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Speed Control of Solar Powered Induction Motor Drive using SVPWM Technique

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Abstract**—**A voltage source inverter is used to supply three phase induction motor load. The non-renewable energy resources are widely used in power generation but they are environmentally unfriendly. The use of non-conventional energy resources is an alternative solution for overcoming the global warming. Solar energy has significant potential among all the renewable energy resources because it is easily available in nature. As photo voltaic array has low configurable efficiency, by tracking the maximum power point by means of boost converter we can get maximum DC power. In this paper, Maximum power point Tracking (MPPT) is used by boost converter and its output is fed to the inverter for speed control of induction motor drive. These drives always require adjustable frequency and voltage. Presently pulse width modulation Inverter (PWM) is one of the ways to achieve better performance. Space vector Pulse Width Modulation (SVPWM) has attracted much interest for advanced industrial applications. Even though implementing SVPWM is computationally complex, it provides better use of supply voltage when compared with SPWM. The developed model is simulated in MATLAB/SIMULINK.

Keywords- *Induction motor, MPPT, Renewable energy, Speed control, SVPWM*

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I. INTRODUCTION

The power generation from non-renewable energy resources like coal, gas, petrol, etc raises environmental concerns, which leads to global warming. A movement towards the generation of non-conventional sources of energy like biogas, geothermal, solar, wind, etc; is therefore solution to reduce greenhouse gas emissions globally. Solar energy has a significant potential among all the non-conventional resources. The main applications of solar energy are photo voltaic, solar heating, solar cookers and food processors, solar thermal electricity, satellites, etc. In industries they are used for Dryers, chilling, electrification, electric furnace, steam processing, water pumping, etc. The advantages of photovoltaic are low maintenance, provides cost effective electricity for remote areas, long life [1].

Voltage source inverters (VSI) are widely used in electric drive applications. The performance of an inverter mainly depends on the type of PWM technique used. PWM techniques produces high quality Waveforms [2], ensures reduction of problems like harmonic losses [3], common mode voltage reduction [4] and these can be implemented with modern control chips [5]. PWMs can also be used to lower the voltage stress and losses in motor loads [6].

In this paper, the developed model has two stages, as shown in Fig. 1. In the first stage, DC supply to inverter was fed from the solar panel; the maximum power was tracked by means of boost converter. In the second stage, the speed of the induction machine (IM) is controlled by the control SVPWM controller. The paper is organized as follows, section II presents about the MPPT based solar power module, section III discusses about SVPWM. Section IV presents the simulation model and results of developed system, finally section V concludes the solar powered system with its applications.

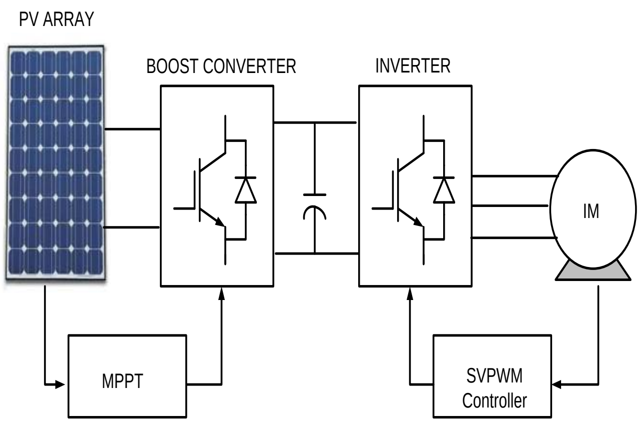

Fig.1. Block diagram of solar power fed IM drive system

II. MPPT BASED SOLAR POWER MODULE

The MPPT based solar power module has three main parts; namely PV array, controller (MPPT), and boost converter. The modeling of PV array is given in [5] and its V-I characteristics equation is given by,

$$I = I_{sc} - I_o\left\{e^{\left[q\left(\frac{v+R_s I}{nKT_k}\right)\right]} - I\right\} - \left((v + R_s I)/R_{sh}\right) \tag{1}$$

Where,

V and I represent the output voltage and current of the PV, respectively.
R_s and R_{sh} are the series and shunt resistance of the cell.
q is the electronic charge.
I_{SC} is the light-generated current.
I_o is the reverse saturation current.

