Daffodil International University
Faculty of Science & Information Technology

Design control of DC/AC converter for a grid Connected PV systems using Mathlab/simulink.

Department of Electrical & Electronics Engineering

Thesis submitted for examination for the degree of Bachelor
In **Electrical & Electronics Engineering**.

Thesis supervisor:
Dr. Md. Shamsul Alam
Professor and Dean,
Faculty of Science & Information Technology
Daffodil International University

Thesis instructor:
Ms. Tasmia Baten
Senior Lecturer
Department of EEE
Daffodil International University

Submitted By:

1. Md. Mahmudul Hasan
ID: 101-33-151
Daffodil International University

2. Md. Shoud Mahadi Jars
ID: 101-33-188
Daffodil International University

Department of EEE 2nd Batch

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Preface:

This thesis has been conducted at the Power Electronic Unit in the Department of Electrical & Electronics Engineering under the Faculty of Science and Information Technology. I would like to acknowledge all the people and institutions that have contributed directly and indirectly in this work.

First of all, I would like to express my gratitude to my supervisor, Professor Dr. M. Shamsul Alam for giving me the opportunity of working under his supervision. To Ms. Tasmia Baten, instructor of this thesis: it would have not been possible to complete this work without his invaluable guidance, advice and support. I have learnt a lot from him during the realization of this thesis.

Abstract:

Grid connected photovoltaic (PV) systems feed electricity directly to the electrical network operating parallel to the conventional source. This paper deals with design and simulation of a three phase inverter in MATLAB SIMULINK environment which can be a part of photovoltaic grid connected systems. The converter used is a Voltage source inverter (VSI) which is controlled using synchronous d-q reference frame to inject a controlled current into the grid. Phase lock loop (PLL) is used to lock grid frequency and phase.

Contents:

Chapter 1: Introduction

Chapter 2: D-Q transformation

Chapter 3: Control unit

Chapter 4: working principle of control system

Chapter 5: conclusion

Chapter-1: Introduction

1.1 Abbreviations

AC	**Alternative current**
DC	**Direct current**
PV	**Photovoltaic**
PLL	**Phase lock loop**
PI	**Proportional integral**
VSI	**Voltage source inverter**
IGBT	**Insulated gate bipolar transient**
V_{DC}	**Dc voltage**
$V_{DC\ REF}$	**Reference dc voltage**
I_D	**Direct axis current**
I_{DREF}	**Reference current of direct axis**
I_Q	**Quadratic axis current**
I_{QREF}	**Reference current of quadratic axis**

1.2 Introduction

The continuously increasing energy consumption, overloads the distribution grids by creating problems such as outages, grid instability, deterioration of power quality, power security etc. To balance the energy demand and generation, renewable energy resources such as Photovoltaic (PV), Wind, and Biomass could be a good solution. Among these, solar energy is considered to be one of the most useful sources because it is free, abundant, pollution free and maintenance free. Since the generated voltage from PV is DC, we need inverter for converting DC voltage from PV to AC before connecting it to grid. Grid is a voltage source of infinite capability. The output voltage and frequency of inverter should be same as that of grid frequency and voltage. The work presented here is about the simulation of a VSI where the output current of inverter is controlled in synchronously rotating d-q reference frame. PLL is used to synchronize grid with PV.

1.3 Literature Review

This paper focuses on a DC/AC converter for grid-connected PV system. In this system, a DC-AC inverter has been interfaced between the PV modules and utility grid. The inverter operates in the current controlled mode to ensure a high-power factor is achieved.

Various control strategies have been proposed on grid-connected PV systems. Although these control strategies can achieve the same goals, their performances are quite different. Many controllers have been widely investigated over the last few decades: hysteresis regulators, linear PI regulators, Fractional Order Operators, predictive dead-beat regulators etc. All the VSI current control techniques discussed in the literature are analyzed for advantages and disadvantages to satisfy these objectives.

The advantages of hysteresis controllers are their simplicity, fast dynamic response, and robustness. The major drawback of this type of controller is an uneven and random switching frequency pattern, due to the variation of current reference or DC-link voltage, which makes the filtering of output waveform quite expensive Moreover, it results in additional stresses on the switching devices . Although there are a number of active researches to improve the hysteresis current control technique, but applying the variable frequency noises into the utility grid is not recommended because it can trigger unpredictable resonances in the grid utility.

The other control strategy which has been applied to the grid-connected system is the model predictive control (MPC). The advantages of predictive dead-beat control are fast dynamic response and accurate reference tracking. However, this controller has a model based regulator and therefore it is quite sensitive to parameter variations, uncertainties, in accuracies and delays.

In several research studies, proportional-integral (PI) controllers are employed to control the AC side currents. In these control schemes, the DC-link voltage is controlled by a voltage control loop, where a PI controller acts on the DC voltage error to generate references for the AC current in the stationary (abc or dq) or synchronous (dq) frames. PI current regulators ensure that a clean, in phase AC current feeds the grid. PI controller has been largely used in the grid-connected PV systems.

Chapter – 2: DQ transformation

2.1: Definition

In electrical engineering, direct–quadrature–zero (or *dq*0 or *dqo*) transformation or zero–direct–quadrature (or 0*dq* or *dq0*) transformation is a mathematical transformation that rotates the reference frame of three-phase systems in an effort to simplify the analysis of three-phase circuits. In the case of balanced three-phase circuits, application of the dqo transform reduces the three AC quantities to two DC quantities. Simplified calculations can then be carried out on these DC quantities before performing the inverse transform to recover the actual three-phase AC results. It is often used in order to simplify the analysis of three-phase synchronous machines or to simplify calculations for the control of three-phase inverters. In analysis of three-phase synchronous machines park transformation transfers three phase stator and rotor quantities in to a single rotating reference frame to eliminate the effect of time varying inductances. The dqo transform presented here is exceedingly similar to the transform first proposed in 1929 by Robert H. Park. In fact, the dqo transform is often referred to as Park's transformation.

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2.2: abc_to_dq0 Transformation

Perform Park transformation from three-phase (abc) reference frame to dq0 reference frame. The abc_to_dq0 Transformation block computes the direct axis, quadratic axis, and zero sequence quantities in a two-axis rotating reference frame for a three-phase sinusoidal signal. The following transformation is used:

$$V_d = \frac{2}{3}(V_a \sin(\omega t) + V_b \sin(\omega t - 2\pi/3) + V_c \sin(\omega t + 2\pi/3))$$

$$V_q = \frac{2}{3}(V_a \cos(\omega t) + V_b \cos(\omega t - 2\pi/3) + V_c \cos(\omega t + 2\pi/3))$$

$$V_0 = \frac{1}{3}(V_a + V_b + V_c)$$

Where ω = rotation speed (rad/s) of the rotating frame.

The transformation is the same for the case of a three-phase current; you simply replace the Va, Vb, Vc, Vd, Vq, and V_0 variables with the Ia, Ib, Ic, Id, Iq, and I_0 variables.

This transformation is commonly used in three-phase electric machine models, where it is known as a Park transformation. It allows you to eliminate time-varying inductances by referring the stator and rotor quantities to a fixed or rotating reference frame. In the case of a synchronous machine, the stator quantities are referred to the rotor. Id and Iq represent the two DC currents flowing in the two equivalent rotor windings (d winding directly on the same axis as the field winding, and q winding on the quadratic axis), producing the same flux as the stator Ia, Ib, and Ic currents.

2.3 dq0_to_abc Transformation

Perform Park transformation from dq0 reference frame to abc reference frame. The dq0_to_abc Transformation block performs the reverse of the so-called Park transformation, which is commonly used in three-phase electric machine models. It transforms three quantities (direct axis, quadratic axis, and zero-sequence components) expressed in a two-axis reference frame back to phase quantities. The following transformation is used:

$$V_a = V_d \sin(\omega t) + V_q \cos(\omega t) + V_0$$
$$V_b = V_d \sin(\omega t - 2\pi/3) + V_q \cos(\omega t - 2\pi/3) + V_0$$
$$V_c = V_d \sin(\omega t + 2\pi/3) + V_q \cos(\omega t + 2\pi/3) + V_0$$

Where ω = rotation speed (rad/s) of the rotating frame

The transformation is the same for the case of a three-phase current; you simply replace the Va, Va, Vb, Vd, Vq, and V0 variables with the Ia, Ib, Ic, Id, Iq, and I0 variables.

The dq0_to_abc Transformation block is used in the model of the Synchronous Machine block where the stator quantities are referred to the rotor. The Park transformation then eliminates time-varying inductances by referring the stator and rotor quantities to a fixed or rotating reference frame. The Id and Iq currents represent the two DC currents flowing in the two equivalent rotor windings (d winding on the same axis as the field winding, and q winding in quadratic) producing the same flux as the stator Ia, Ib, and Ic currents.

2.4 phase lock loop (PLL)

The PLL block models a Phase Lock Loop (PLL) closed-loop control system, which tracks the frequency and phase of a sinusoidal signal by using an internal frequency oscillator. The control system adjusts the internal oscillator frequency to keep the phase difference to 0.

The figure2.1 shows the internal diagram of the PLL.

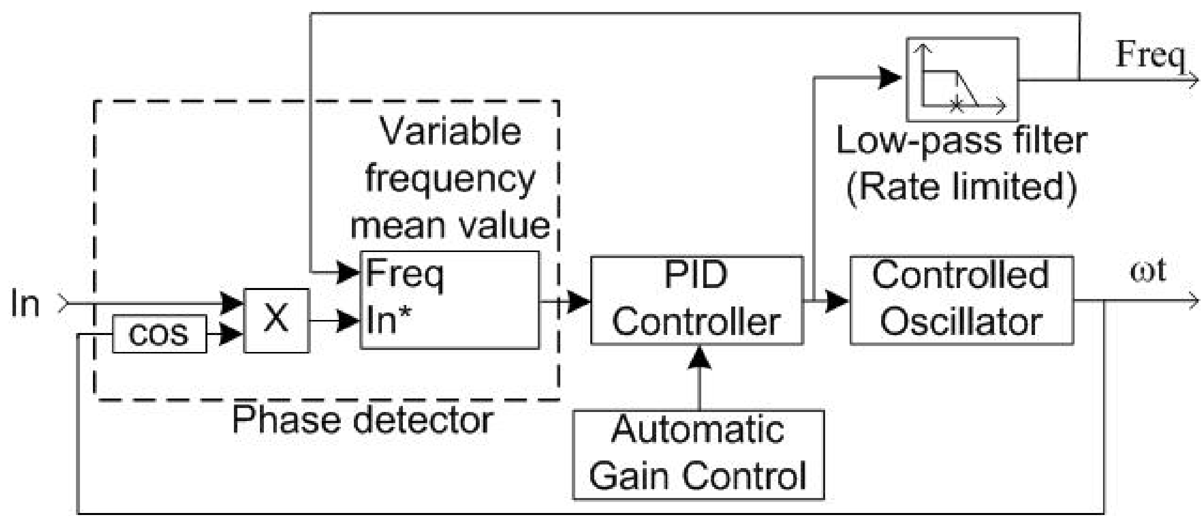

Fig-2.1: The internal diagram of the PLL

The input signal is mixed with an internal oscillator signal. The DC component of the mixed signal (proportional to the phase difference between these two signals) is extracted with a variable frequency mean value. A Proportional-Integral-Derivative (PID) controller with an optional automatic gain control (AGC) keeps the phase difference to 0 by acting on a controlled oscillator. The PID output, corresponding to the angular velocity, is filtered and converted to the frequency, in hertz, which is used by the mean value.

