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# MATLAB Realisation of SVPWM Based Speed Control of Asynchronous Machine Fed From Solar Cell Array

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**ABSTRACT**: The lake of Conventional resources and high cost of electrical energy production form oil, gas and coal lead to the development and enhancement of new alternate energy sources like solar, wind, tidal etc. The solar energy sources best advantage is environmental friendly and enormous source of huge amount of energy. This energy operating cost is also cheap and easy to setup in domestic and industrial purposes. This paper is mainly Focuses on MATLAB/ SIMULINK model of Space Vector controlled Asynchronous Motor Using Solar cell Array. The reason to choose MATLAB / SIMULINK as a development tool is because it is the most widely used software in Electrical Engineering. The Solar cell simulation model has been developed in the Sim Electronics Tool box and SVPWM based speed control model has been developed in Sim Power System Tool box. These two different tool models are connected through PS-SIMULINK converters. In this paper we are controlling the speed of asynchronous motor using SVPWM and motor is operated through Solar cell array. We are using 3-level inverter to convert DC to DC converter output into AC voltage. This inverter output is fed into asynchronous motor. Inverter gate pulses are generated through SVPWM.

**KEYWORDS:** Solar cell Array, DC to DC converter, 3-level inverter, asynchronous motor SIMULINK converters.

## I.INTRODUCTION

Energy is the basic need of a human life and it plays a very important role for the economical development of any Country. For the environment point of view, the big disadvantages of conventional energy sources are of their pollution. The renewable energy sources are free from pollution. Solar energy is the biggest alternative source of electrical energy and has a potential of about 178 billion MW which is about 20,000 times of the world energy demand. It has disadvantage of large space requirement to establish it. India is a country where sun light is always present throughout the major part of the year [2].

The application of solar energy which is most popular is solar water heater, solar cookers, food refrigeration, satellites, emergency power supply, portable power supply and solar Photovoltaic cell. In this work solar photovoltaic cell and SVPWM controlled Inverter are the main concern. The physical quantity (Sun radiation) is directly convert into DC voltage using solar cell array and then generate a SVPWM from the reference speed to operate the inverter [1] & [2]. A DC-DC converter is a combination of power electronic switches used to convert DC into variable DC and it is autonomous to DC equivalent to AC transformer [4] & [5]. As output of solar array is very less but in this SIMULINK model 72 cells are connected in series manner which output is 23.75 V so that we have to increase its output via DC-DC converter. Figure 1 shows the block diagram of Speed control of three phase asynchronous motor fed from solar cell array through the 3 phase inverter. Inverter is a combination of solid state power electronics devices to convert DC voltage into AC voltage for the 3 phase Motor load. There are 2 configurations of inverter mode of operation which is (1) 120 degree mode of conduction and (2) 180 degree mode of conduction. 180 degree conduction is more effective than 120 degree conduction because in 120 degree conduction, one transistor conducts for 120 degree so the transistors are less utilized as compared to that of 180 degree conduction for the same load condition [7].

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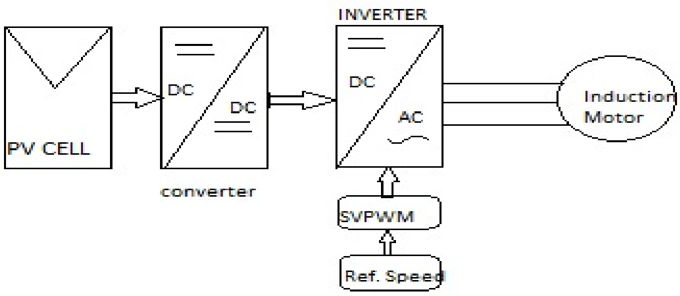


Figure 1: A Proposed Block diagram of Simulation

## II. SOLAR CELL ARRAY MODULE

Solar cell is basically a PN junctions in which the light is incident and the electromagnetic radiation of sun is directly convert into electricity through Photovoltaic effect. In this paper for making Solar cell array 72 cells are connected in series. The block model of solar cell is a parallel combination of Current source, two diodes and a parallel resister Rp in series with the resistance Rs. The output current equation of solar cell is given by

$$I = Iph - Is*(e^{\wedge}((V+I*Rs)/(N*Vt))-1) - Is2*(e^{\wedge}((V+I*Rs)/(N2*Vt))-1) - (V+I*Rs)/Rp$$

Here I = output current
Is and Is2 = diode saturation currents
Vt = thermal voltage
N and N2 = quality factors (diode emission coefficients)
Iph = solar-generated current

the parameters of the solar cell are shown in the figure 2.