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n is a dimensionless factor.
k is the Boltzman constant, and
T_k is the temperature in ^oK.

MPPT is algorithm that includes in charge controllers used for extract maximum available power from PV model under certain considerations. The voltage at which maximum has tracked is called MPPT point. It varies with ambient temperature, radiation and solar cell temperature. The main different types of MPPT algorithms available are perturb and observe (P&O), incremental conductance (INC), current shift method, and constant voltage [7, 8]. There some special algorithms based on fuzzy, neural networks, PSO and pilot cells [9, 10]. In spite of these, P&O and INC techniques are mostly used for low cost implementation. Maximum power is tracked by periodically incrementing and decrementing the PV array voltage. If a given perturbation results in increase/decrease output power of PV, then the subsequent perturbation is generated in same/opposite direction [11]. Fig. 2 shows the flowchart of the P&O algorithm technique.

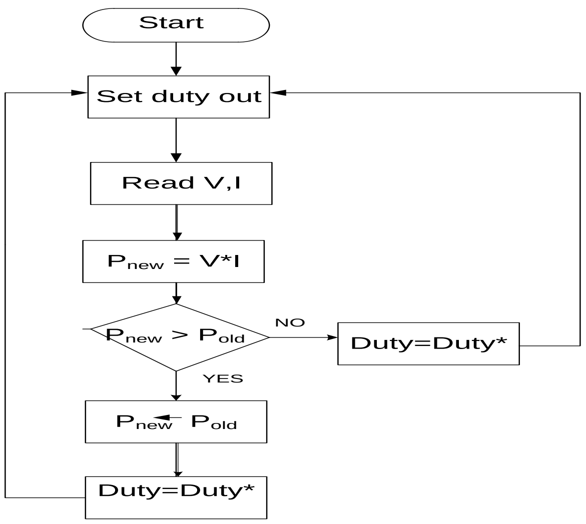
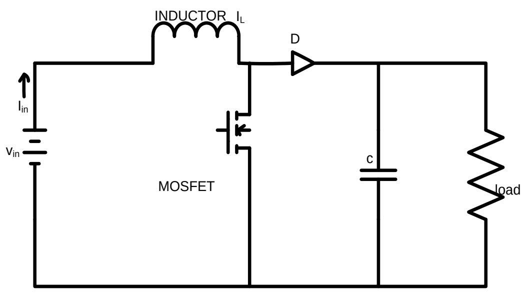


Fig.2 Flow chart of P&O algorithm

The boost converter is used to boost up the DC voltage of PV array to the DC link of inverter. The duty ratio is set by the MPPT. The boost converter topology and its waveforms are shown in figure 3.