2.5 Advantage of dq transformation

There are to many advantages that become the reason for researcher using it in their field. The most common one is because this method simplified the system that make easier to analysis

Chapter 3 : Control Unit

3.1 DESIGN OF VOLTAGE CONTROLLER

The DC voltage is set by a PI controller that compares the actual dc bus voltage and the reference generated by the MPPT, and provides an active current reference Id_{ref} in a synchronous reference frame attached at grid voltage vector. The other component of current vector represents the reactive current and it can be fixed at the desired level for power factor or voltage control.

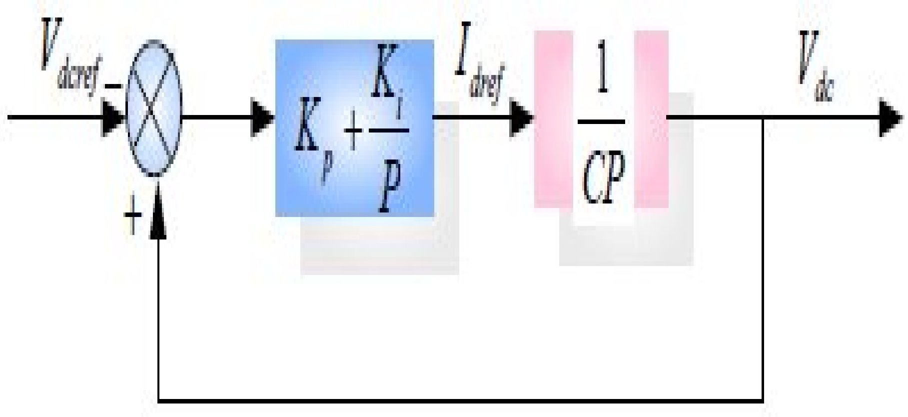

Fig-3.1: Regulation of voltage with a PI controller

3.2: DESIGN OF ALTERNATIVE CURRENT CONTROLLER

The control of current has two objectives, first to have a purely sinusoidal current without harmonic distortion and with a unity power factor, second to be able to carry out the ordering of dc voltage. Thus, the total execution of system depends on the design of current control. As illustrated in fig 3.2

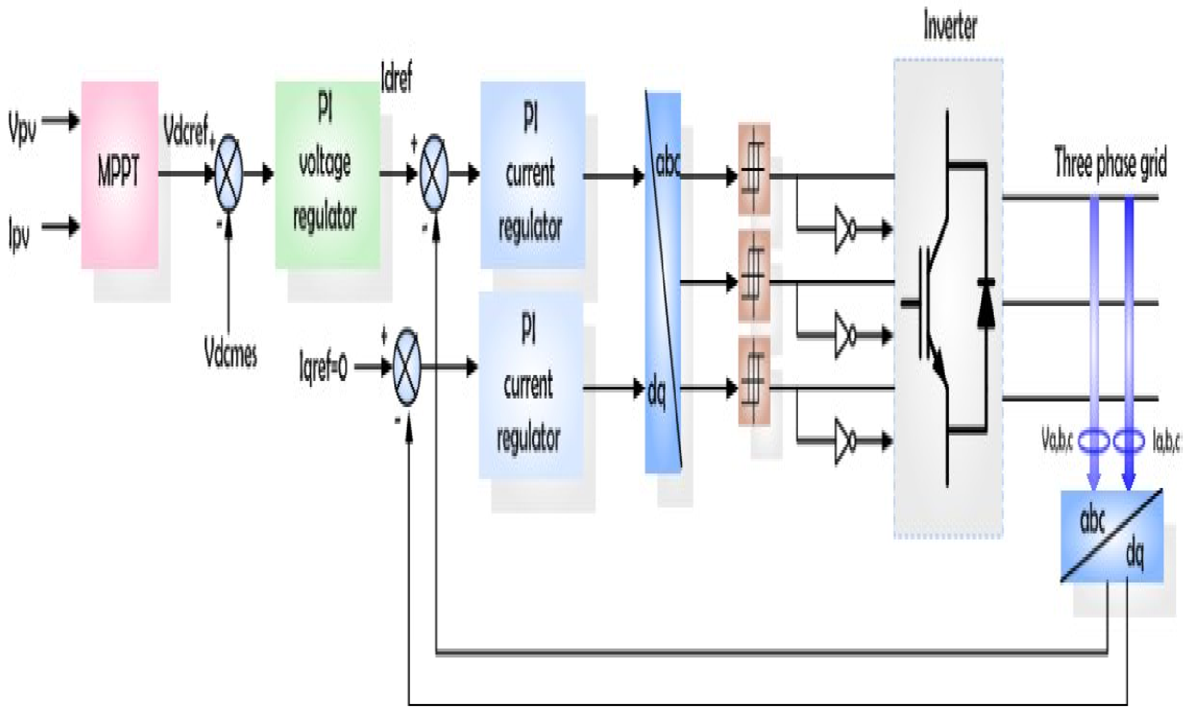

Fig-3.2: Proposed control scheme of three-phase grid-connected PV system

The current control is realized by choosing two currents reference in synchronous d-q rotating such as:

• For an operation with a unity power factor, the current reference on the q axis is selected equal to zero.

• The component current on the d axis adjusted by the automatic feedback controller who depends on the difference between the reference voltages.

The diagram of current control with a PI regulator in synchronous d-q rotating can be illustrated by fig.

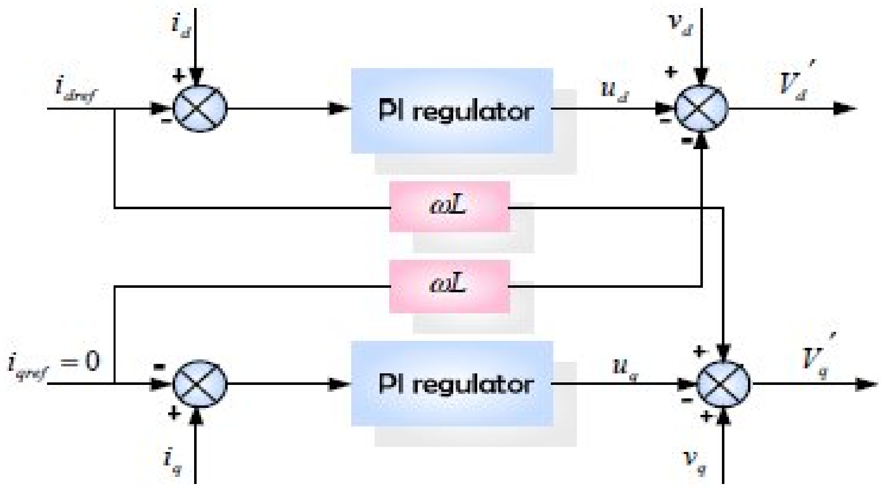

Fig-3.3: Proposed current control scheme in synchronous d-q rotating.

3.3 P-I Controller:

P-I controller is mainly used to eliminate the steady state error resulting from P controller. However, in terms of the speed of the response and overall stability of the system, it has a negative impact. This controller is mostly used in areas where speed of the system is not an issue.

The combination of proportional and integral terms is important to increase the speed of the response and also to eliminate the steady state error. The PID controller block is reduced to P and I blocks only as shown in figure 3.4

A PID Controller works by correcting the error between a measured process variable and a desired set point by calculating and then outputting a corrective action that can adjust the process accordingly - and rapidly - to keep the error minimal.

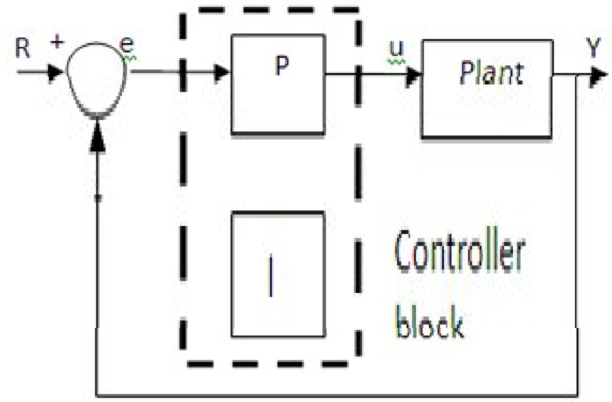

Fig-3.4: Proportional Integral (PI) Controller block diagram

3.4 Negative feedback:

Negative feedback occurs when some function of the output of a system, process, or mechanism is feed back into the input with a polarity that tends to reduce the fluctuations in the output, whether caused by changes in the input or by other disturbances. Whereas positive feedback tends to lead to instability via exponential growth or oscillation, negative feedback generally promotes stability. In some applications, negative feedback promotes a settling to equilibrium, and in most applications it reduces the effects of perturbations. Negative feedback loops in which just the right amount of correction is applied in the most timely manner can be very stable, accurate, and responsive.

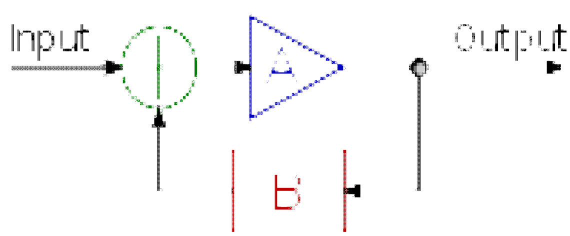

Fig-3.5: Block diagram of negative feedback.

A simple negative feedback system, and many electronic amplifiers, can be represented by this diagram. The feedback is negative if the loop gain AB is negative.

Negative feedback is widely used in mechanical and electronic engineering, but it also occurs naturally within living organism, and can be seen in many other fields from chemistry and economics to physical systems such as the climate. General negative feedback systems are studied in control systems engineering.

3.5 Inverter

A power inverter, or inverter, is an electronic device or circuitry that changes direct current (DC) to alternating current (AC). The input voltage, output voltage and frequency, and overall power handling depend on the design of the specific device or circuitry. The inverter does not produce any power; the power is provided by the DC source.