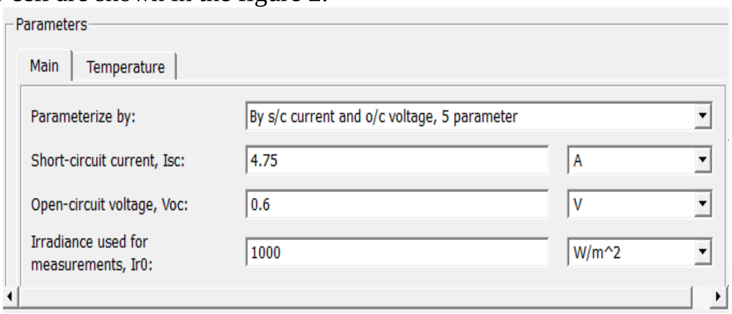


Figure 2: Solar cell parameters

72 solar cells are connected in series to get the output of 23.75 V.

## III. DC-DC CONVERTER

A boost converter is a type of DC-DC converter which uses Power Electronic switch to convert the DC voltage level to a higher level with minimum ripple. The boost converter is a popular non-isolated step up converter. This converter is using in solar system to step up lower output of solar array to a high level . In this system output of Solar array is 23.75 V and the output of DC-DC converter is 45.66 V. The boost converter input current is continues and non pulsating and a output diode is only conducts in a portion of switching cycle then output capacitor only supplies continues the load current for the rest of switching cycle . The boost converter is a medium of power transfer between input to output and output to input to perform energy absorption and injection from solar panel to the three phase inverter. The process of power transfer is by a combination of 4 components which are inductor, Power electronic switch, and diode and output capacitor. The connection of a boost converter is shown in Figure 3. The process of energy absorption and injection will constitute a switching cycle. In other way, the average output voltage is controlled by the switch ON and OFF time of the duty cycle. At constant switching frequency, adjusting the ON and OFF time duration of the switch is called

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pulse-width-modulation (PWM) switching technique. The switching duty cycle, k is defined as the ratio of the ON time to the total switching time period. The output voltage of the boost converter is

$$V_{out} = \frac{1}{(1-k)}\ \text{Vs}$$

Where is k = Duty Cycle

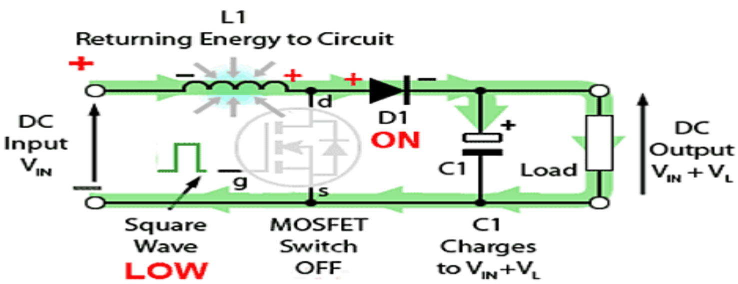


Figure 3: Basic circuit diagram of boost converter

## IV. INVERTER CIRCUIT

Now a day's generation is mainly depends on renewable energy sources. Most of these generate the electricity in DC so that our maximum Loads are working on Ac. So it is very important that we have to convert DC into AC. It is done by power electronics converter called Inverter. By choosing Appropriate modulation index and control of static switches of inverter the voltage and frequency levels are varied. The extensive use of SVPWM technique is because of it's digital implementation and maximum utilization of DC bus voltage. 3 phase inverter is having 8 switching states in that 2 are null states and 6 are active states which are used to control the inverter output voltage and frequency.

For the study of SVPWM technique 3 Phase coordinate system is converted in to $\alpha - \beta$ Plane. In this technique the referring voltage vector $V_{ref}$ that rotates in the space with an angular velocity w is selected as a control instruction. When it arrives in one of the 6 sectors 1~6, two effective voltage space vectors nearest to $V_{ref}$ as well as one of the two null vectors (V0 or V1) are selected to equal $V_{ref}$ by means of different operating time of various vectors, and the power switches in the inverter are drove under the switch conditions corresponding to selected vectors, (000, 001,...or 111), "0" for off and "1". The inverter outputs a cycle of sinusoidal voltage when $V_{ref}$ has made one revolution in space.