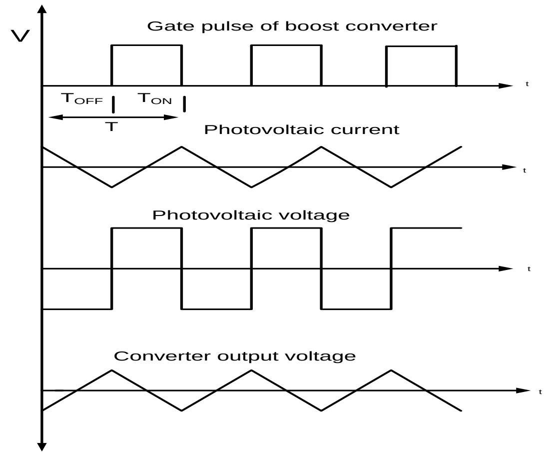


Fig.3 Boost converter circuit and its wave forms

The equations of boost converter are given by,

$$V_{out} = (1/(1-\delta)) * V_{in} \quad (2)$$

$$\delta = t_{on}/T \quad (3)$$

$$T = (t_{on} + t_{off}) \quad (4)$$

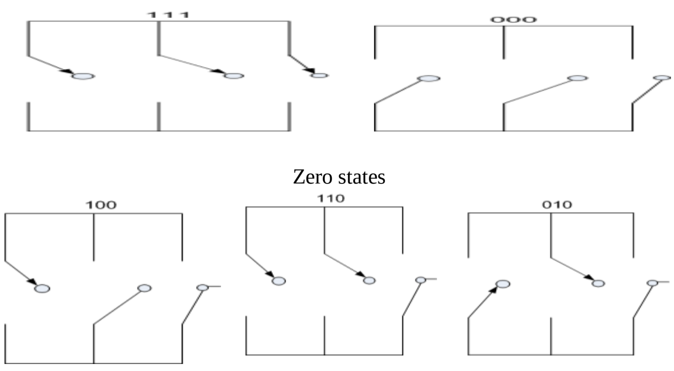
Where, V_{in} and V_{out} are the input and output voltage of boost converter respectively
T is time period of pulse

III. SPACE VECTOR PULSE WIDTH MODULATION

A. General Description

SVPWM offers better performance over other PWMs. We can implement it on n-level inverter [12]. SPWM treats three phase inverter as three different units. Unlike SPWM, SVPWM treats it as a single unit.

Generally modulation can be done with the help of switching inverter state [13]. In this technique selection of switching states and their time periods calculation is very important. This can be done by space vector transformation [14]. There are 8 possible vectors are possible in 2 level inverters. If the top switch is on state =1, if the bottom switch is on switch state =0. Eight possible states are base for SVM principle as shown in figure 4 and corresponding state space representation is shown in figure 5.



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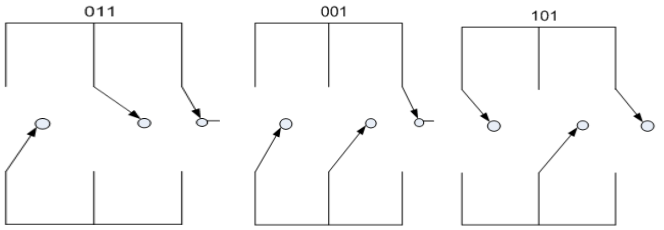

Active states

Fig.4 switching states

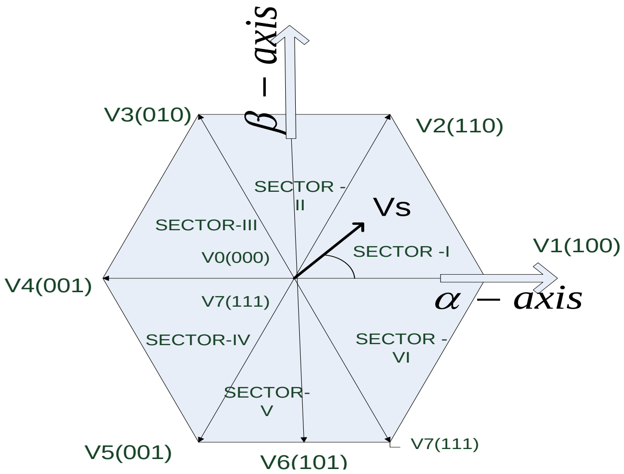

Fig.5 State space representation

In the state space representation each sector makes an angle of 60^0. Zero vectors are placed at the Centre of hexagon and active vectors are located at the edges of the hexagon.

B. Development of Simulation Model

Concept of space vector (SV) originates from axes-transformation [15]. SV leads to transformation of 3 phase quantities to 2 phase quantities. SVPWM offers better flexibility in terms of switching sequences. Its implementation is computationally complex because it involves so many mathematical calculations and efforts. Steps involved for development of simulation model are discussed briefly here.