3.6 Working principle of inverter

S_1	S_3	S_5	$v_{ao}(t)$	$v_{bo}(t)$	$v_{co}(t)$
0	0	0	$-\frac{V_{dc}}{2}$	$-\frac{V_{dc}}{2}$	$-\frac{V_{dc}}{2}$
0	0	1	$-\frac{V_{dc}}{2}$	$-\frac{V_{dc}}{2}$	$+\frac{V_{dc}}{2}$
0	1	0	$-\frac{V_{dc}}{2}$	$+\frac{V_{dc}}{2}$	$-\frac{V_{dc}}{2}$
0	1	1	$-\frac{V_{dc}}{2}$	$+\frac{V_{dc}}{2}$	$+\frac{V_{dc}}{2}$
1	0	0	$+\frac{V_{dc}}{2}$	$-\frac{V_{dc}}{2}$	$-\frac{V_{dc}}{2}$
1	0	1	$+\frac{V_{dc}}{2}$	$-\frac{V_{dc}}{2}$	$+\frac{V_{dc}}{2}$
1	1	0	$+\frac{V_{dc}}{2}$	$+\frac{V_{dc}}{2}$	$-\frac{V_{dc}}{2}$
1	1	1	$+\frac{V_{dc}}{2}$	$+\frac{V_{dc}}{2}$	$+\frac{V_{dc}}{2}$

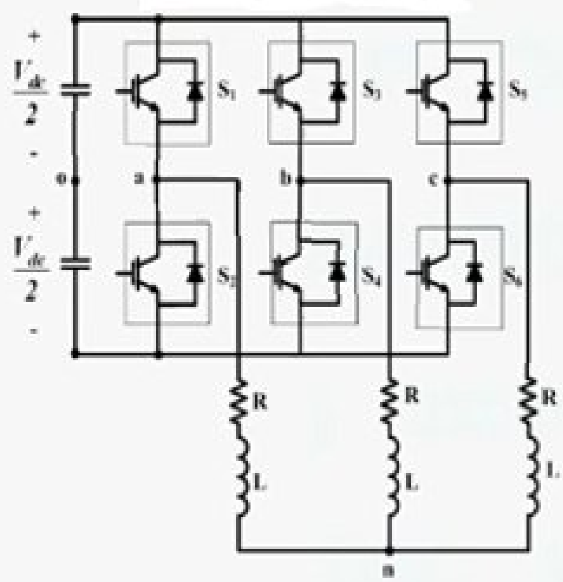

Fig-3.6: circuit diagram of three phase inverter

In a three phase inverter, we have three lag (lag a, lag b, lag c) and we have three switches. We also have eight different combinations for three switches. First case 000 that means top switches are off. So definitely bottom switches are on. So when the switches are on or off we have different voltage at terminal a, b, c with respect of neutral point. With different switching state and also look at the voltage way form when the switching frequency is low. That means we have only one pulse for each phase over each lag. Figure shows the gate signal for switches.
We can define switching state in two parts. One is active switching and another is zero switching.

3.6.1 Active switching state

i. Switching state 101

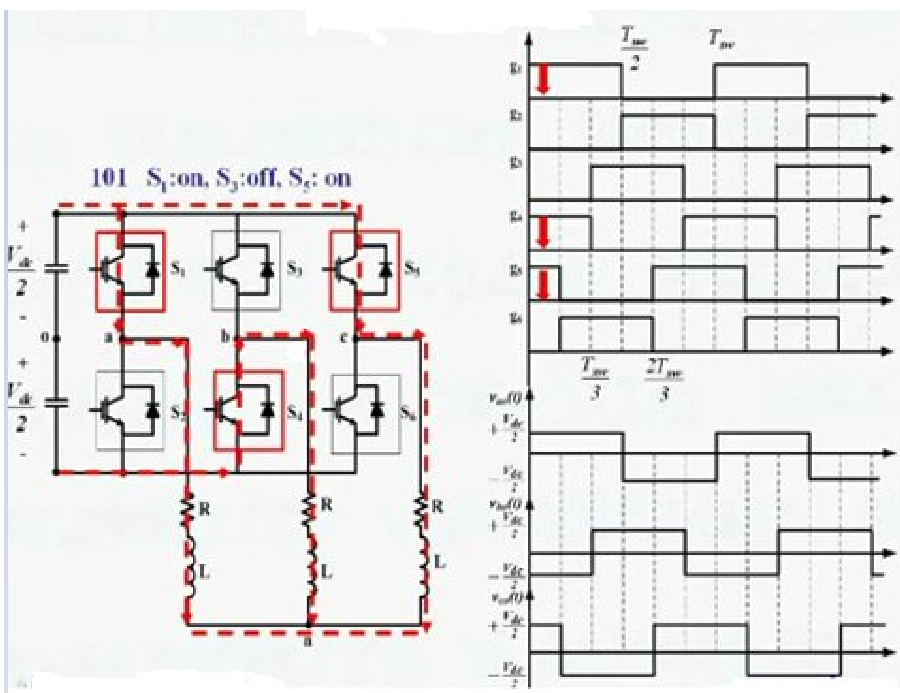

Fig-3.7: Switching state 101 in inverter

Switching state 101 means S_1: on, S_3: off, S_5: on. In this figure shows gate pulse of switches. Gate pulse g_1 is passing through the switch 1. When S_1 is on it is connect through the positive voltage. So the voltage of lag a is positive. Switch S_4 is on and it is connected with negative voltage. So lag b voltage is negative. Switch 5 is on and it is connected with positive voltage and lag c voltage is positive which so in figure.

ii. **switching state 100**

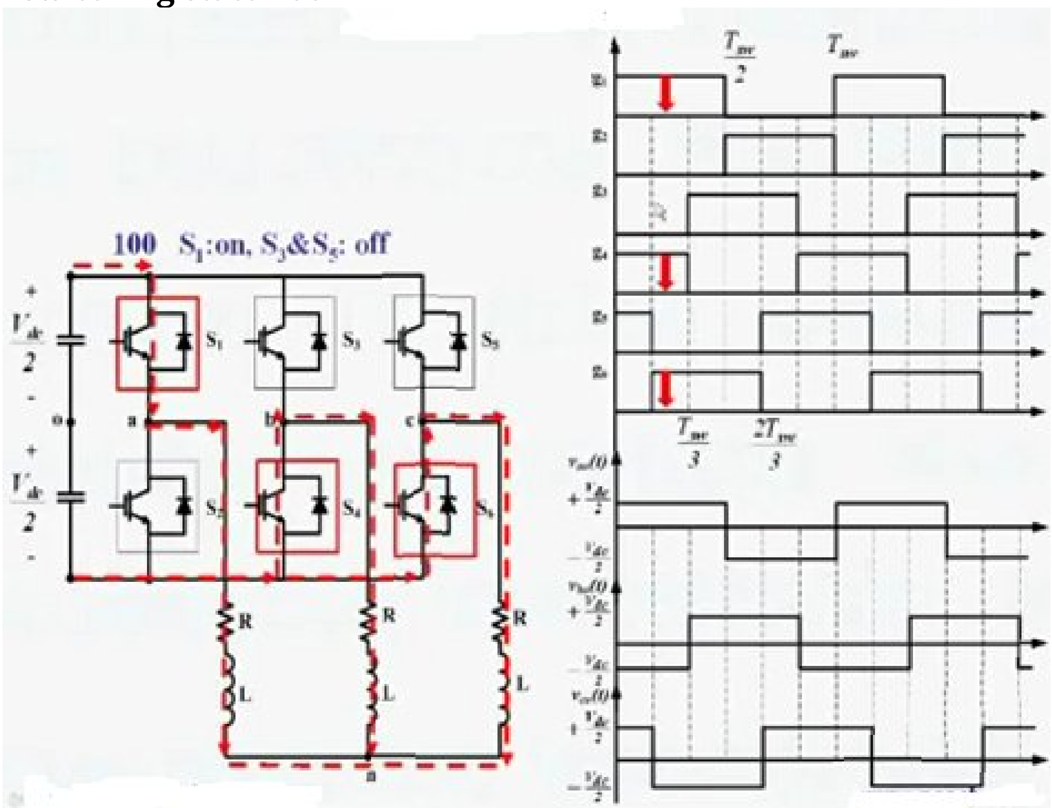

Fig-3.8: switching state 100 in inverter

Switching state 100 means $S_{1:}$ on, $S_3$and S_5: off. . When S_1 is on it is connect through the positive voltage. So the voltage of lag a is positive. Switch S_3 and S_5 is off and it is connected with negative voltage. So lag b and lag c voltage is negative

iii. switching state 110

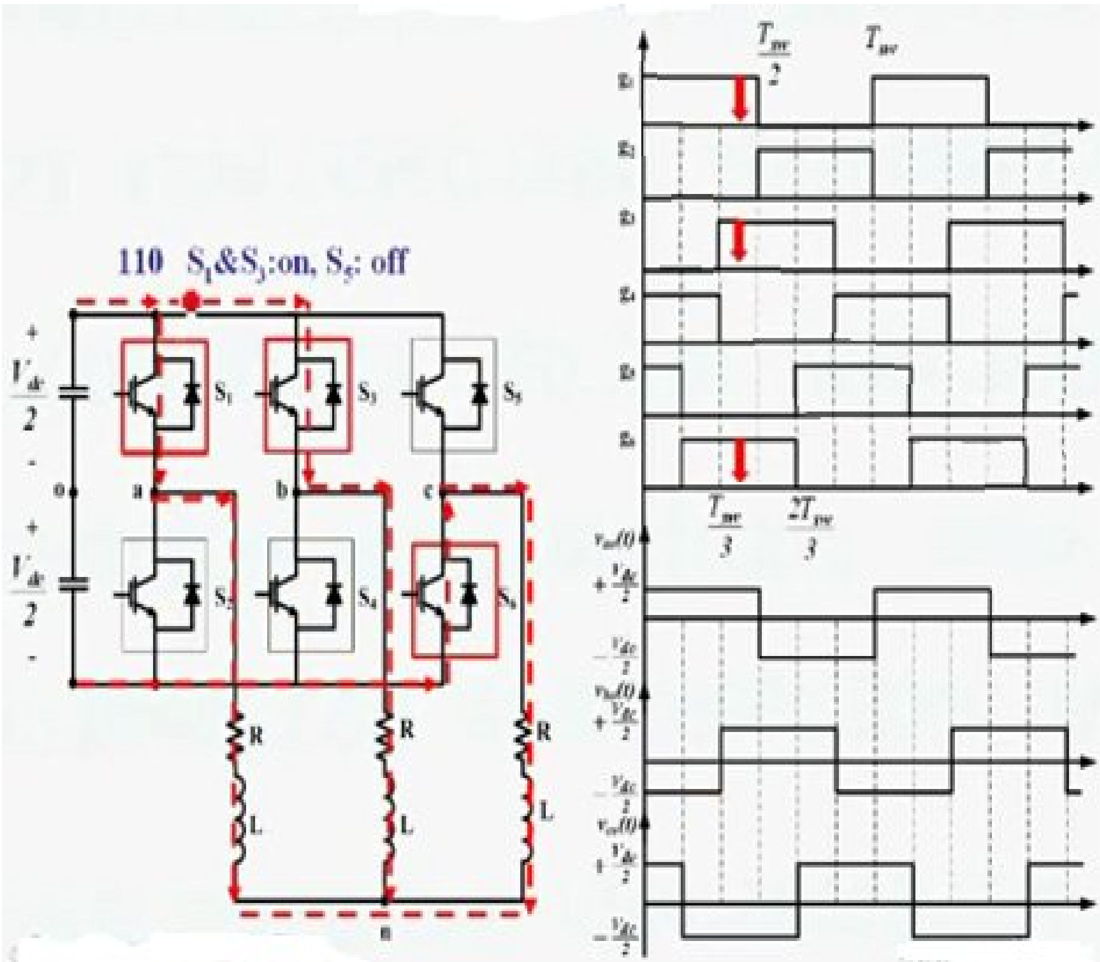

Fig-3.9: Switching state 110 in inverter

Switching state 110 means S_1 and S_3: on, S_5: on.. When $S_{1 \text{ and}}$ S_3 is on it is connect through the positive voltage. So the voltage of lag a and lag b is positive. Switch S_5 is off and it is connected with positive voltage. So lag c voltage is positive.