### A. SVPWM ALGORITHEM STEPS

SVPWM methods have fallowing steps:
1. Determination of $V_\alpha, V_\beta, V_{ref}$ and angle (α).
2. Determination of time durations $T_1, T_2, T_0$
3. Determination of switching times of the switches

Step – 1:- Determination of $V_\alpha, V_\beta, V_{ref}$ and angle (α).
Space vector is defined as,

$$V_S = \frac{2}{3}(V_A + \alpha V_B + \alpha^2 V_C)$$

$$\text{Where } \alpha = e^{-j\frac{2\pi}{3}}$$

By the principle of SVPWM $V_\alpha$ and $V_\beta$ are obtained by

$$\begin{bmatrix} V_\alpha \\ V_\beta \end{bmatrix} = \frac{2}{3}\begin{bmatrix} 1 & -1/2 & -1/2 \\ 1 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix}\begin{bmatrix} V_A \\ V_B \\ V_C \end{bmatrix}$$

Here 3-phase quantities are reduced to two phase, one is direct axis (real axis) and other is quadrature axis (imaginary axis). These two quantities represented as the magnitude ($V_{ref}$) and angle (w). $V_{ref}$ Rotates with the speed of angular velocity (w=2πf). SVPWM is the combination of the reference voltage and 8 switching states of the inverter. The Basic switching vector and sector diagram is shown in figure 2, forms a hexagon which can be seen as consisting of six

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sectors spanning 60°each. The reference vector which represents three-phase sinusoidal voltage is generated using SVPWM by switching between two nearest active vectors and zero vectors.

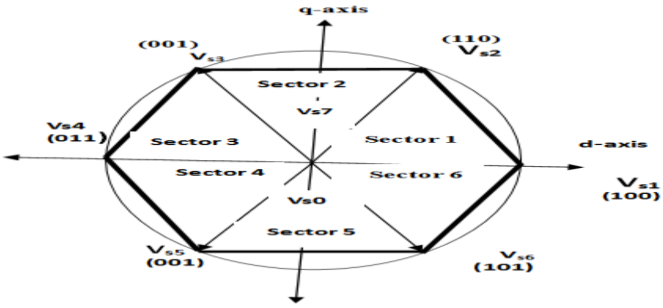



Figure 4: Representation of space vector in complex plane

The $V_{ref}$ and angle α is given by:

$$V_{ref} = \sqrt{V_\alpha^2 + V_\beta^2} \text{ and } \alpha = tan^{-1}\left(\frac{V_\beta}{V_\alpha}\right)$$

Step- 2:- Determination of time durations $T_1$, $T_2$ , $T_0$ To calculate the time of application of different vectors, consider Figure 5, depicting the position of different available space vectors and the reference vector in the first sector.

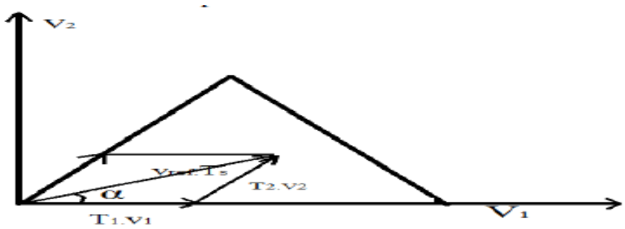



Figure 5: principles of space vector time calculations

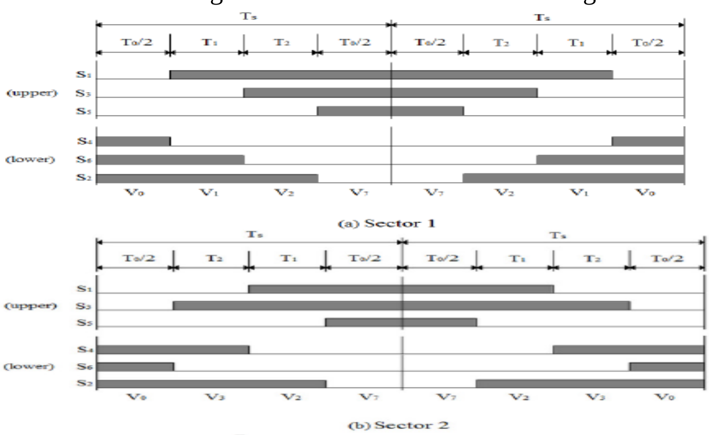
The time of active vector is calculated by following equations:

$$T_1 = \sqrt{3}\,\frac{V_{ref}}{V_d}\,T_S \sin\left(\frac{n\,\pi}{3} - \alpha\right)$$

$$T_2 = \sqrt{3}\,\frac{V_{ref}}{V_d}\,T_S \sin\left(\alpha - \frac{(n-1)\pi}{3}\right)$$

$$T_0 = T_s - T_1 - T_2$$

The switching time of each sector is shown in figure 6



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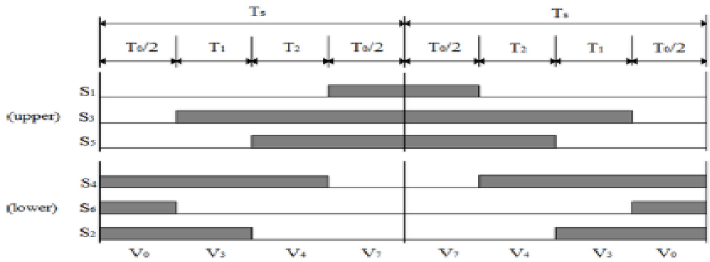
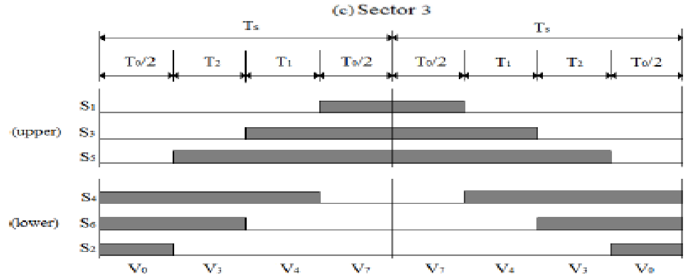
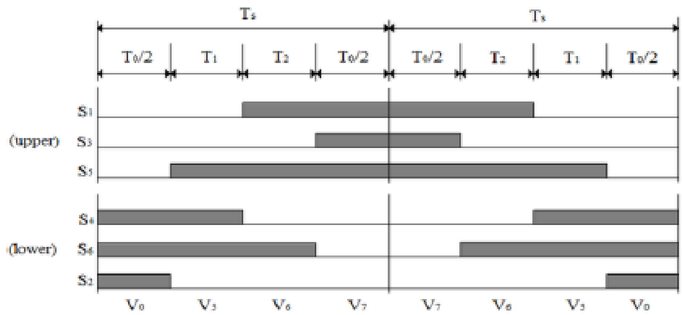


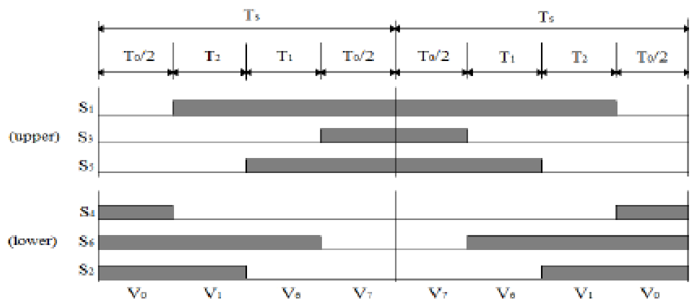

(c) Sector 3




(d) Sector 4




(e) Sector 5




(f) Sector 6

Figure 6: switching states ($S_1$ to$S_6$)

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TABLE 1: Switch time calculations