1. Three phase to two phase transformation

The three phase signals which are displaced by an angle of 120^0 are converted into two phase signals. This transformation is shown in Fig .6

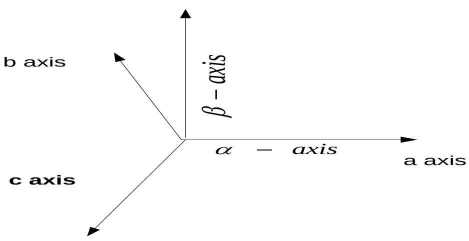

Fig. 6 abc to αβ Transformation

Equations corresponding to 3 phase to 2 phase transformation.

$$V_\alpha = \frac{2}{3}[(V_a) - \frac{1}{2}(V_b + V_c)] \quad (5)$$

$$V_\beta = \frac{1}{\sqrt{3}}[(V_b + V_c)] \quad (6)$$

2. Calculation of angle and identification of sector

Generally space vector hexagon is subdivided into 6 parts. Each part represents a sector, conventionally depending on the angle made by reference vector we can identify the sector number and corresponding calculations can be done. The coefficient of time calculation is given by equation (5).

$$K = \frac{2}{\sqrt{3}}\frac{V_S}{V_{dc}}T_s \quad (7)$$

3. Calculation of Dwell Times

For deriving dwell times any one of the sectors should be selected. By considering the sector 1 as shown Fig. 7

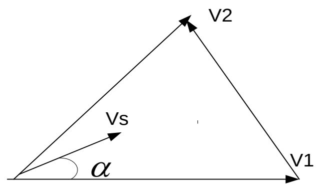

Fig. 7 Sector 1

Along the axis:

$$V_1T_1 + V_2T_2\cos 60 = V_ST_S\cos\alpha \quad (8)$$

Along the β axis:

$$V_2T_2 Sin60 = V_ST_s\, Sin60 \quad (9)$$

By solving above equations, expressions obtained for T_1 and T_2 are as shown below.

$$T_1 = T_S\frac{V_S}{V_{dc}}\frac{2}{\sqrt{3}}Sin(60-\alpha) \quad (10)$$

$$T_2 = T_S\frac{V_S}{V_{dc}}\frac{2}{\sqrt{3}}Sin\alpha \quad (11)$$

Actually,

$$T_0 + T_1 + T_2 = T_s \quad (12)$$

From the above equation

$$T_{0/2} = \frac{1}{2}[T_s - (T_1 + T_2)] \quad (13)$$

Where T1, T2, T0/2 are dwell times. Same rules can be used for calculation of dwell times in sectors 2 to 6.

4. Calculation of Times for each switch

For generating the gate pulses, switching times should be decided. This can be done with the help of the following Table1.

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Table.1

sector	Upper switches		
	a	b	c
1	$T_1+T_2+T_0/2$	$T_2+T_0/2$	$T_0/2$
2	$T_2+T_0/2$	$T_1+T_2+T_0/2$	$T_0/2$
3	$T_0/2$	$T_1+T_2+T_0/2$	$T_2+T_0/2$
4	$T_0/2$	$T_2+T_0/2$	$T_1+T_2+T_0/2$
5	$T_2+T_0/2$	$T_0/2$	$T_1+T_2+T_0/2$
6	$T_1+T_2+T_0/2$	$T_0/2$	$T_2+T_0/2$

Once the upper switches switching timings are known it is easy to calculate the lower switches switching times by complementing the upper switching times.

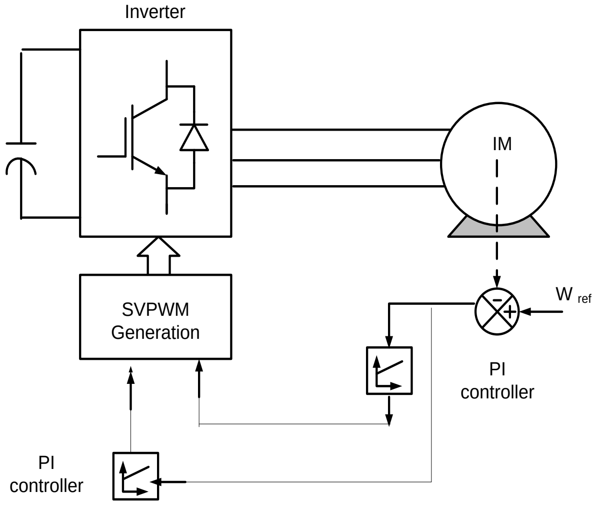

Fig.. 8 Block diagram of speed control of Induction motor

Reference speed is sensed and it is processed through a speed limiter. This signal is controlled through SVPWM via PI controllers.