iv. Switching state 010

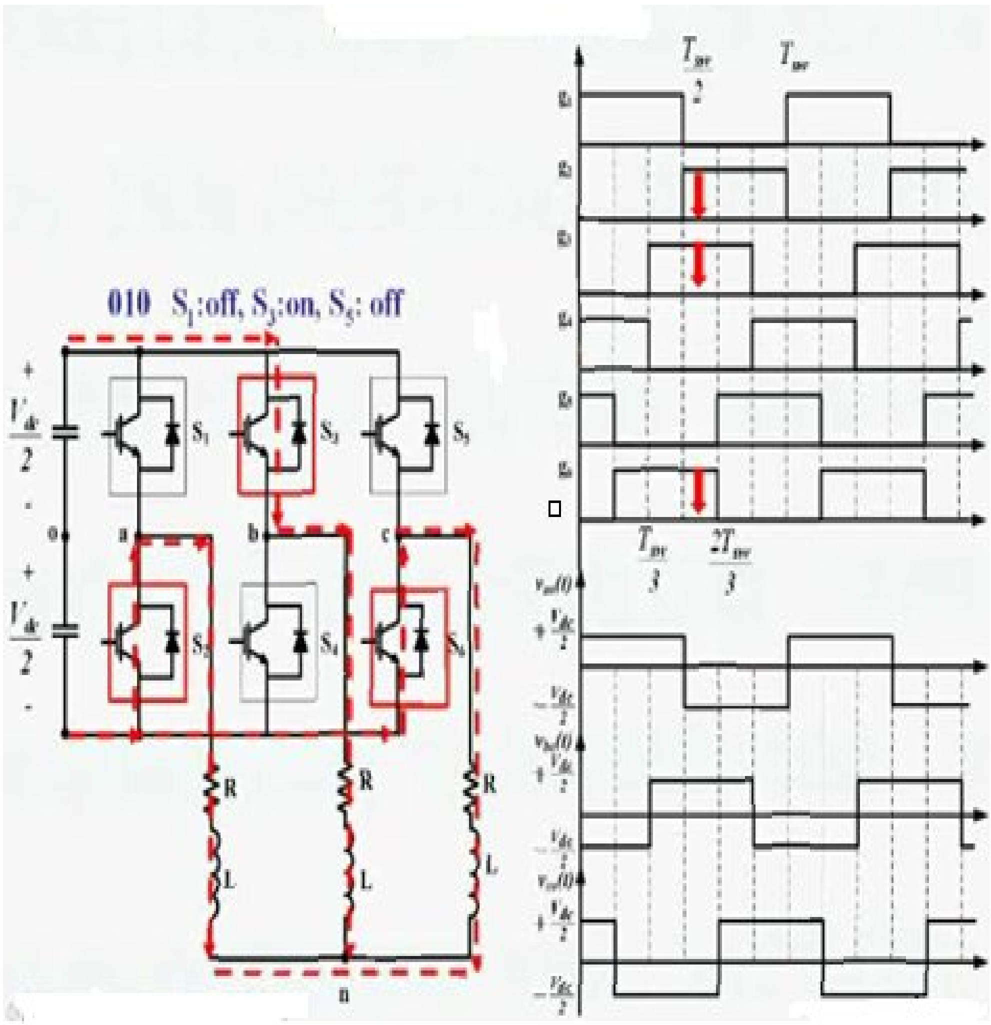

Fig-3.10: Switching state 010 in inverter

Switching state 010 means S_1 : off, S_3: on, S_5: off.. When S_1 is off it is connect through the negative voltage. So the voltage of lag a is negative. Switch S_3 is on and it is connected with positive voltage. So lag b voltage is positive. Switch 5 is off and it is connected with negative voltage and lag c voltage is negative which so in figure.

v. Switching state 011

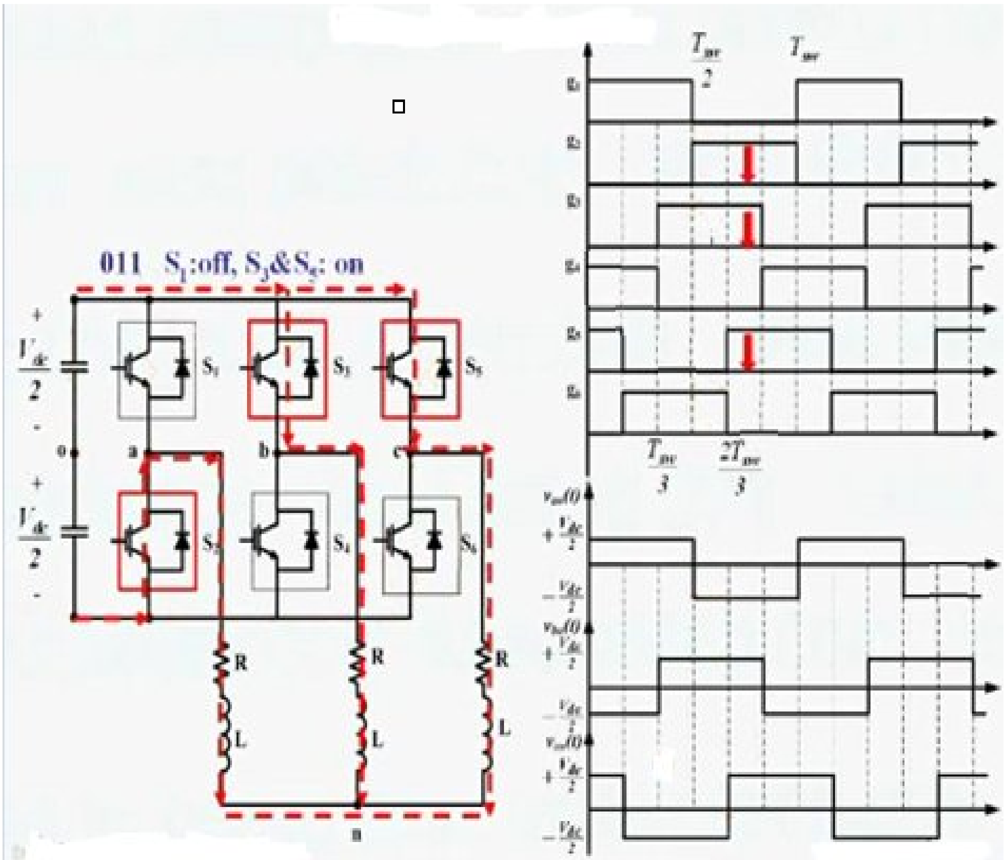

Fig-3.11: Switching state 011 in inverter

Switching state 011 means $S_{1:}$ off, $S_3$and S_5: on. When S_1 is off it is connect through the negative voltage. So the voltage of lag a is negative. Switch S_3 is on and it is connected with positive voltage. So lag b voltage is positive. Switch 5 is on and it is connected with positive voltage and lag c voltage is positive which so in figure.

vi. Switching state 001

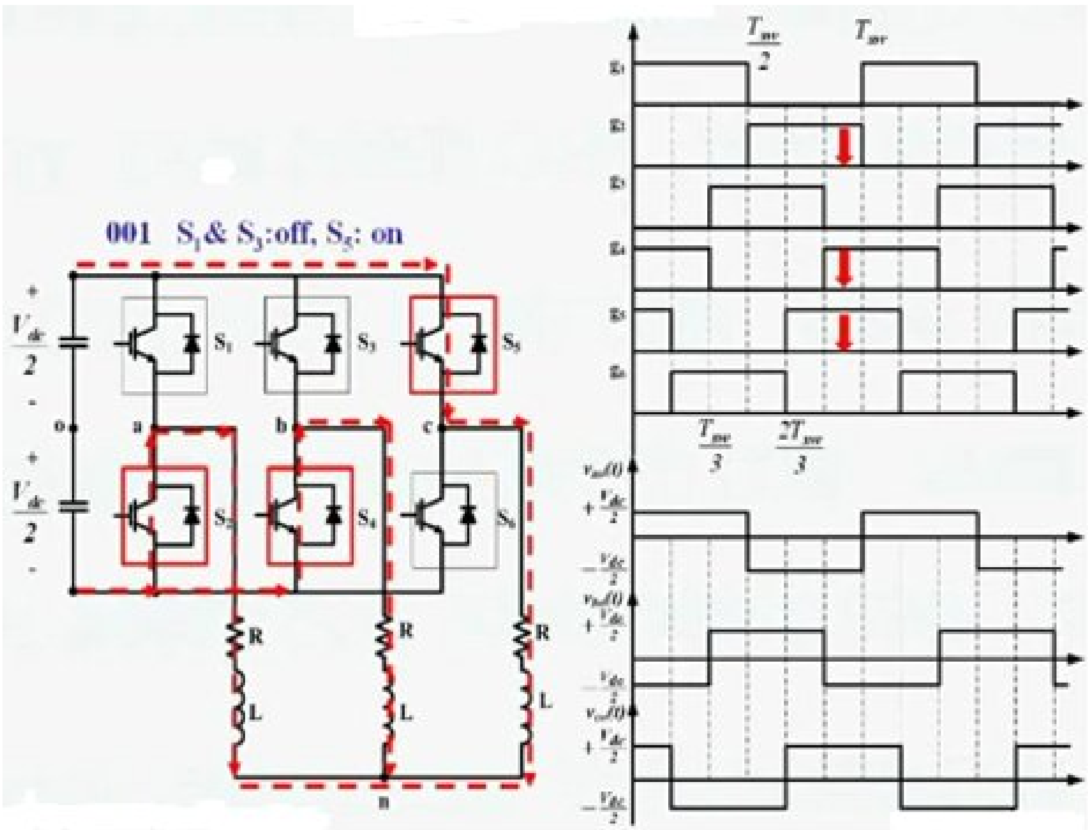

Fig-3.12: Switching state 001 in inverter

Switching state 001 means S_1 and S_3: off, S_5: on. When S_1 and S_3 is off it is connect through the negative voltage. So the voltage of lag a and lag b is negative. Switch S_5 is on and it is connected with positive voltage. So lag b voltage positive.