| Sector | Upper switches $(S_1, S_3, S_5)$ | Lower switches $(S_4, S_6, S_2)$ |
|---|---|---|
| 1 | $S_1 = T_1 + T_2 + {T_0}/{2}$ $S_3 = T_2 + {T_0}/{2}$ $S_5 = {T_0}/{2}$ | $S_4 = {T_0}/{2}$ $S_6 = T_1 + {T_0}/{2}$ $S_2 = T_1 + T_2 + {T_0}/{2}$ |
| 2 | $S_1 = T_1 + {T_0}/{2}$ $S_3 = T_1 + T_2 + {T_0}/{2}$ $S_5 = {T_0}/{2}$ | $S_4 = T_2 + {T_0}/{2}$ $S_6 = {T_0}/{2}$ $S_2 = T_1 + T_2 + {T_0}/{2}$ |
| 3 | $S_1 = {T_0}/{2}$ $S_3 = T_1 + T_2 + {T_0}/{2}$ $S_5 = T_2 + {T_0}/{2}$ | $S_4 = T_1 + T_2 + {T_0}/{2}$ $S_6 = {T_0}/{2}$ $S_2 = T_1 + {T_0}/{2}$ |
| 4 | $S_1 = {T_0}/{2}$ $S_3 = T_1 + {T_0}/{2}$ $S_5 = T_1 + T_2 + {T_0}/{2}$ | $S_4 = T_1 + T_2 + {T_0}/{2}$ $S_6 = T_2 + {T_0}/{2}$ $S_2 = {T_0}/{2}$ |
| 6 | $S_1 = T_1 + T_2 + {T_0}/{2}$ $S_3 = {T_0}/{2}$ $S_5 = T_1 + {T_0}/{2}$ | $S_4 = {T_0}/{2}$ $S_6 = T_1 + T_2 + {T_0}/{2}$ $S_2 = T_2 + {T_0}/{2}$ |
| 5 | $S_1 = T_2 + {T_0}/{2}$ $S_3 = {T_0}/{2}$ $S_5 = T_1 + T_2 + {T_0}/{2}$ | $S_4 = T_1 + {T_0}/{2}$ $S_6 = T_1 + T_2 + {T_0}/{2}$ $S_2 = {T_0}/{2}$ |

Here in this model we are using reference speed for the generation of SVPWM.

## V. MATLAB SIMULATION of PV ARRAY FED ASYNCHRONOUS MOTOR

In this model by using SVPWM the speed of motor is controlled. Reference speed is the most advantage to give SVPWM to control the inverter Switches.

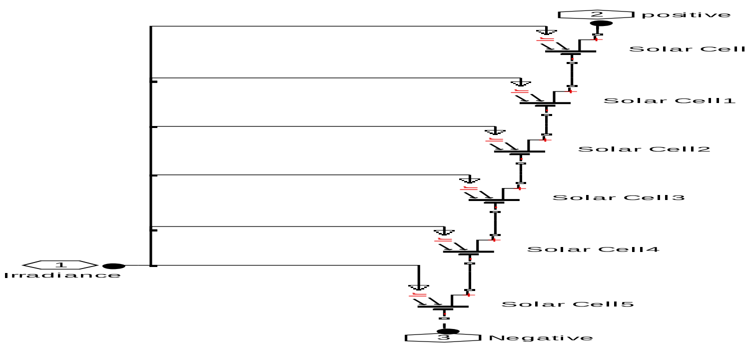


Figure 7: 6 solar cell connected in series

All the solar cell array are connected in series to get better output voltage.

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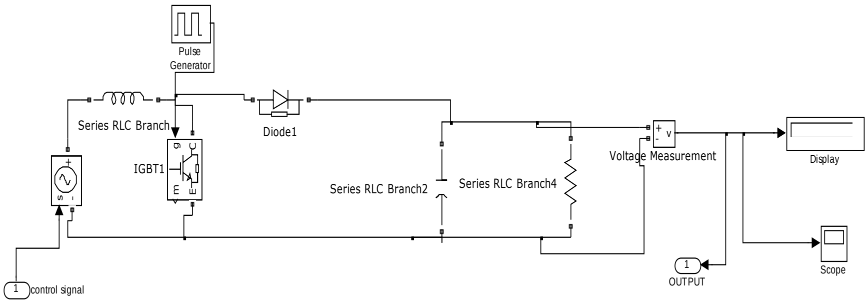


Figure 8: DC to DC converter

This is the boost converter circuit which can be used to boost up the solar cell array output voltage.

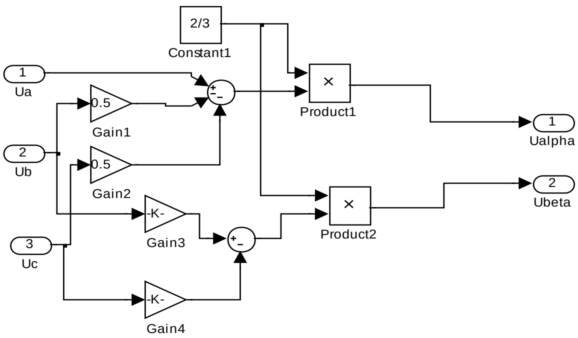


Figure 9: 3 phases to 2 phase conversion

This is the circuit which used to convert 3 phase ABC in to 2 phase conversion (dq). This technique can be used for reduced the mathematical calculations.

