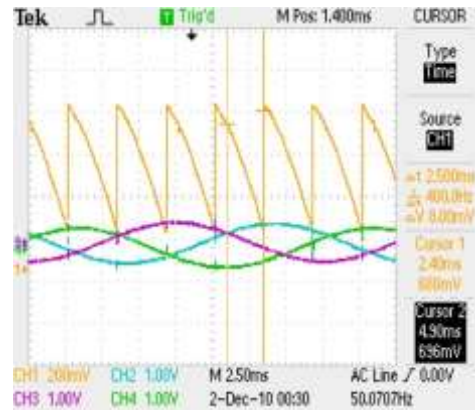


Figure 20: Voltage waveforms firing angle  $\alpha$  set to  $45^{\circ}$

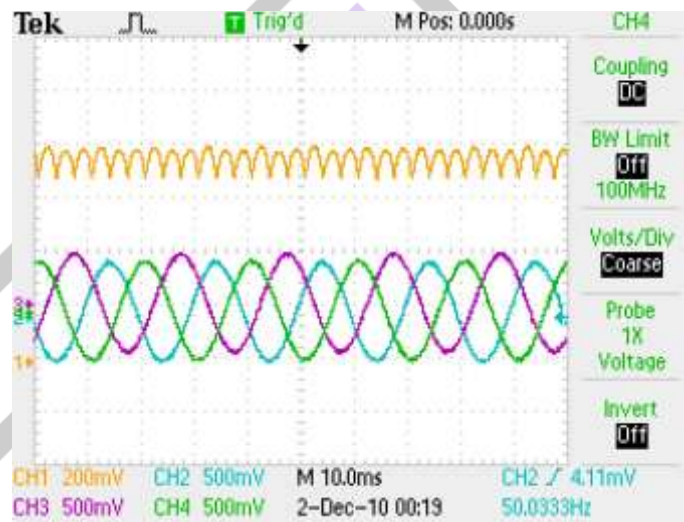


Figure 21: Voltage waveforms with firing angle set to zero

**3.CONCLUSION**

A PV system can be made to track maximum power point by incorporating a PI controller into the PV system. The PI controller adjusts the PV voltage based on the maximum power point. With properly tuned values of proportional gain and integral gain, the PI controller reduces ripples and improves transient response.

For a PV system with varying weather conditions, the irradiation  $G$  ( $KW/m^2$ ) has a significant effect on the current supplied by PV generator and is directly proportional to the current. Therefore a slight decrease in the irradiation would lead to a significant decrease in current. How large the decrease would be is dependent upon other weather conditions such as ambient temperature.

For a PV system with varying weather conditions, change in ambient temperature has a significant effect on the PV terminal voltage. For a slight drop in temperature would lead to a significant increase in the terminal voltage. Also how large the increase of terminal voltage would be is determined by the other weather conditions such Irradiance. Duty ratio of the boost converter also affects the terminal voltage. The higher the duty ratio the lower the terminal voltage. If duty ration is made to high the terminal voltage becomes unstable.

In thyristor 3 phase rectified circuits the amount of power supplied to the load is determined by the delay angle of the thyristors. The maximum delay angle that can be achieved is  $180^{\circ}$  and when there is no angle of delay (delay angle= $0$ ), maximum power is transferred to the load.

In a 3 phase thyristor rectifier using 6 thyristors, the thyristors are triggered it sequence resulting in the formation of 6 pulse DC voltage waveforms.

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