3.6.2: zero vectors

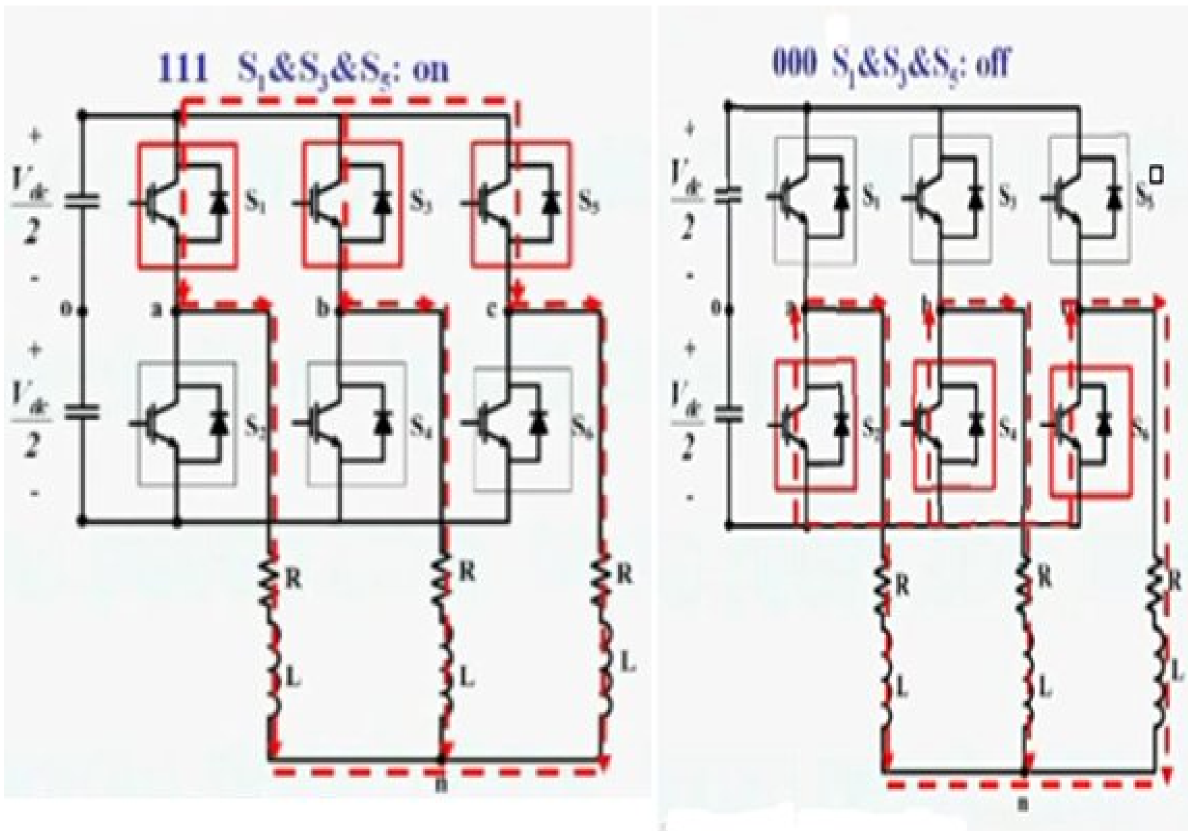

Fig-3.13: Zero vector of inverter

Switching state 000 and 111 is called zero vectors. In switching state 111 all switch of upper is on and they connected with each other. So there is no voltage at any lag. Same as switching state 000. Bottom switches are connected with each other. Accept zero vector other switching state called active vector**.**

<u>Chapter 4</u>
Working principle of simulation

4.1 Circuit Diagram :

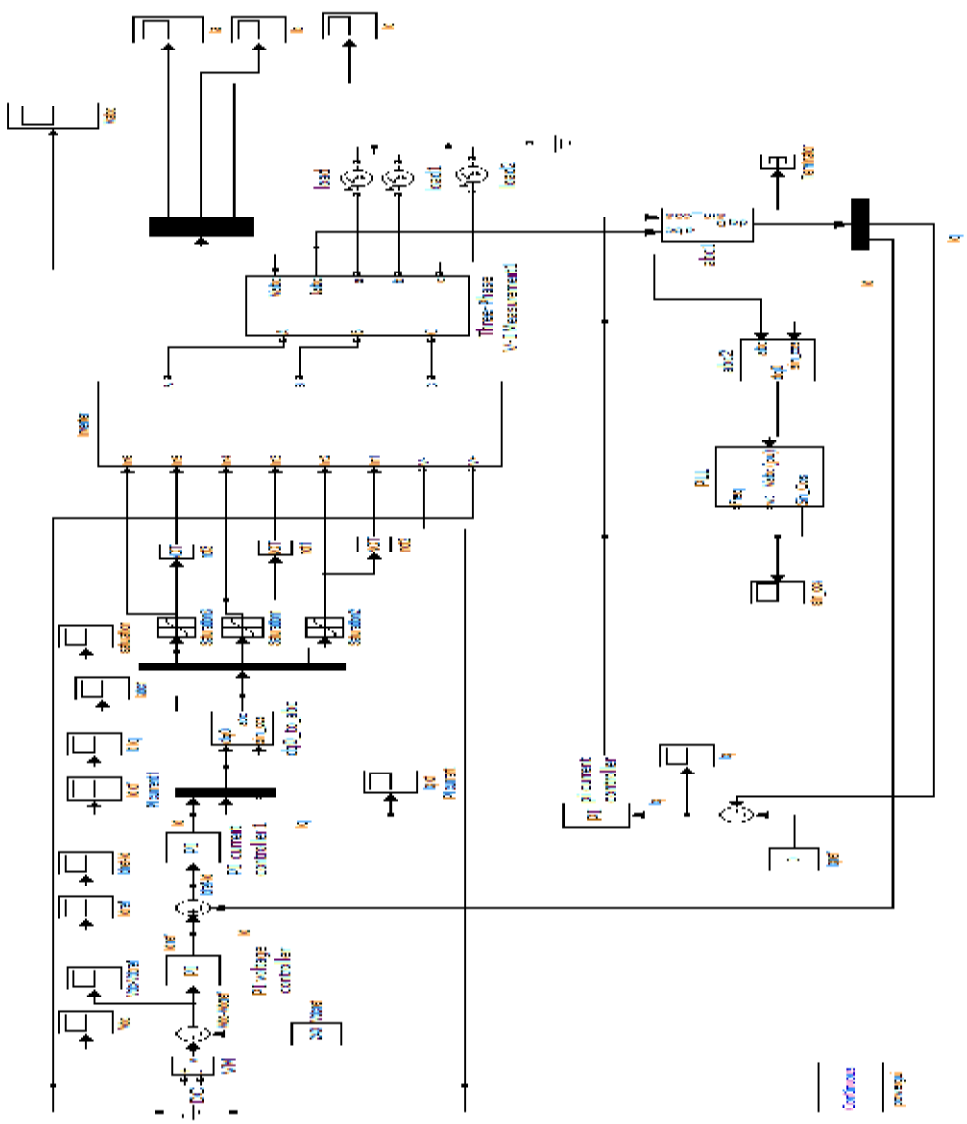

Fig 4.1: **simulation of grid connected inverter of solar system**

4.2 Instrument :

i. DC voltage source.
ii. Voltmeter.
iii. PI voltage controller.
iv. PI current controller.
v. DQ0_to_ABC transformation.
vi. Demultiplexer.
vii. Saturation.
viii. Logical gate NOT.
ix. Inverter subsystem.
x. IGBT.
xi. Three phase V-I measurement.
xii. ABC_to_DQ0 transformation.
xiii. Phase lock loop (PLL).
xiv. Multiplexer.
xv. Oscilloscope.

4.3 Using purpose of instrument:

i. **DC voltage source:** DC voltage source supply dc voltage to circuit.

ii. **Voltmeter:** The Voltage Measurement block measures the instantaneous voltage between two electric nodes. The output provides a Simulink signal that can be used by other Simulink blocks

iii. **PI voltage controller:** A PI voltage controller create reference current according to reference voltage.

iv. **PI current controller:** A PI Controller (proportional-integral controller) is a special case of the PID controller in which the derivative (D) of the error is not used. Pi generates reference current according to another current or voltage. We used Three PI controller in this simulation.

v. **DQ0_to_ABC transformation:** Perform Park transformation from dq0 reference frame to abc reference frame. . It transforms three quantities (direct axis, quadratic axis, and zero-sequence components) expressed in a two-axis reference frame back to phase quantities. Output of PI controller transform to abc reference frame using dq0_to_abc block.

vi. **De-multiplexer:** Extract and output elements of vector signal. The Demux block extracts the components of an input signal and outputs the components as separate signals. The output signals are ordered from top to bottom output port.

vii. **Saturation:** Limit range of signal. The Saturation block imposes upper and lower bounds on a signal. When the input signal is within the range specified by the Lower limit and Upper limit parameters, the input signal passes through unchanged. When the input signal is outside these bounds, the block clips the signal to the upper or lower bound. Output of dq0 to abc block passes through saturation block into inverter. We use three inverter in our simulation for provide gate pulses of inverter's IGBT.

viii. **Logical gate NOT:** Perform specified logical operation on input. The Logical Operator block performs the specified logical operation on its inputs. An input value is TRUE (1) if it is nonzero and FALSE (0) if it is zero. We select the Boolean operation connecting the inputs with the Operator parameter list. If you select rectangular as the Icon shape property, the block updates to display the name of the selected operator. The supported operations are given below.

Operation	Description
AND	TRUE if all inputs are TRUE
OR	TRUE if at least one input is TRUE
NAND	TRUE if at least one input is FALSE
NOR	TRUE when no inputs are TRUE
XOR	TRUE if an odd number of inputs are TRUE
NXOR	TRUE if an even number of inputs are TRUE
NOT	TRUE if the input is FALSE

ix. **Inverter subsystem :** a three phase inverter simulink into the subsystem. It converts dc voltage into ac voltage.

x. **IGBT:** The IGBT/Diode block is a simplified mode of an IGBT (or GTO or MOSFET)/Diode pair where the forward voltages of the forced-commutated device and diode are ignored. Main work of IGBT is switching in this inverter.

xi. **Three phase V-I measurement:** Measure three-phase currents and voltages in circuit.

xii. **ABC_to_DQ0 transformation:** Perform Park transformation from three-phase (abc) reference frame to dq0 reference frame. The abc_to_dq0 Transformation block computes the direct axis, quadratic axis, and zero sequence quantities in a two-axis rotating reference frame for a three-phase sinusoidal signal.

xiii. **Phase lock loop (PLL):** A phase-locked loop or phase lock loop (PLL) is a control system that generates an output signal whose phase is related to the phase of an input signal. While there are several differing types, it is easy to initially visualize as an electronic circuit consisting of a variable frequency oscillator and a phase detector. The oscillator generates a periodic signal. The output of PLL is joined the input port of abc to dq0 and dq0 to abc block.

xiv. **Multiplexer:** Combine several input signals into vector.

xv. **Oscilloscope:** Display signals generated during simulation.

4.4 working principle of control system:

In this circuit DC voltage source supply 240 volts. Figure 4.2 shows the voltage wave shape of DC voltage source. DC voltage source is connected with PI voltage controller by comparing a reference voltage. The PI voltage controller is used to generates the Id reference and reduce the steady state error. The fig-4.3 shows the input voltage wave shape of PI voltage controller and fig-4.4 shows output voltage of PI voltage controller.