IV . SIMULATION MODEL AND RESULTS

The simulation model of speed control of solar powered induction motor drive system using SVPWM technique is shown in Fig. 9.

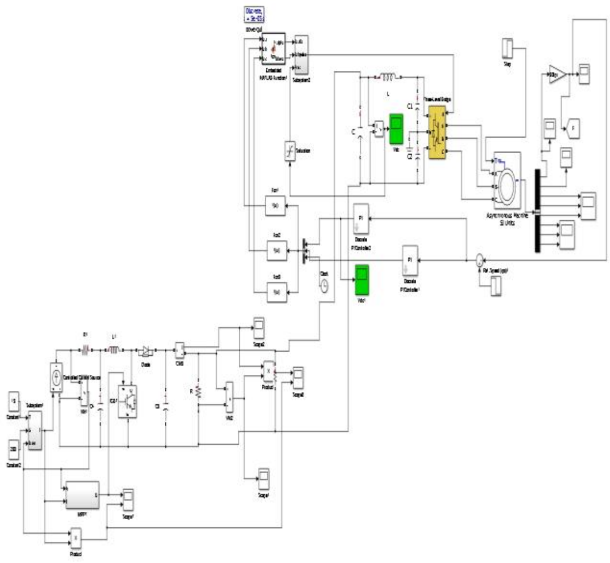

Fig.. 8 Simulink model of speed control of solar powered Induction motor

The output voltage, current, power wavforms of PV array is shown in figures 10, 11 and 12 respectively.