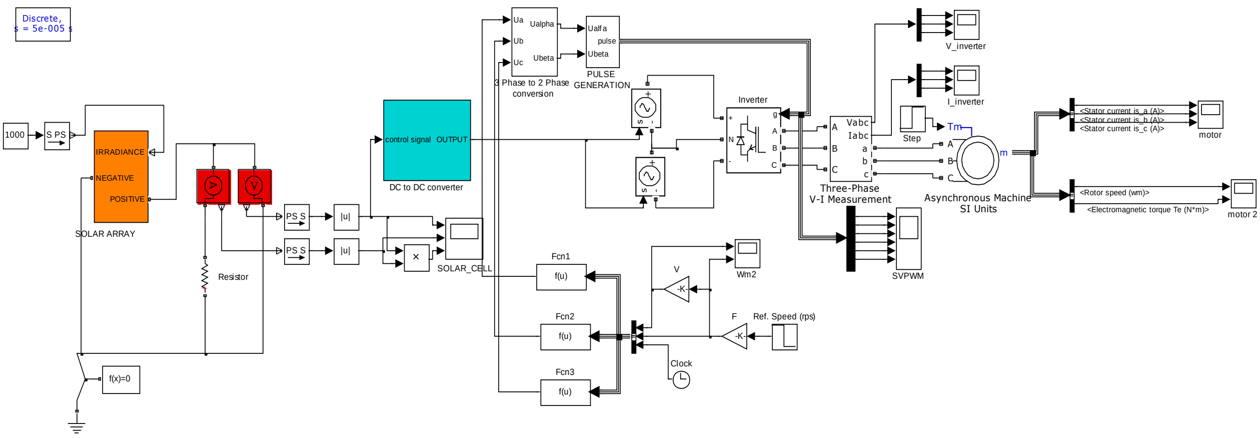


Figure 10: Complete Model

## VI. SIMULATION RESULTS

For this developed model some of the results are taken for solar cell array, DC-DC converter, and inverter, output waveform of reference current generation through SVPWM technique and motor current and torque.

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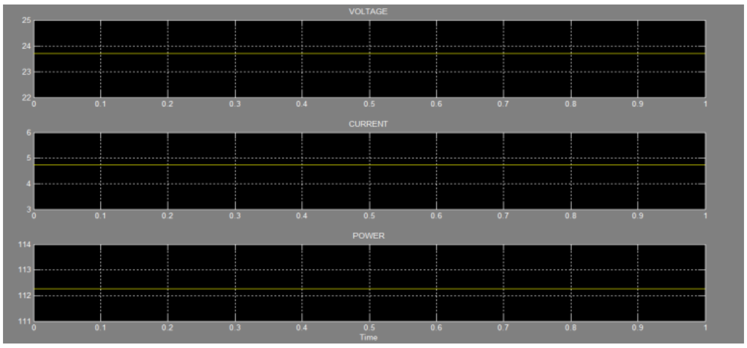


Figure 11: Solar cell Output

This voltage, current and power of 72 cell solar array. The output of this solar cell array is 23.75 V.

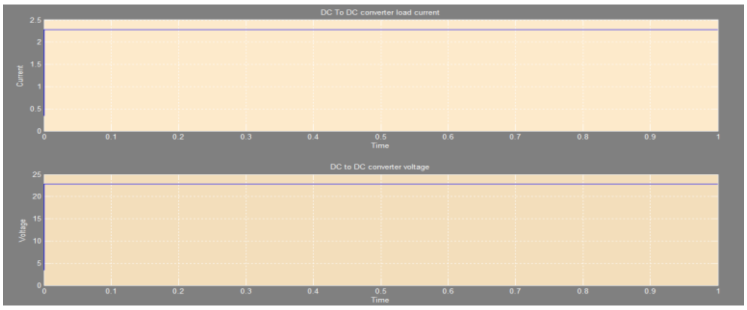


Figure 12: DC to DC converter Output

This is the output of boost converter which boosts the voltage of solar cell array.

Figure 13: SVPWM generation

This is the reference current generation for 3 level inverter through SVPWM. The input of SVPWM is reference speed of asynchronous motor.