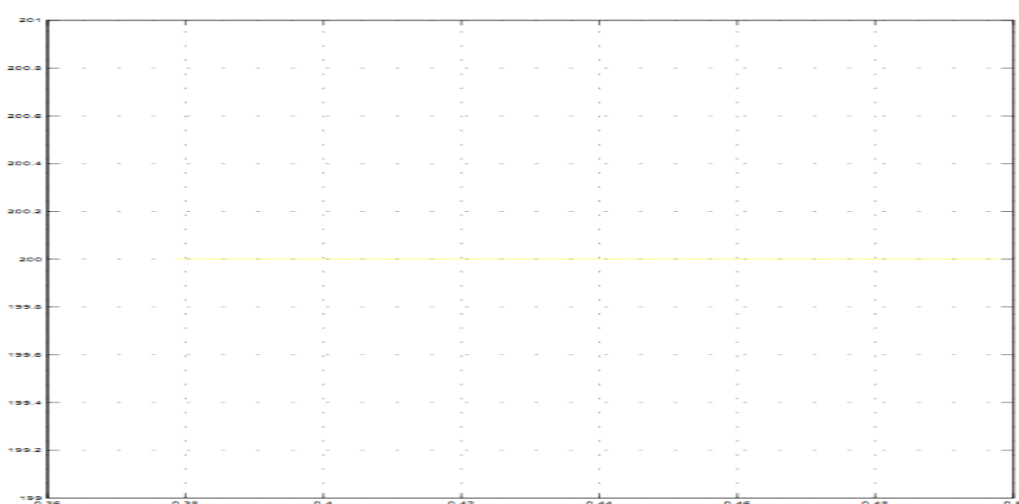

Fig 4.2: voltage of DC voltage source

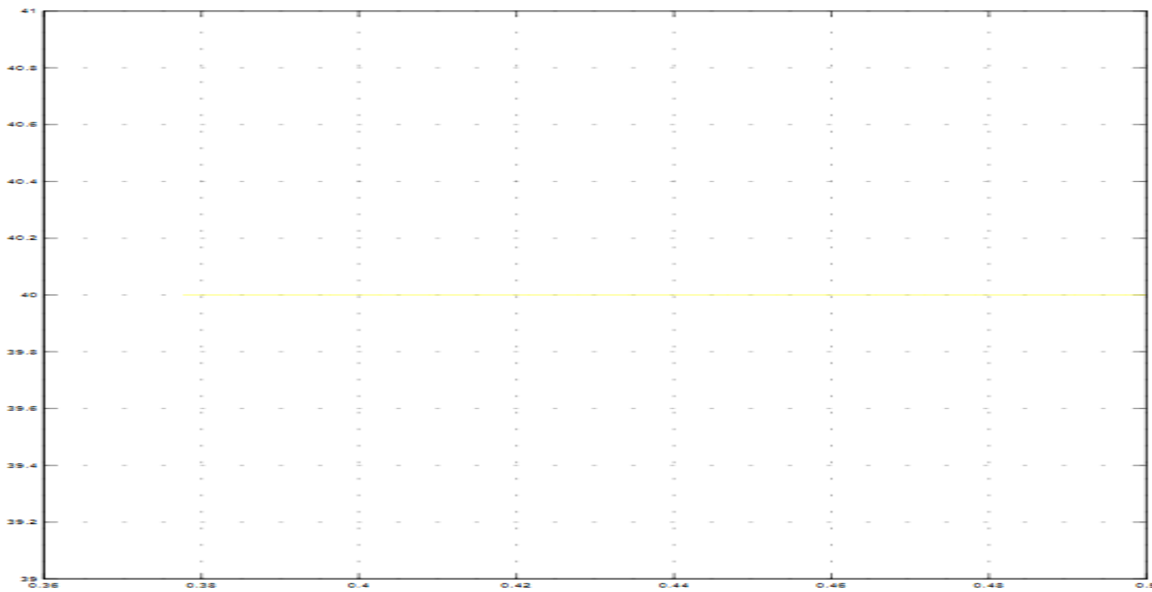

Fig-4.3: **$V_{dc} - V_{dcref}$**

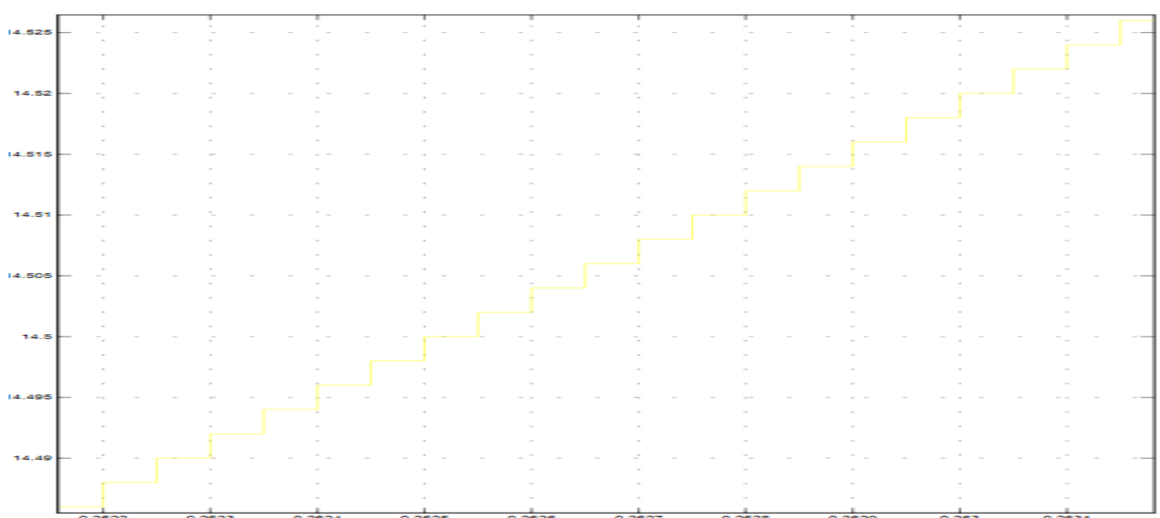

Fig-4.4: **Output Voltage of PI voltage controller**

Then actual Id current which is negative feedback generated by abc_to_dq0 block is compare with Id reference and then put into PI current controller. The input of PI current controller (I_{dref}-I_d) shows in fig-4.5 and output of PI current controller is shown in fig-4.6 .

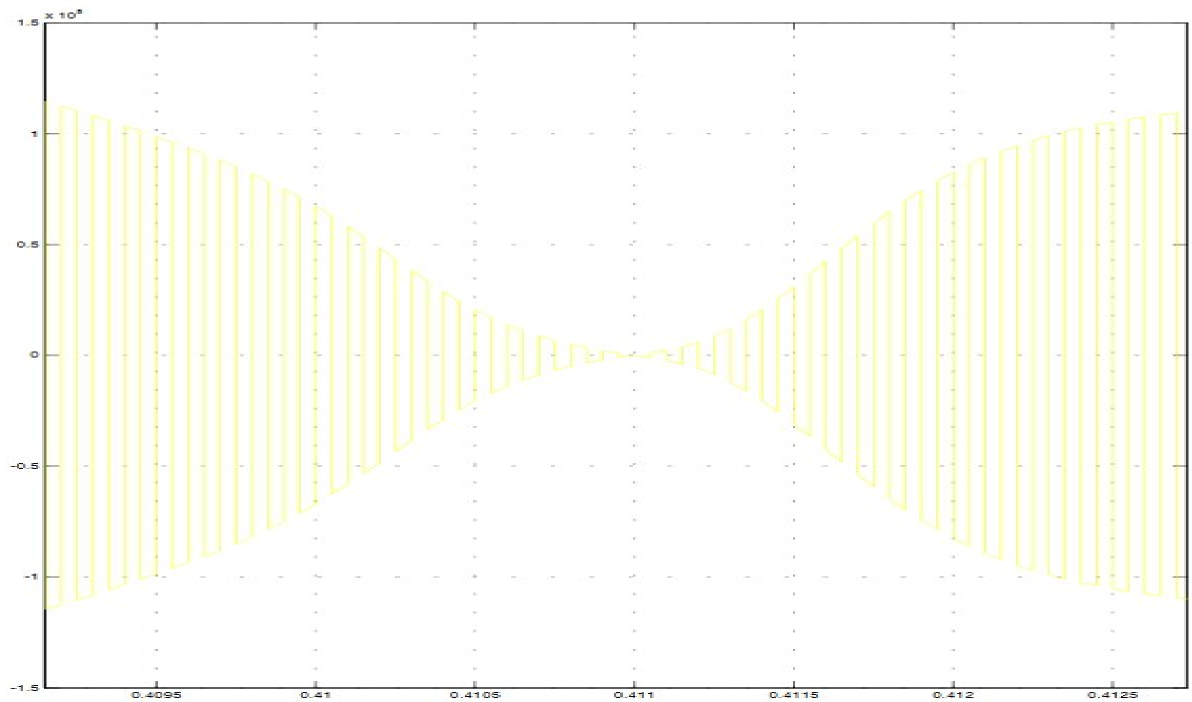

Fig-4.5: $\mathbf{I_{dref} - I_d}$

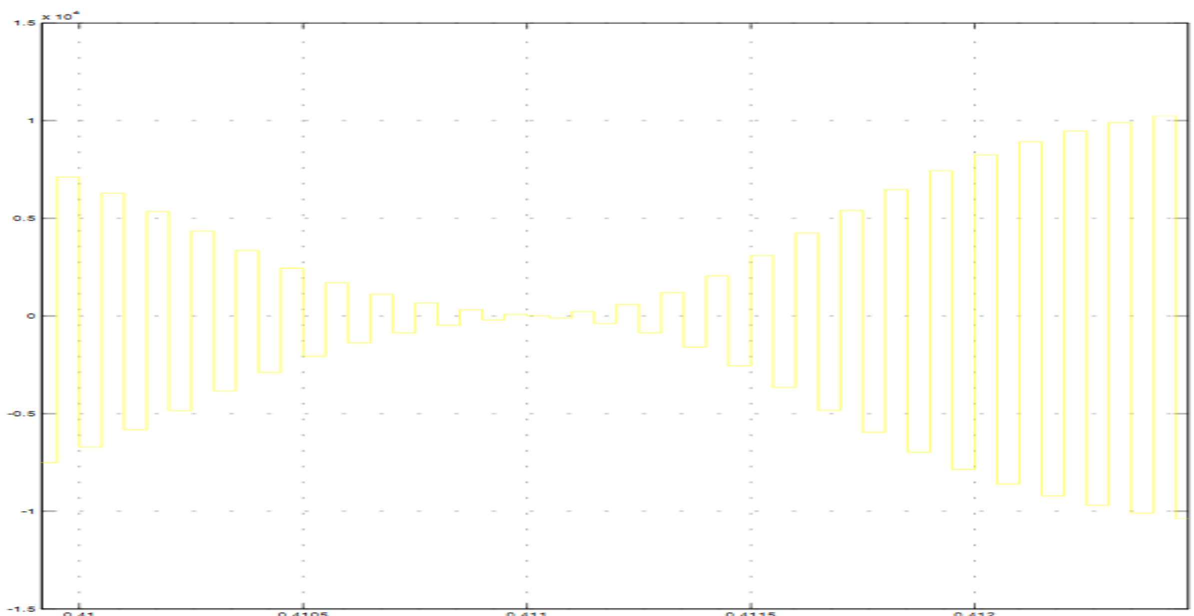

Fig-4.6: **Output voltage of PI current controller 1**

The actual I_q current which is negative feedback compared with reference I_q current is equal to zero. Then it passes through another PI current controller 2. The input and output of PI current controller 2 showed respectively fig-4.7 and fig-4.8. PI current controller reduces steady state error and this is the reason of using PI controller.