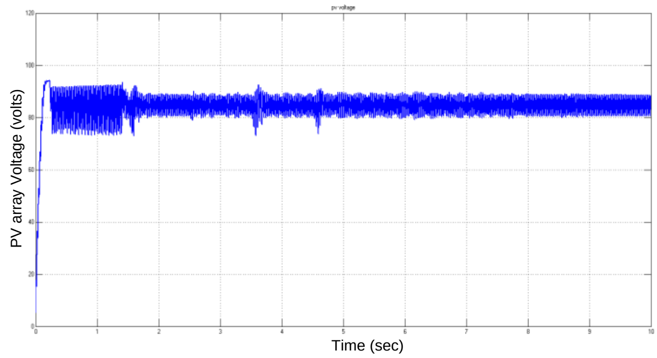

Fig. 10 PV array output Voltage waveform

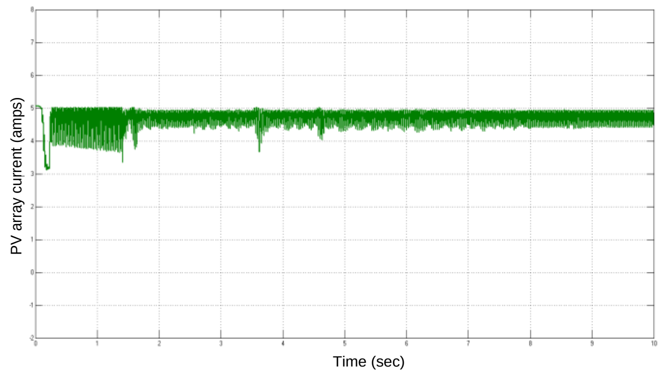

Fig.11 PV array output current waveform

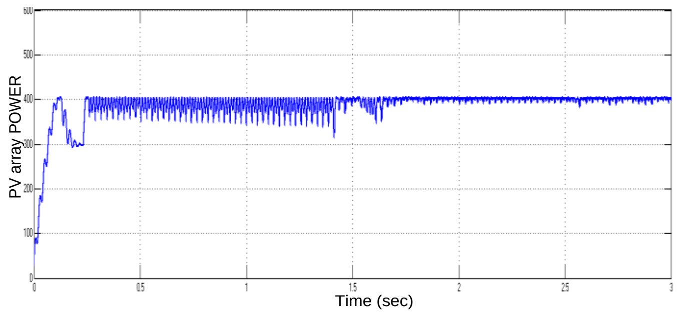

Fig. 12 PV array output power waveform

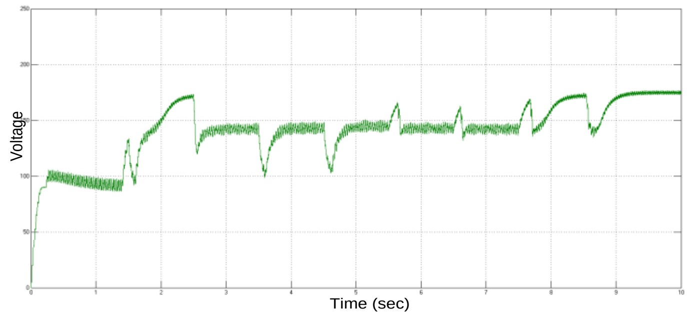

Fig. 13 Boost converter output voltage waveform

The speed and torque developed by the speed control of solar powered drive with SVPWM are shown in figure 15 and 16.

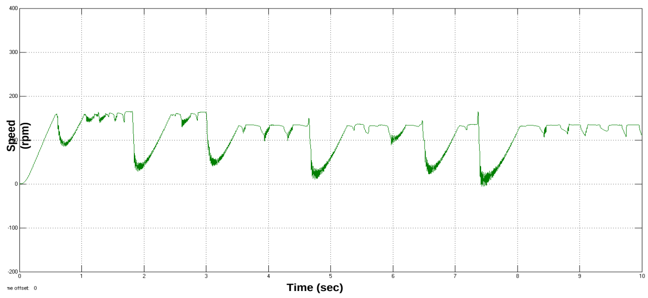

Fig.14 speed of solar power fed IM drive with SVPWM

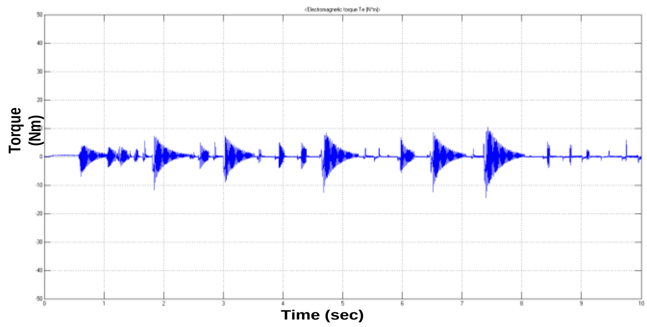

Fig. 15 Electromagnetic Torque solar power fed IM drive with SVPWM

The speed control of induction motor shows the charcteristics of IM drive. Thus by this response the Speed control solar powered induction motor drive with SVPWM is applicable in HVAC, fans and water pumps, food processing, petro chemicals, Mining and metals, pulp and paper/forest producers, machine tools, transportation.

V. CONCLUSION

The solar powered IM drive with SVPWM has been simulated in MATLAB/SIMULINK and its results are discussed. As the solar has significant potential among all the renewable energy resources, solar power modules should be installed in domestic and industries for electrification or various applications which are listed. Performance of inverter is improved with SVPWM. SVPWM Inverter has excellent characteristic like near sinusoidal output waveform.

By utilizing solar powered system with SVPWM for IM speed control, losses can be reduced, power supply problems can be reduced, motor heating and stress can be reduced, increases efficiency, high saving in energy, low maintenance, long life and improves the process of control. Thus the developed model is robust and energy saving system.

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