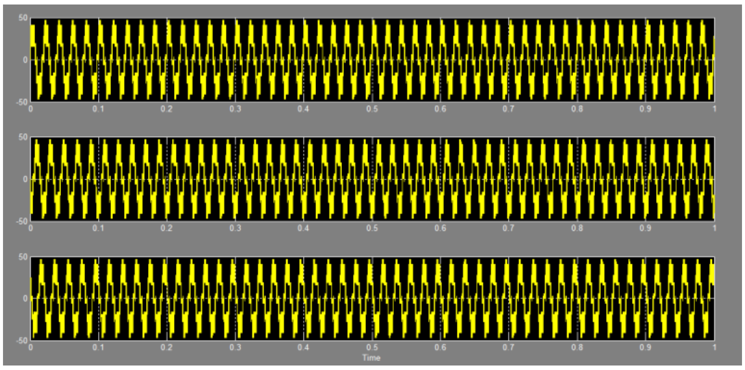

Figure 14: 3-Phase voltage of inverter

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This is the 3 level output of inverter.

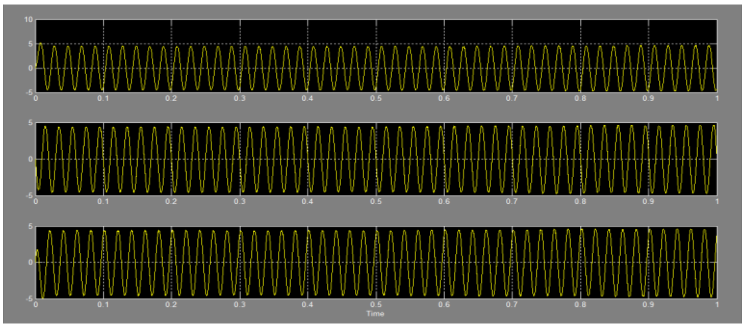

Figure 15: 3-Phase Current of inverter

It is three phase current of inverter which is given to the motor.

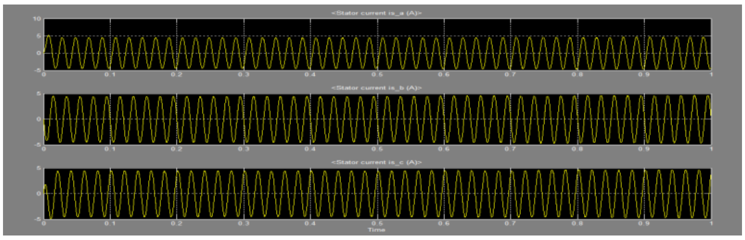

Figure 16: 3-Phase Motor Currents

It is the stator current of 3 phases of motor.

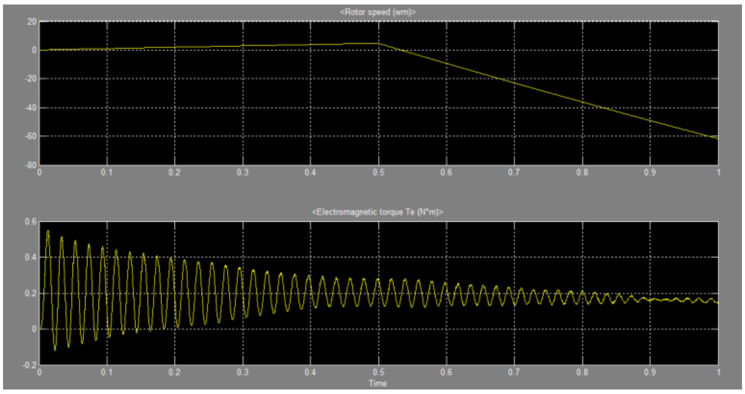


FIGURE 17: 3-PHASE MOTOR TORQUE AND ROTOR SPEED

It is the torque and rotor speed of induction motor.

## VII. CONCLUSION

In this paper a simple MATLAB / SIMULINK model has been presented to implement SVPWM based speed control of Asynchronous machine fed from SOLAR CELL ARRAY. A brief description is also given on solar cell array, DC to DC converter, SVPWM controlled inverter and speed control of asynchronous motor. The step by step development of the model is reported. By changing the irradiance on the solar cell varying the output of voltage and current of solar Array.

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## BIOGRAPHY

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