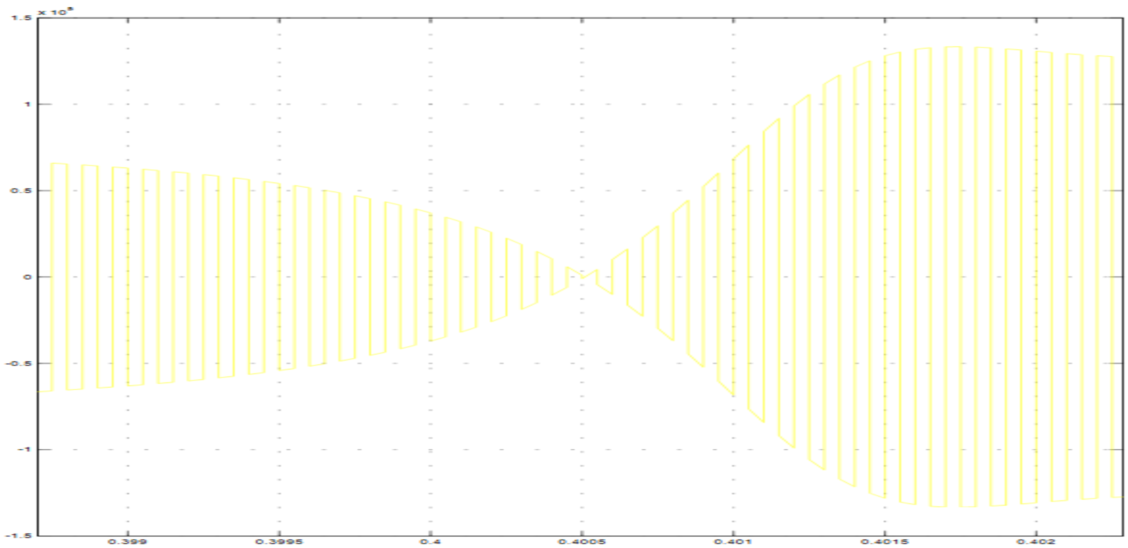

Fig-4.7: **Quadratic axis current**

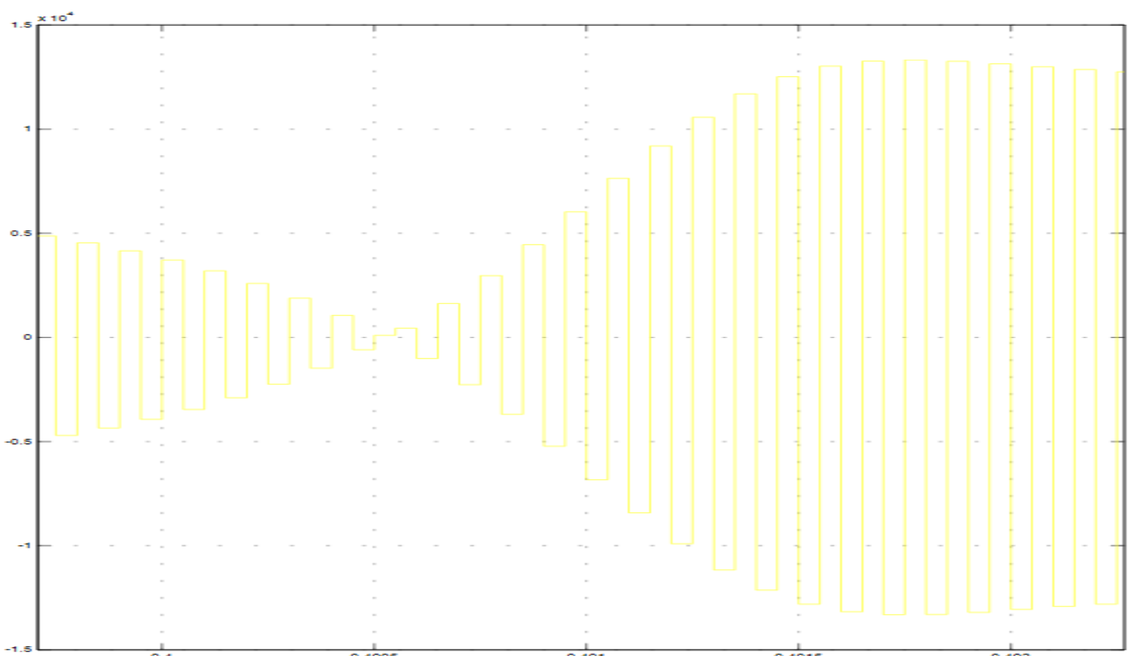

Fig-4.8: **Output current of PI controller-2**

The Id current and Iq current is transformed into three reference abc by dq0_to_abc transformation block. Dq0_to_abc transformation performs park transformation. It transforms three quantities (direct axis, quadratic axis, and zero-sequence components) expressed in a two-axis reference frame back to phase quantities. It require two input one is dq0 and another angular frequency which generated by phase lock loop. The output of dq0_to_abc block is connected with a multiplexer. Multiplexer separated output signal of dq0_to_abc block into three signals. Then three signals connect with three saturation block. Fig-4.9 shows wave shape of before multiplexer and Fig-4.10 shows signal wave shape after multiplexer.

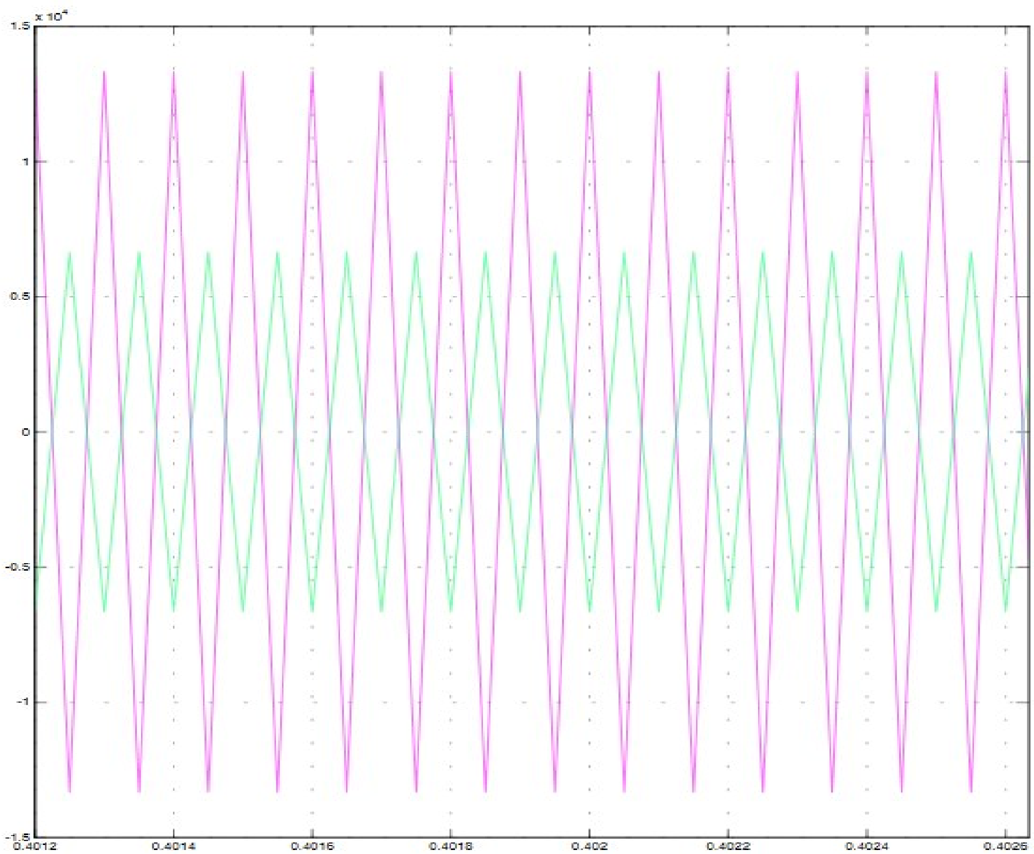

Fig-4.9: I_{abc} before mux

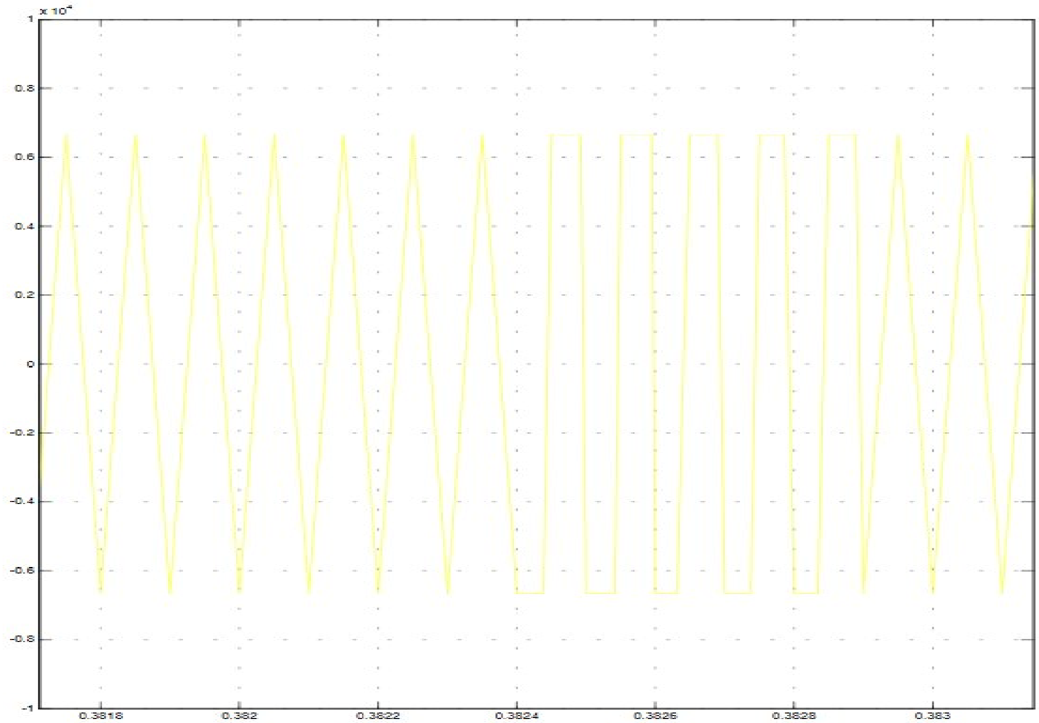

Fig-4.10: input of saturation

The output signal of saturation block connected with inverter's IGBT gate. The Saturation block imposes upper and lower bounds on a signal. When the input signal is within the range specified by the Lower limit and Upper limit parameters, the input signal passes through unchanged. When the input signal is outside these bounds, the block clips the signal to the upper or lower bound. Fig-4.11 is shown the gate pulse of inverter.

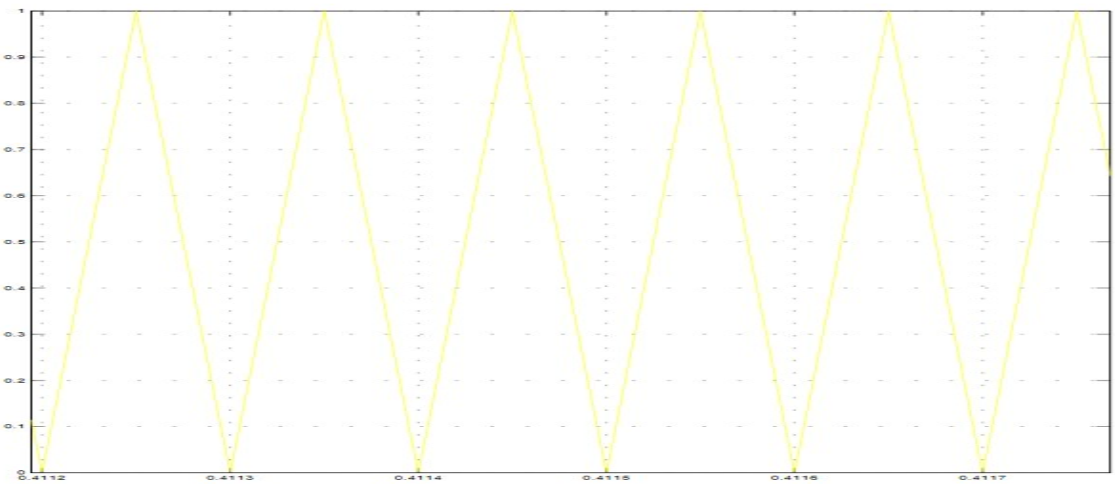

Fig-4.11: gate pulse-1

Inverter is used to convert the dc voltage to ac voltage. Inverter block is shown in fig-4.12 Inverter has six IGBT for switching. We connected a three phase V-I measurement block after inverter for measuring three phase voltage and current. The output of inverter connected with three loads.

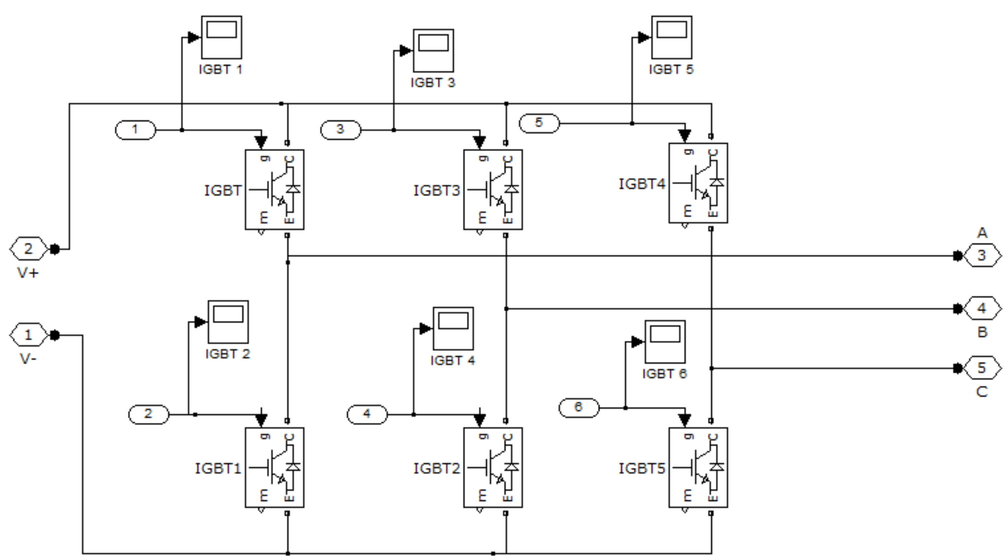

Fig-4.12: inverter circuit diagram

Abc_to_dq0 transformation block is used after inverter to Perform Park transformation from three-phase (abc) reference frame to dq0 reference frame. The abc_to_dq0 Transformation block computes the direct axis, quadratic axis, and zero sequence quantities in a two-axis rotating reference frame for a three-phase sinusoidal signal. The output of this block Id and Iq is connected with two PI current controllers.

A phase lock loop is used to generate an angular frequency which is connected with two abc_to_dq0 block and a dq0_to_abc block. Three phase voltage is shown in fig-4.13 and current of three phases is shown in fig-4.14, 4.15, and 4.16.

Fig-4.17 shows the angular frequency which is measured by phase lock loop (PLL).

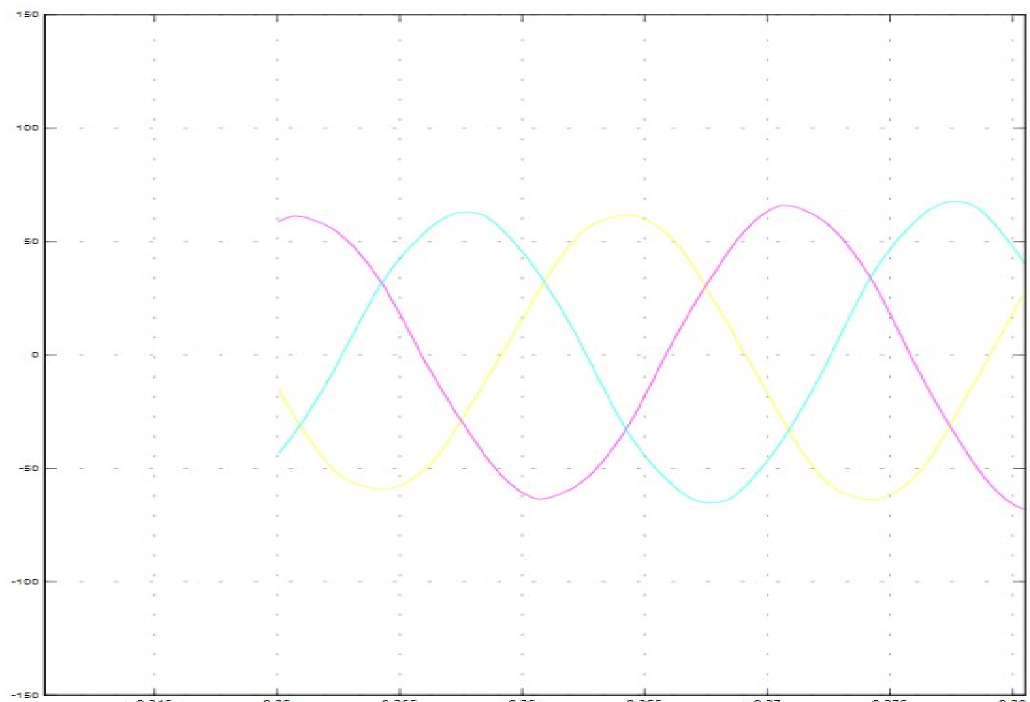

Fig-4.13: three phase voltage

Fig-4.14: current of phase a

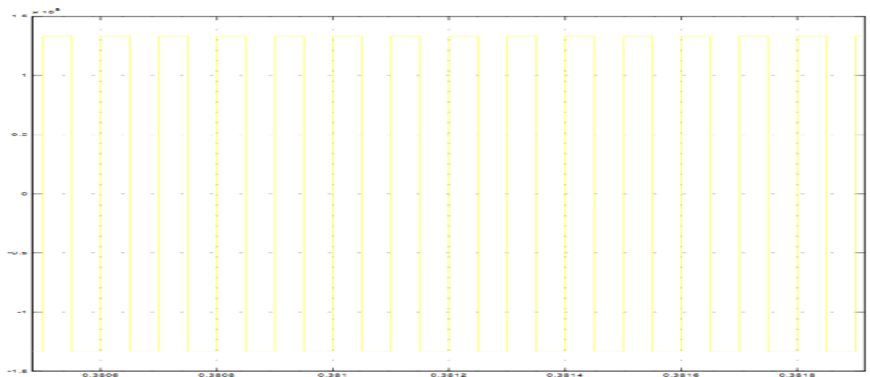

Fig-4.15: current of phase b

Fig-4.16: current of phase c

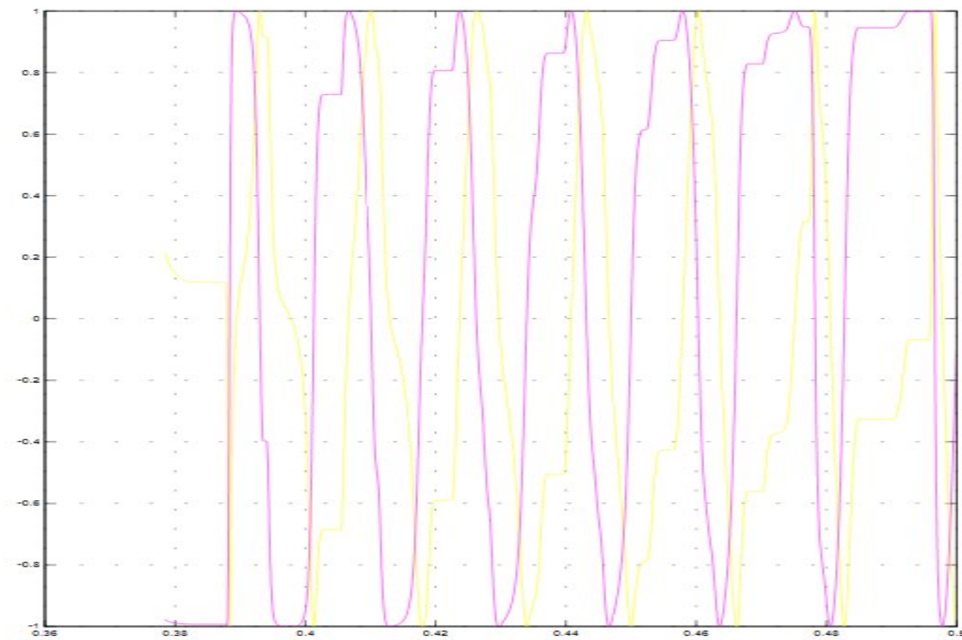

Fig-4.17: output of phase lock loop

Chapter-5: Conclusion

5.1 Conclusion:

This paper presents an approach of modeling and controlling of a grid connected PV system. The simulation of the whole system has been done in Matlab-Simulink. A dc/ac converter is use to convert the dc voltage of pv system into ac voltage. A negative feedback loop is used to control the inverter output voltage. Control block have pi controller to reduce steady state error and d-q transformation used because this method simplified the system that make easier to analysis. PLL is to generate an angular frequency. The output voltage of inverter is pure sine wave and output current of inverter should be continuous.

5.2 Reference:

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