Three Phase Induction Motor Drive using Boost Converter and SVPWM Inverter Fed from Photovoltaic Panel

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Abstract— *This paper proposes a topology of induction motor drive system integrating a boost converter and a three-phase inverter using solar photovoltaic panel. The motor is driven with the available power at the moment. To match impedance between the solar panel and motor load and to step up the panel voltage, a boost dc-dc converter topology is employed. Maximum power point tracking algorithm is implemented to extract maximum power from the PV panel. Space Vector PWM (SVPWM) is a more sophisticated technique for generating a fundamental sine wave that provides a higher voltage to the motor and lower total harmonic distortion). To obtain optimum motor performance and to reduce THD of the inverter output waveform, we employed space vector modulation technique for switching of inverter power circuit. The proposed system is simulated and result is discussed.*

Keywords—*SVPWM space vector pluse width modulation, THD total harmonic distortion, MPPT Maximum power point tracking.*

I. INTRODUCTION

The power electronic device plays an important role in the PV fed drive system for the improvement of efficiency. Maximum power point tracking is use to extract maximum power from the PV panel [1]. There are various algorithms to track maximum power point. MPPT algorithm is use in order to match load side impedance with source. Perturbation and observation algorithm is used in the paper [2-3]. Different duty cycles are calculated from the algorithm with varying irradiation.

The pulses are generated from corresponding duty cycles, which is given to a DC-DC converter. There are different types of DC-DC converters. Boost DC-DC converter is most commonly used [3].

Sinusoidal pulse width (SPWM) modulation is commonly used in the inverter switching, since it is considered as the traditional switching techniques. The paper discusses space vector modulation technique so as reduce the THD and to obtain a better switching pulse. SVPWM technique is slightly complex than SPWM, but since it reduces the THD and switch losses, SVPWM is chosen is here[4].

Here an induction motor is driven using SVPWM inverter and Boost DC-DC converter. Induction motor is the most popular motor in the market. The proposed system can be used for water plumping, and other drive system.

An open loop V/f control is implemented so as to control the speed of the motor. SVPWM speed control is easy to implementation and also gives better control than SPWM.

Fig.1 gives the overall block diagram of the proposed system.

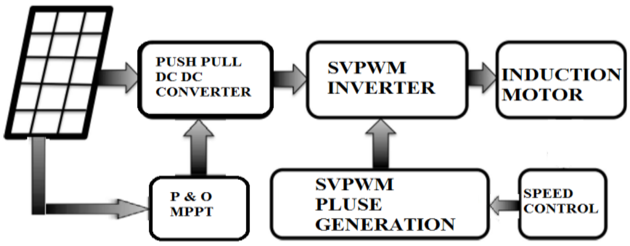

Fig.1. Overall block diagram

II. MODELING OF PHOTOVOLTIC SYSTEM

A solar cell is basically a semiconductor, p-n junction fabricated in a thin wafer of semiconductor which converts sunlight into electrical energy. The electromagnetic radiation of solar energy can be directly converted to electricity through photovoltaic effect. The power on the PV depends on solar irradiance, panel temperature and operating voltage and current. The current-voltage relationship is called as the I-V characteristic which is a complex and non linear function [5-6].

Fig 2 shows the equivalent diagram of a PV cell.

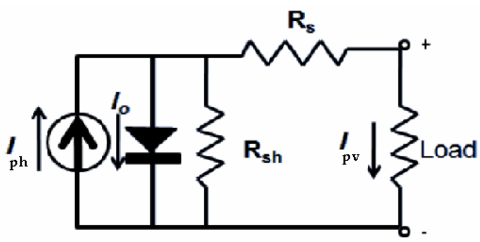

Fig. 2. Equivalent model of a PV cell

PV cells are grouped in larger units called PV modules which are further interconnected in a parallel-series configuration to form PV arrays.

The photovoltaic panel is modeled according to the mathematically equation as given below.

$$I_{ph} = I_{scr} + K_i(T - 298) * \lambda/_{1000}$$ (1)

Equ (1) gives the module current.

$$I_{rs} = I_{scr} \Big/ \left[exp\left(\frac{qV_{oc}}{N_s kAT}\right) - 1\right]$$ (2)

Equ (2) gives the reverse saturation current.

$$I_o = I_{rs} \left(\frac{T}{T_r}\right)^3 \exp\left[\frac{q*E_{go}}{Bk}\left(\frac{1}{T_r} - \frac{1}{T}\right)\right]$$ (3)

Equ (3) gives the module saturation current I_0 which varies with the cell temperature.

$$I_{pv} = N_p * I_{pv} - N_p * I_o\left[\exp\left\{\frac{q*(V_{pv}+I_{pv}R_s)}{N_s AkT}\right\} - 1\right]$$ (4)

Equ (4) gives the PV module current output I_{PV}. Required amount of Power is generated by connecting the PV panel in series and parallel combination.

III. MAXIMUM POWER POINT TRACKING

MPPT is an algorithm to find the maximum power point of the PV panel at different irradiation. Since the P-V curve of the solar panel is non linear, when variable load like motor is connected to the system, it is not necessary that the load will absorb maximum power from the solar panel. As per Maximum Power Transfer theorem, the output power flow is maximum between sources to load side when the Thevenin impedance of the source matches with the load impedance. This matching of impedance is done using the MPPT algorithm..

A. Perturbation And Observation Algorithm

There are many control algorithms for MPPT with basic aim of extracting maximum power from the panel. There are certain requirements that need to be satisfied by MPPT techniques while. P&O method is frequently used tracking algorithm since it has simple structure, low cost of implementation and requires only a few input parameters for its working.

The P&O as its name suggests it works on the principle based on the observation of the panel output power, and on perturbation i.e. incrementing or decrementing the power based on the increments of the array voltage.

P & O algorithm is explained below with the help of a flow chart fig.3 :

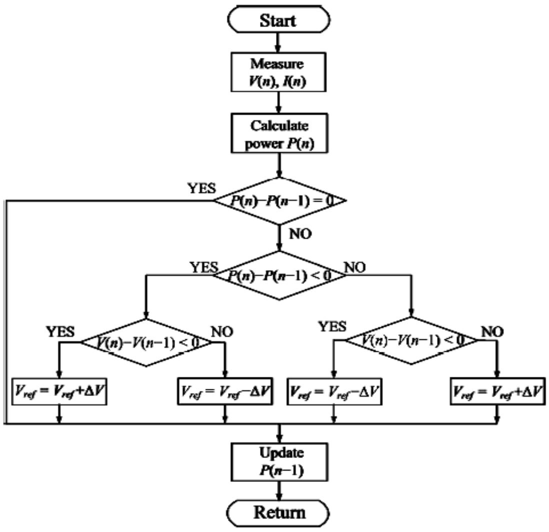

Fig.3. Flow chart of P&O Method

If change in power is positive then the operating voltage is incremented in same direction as that of the panel power. If change in power is negative that means the previous power P (n-1) is greater than P (n) then the system operating power point moves away from maximum power point (MPP). To achieve MPP, the operating voltage needs to be moved in the direction opposite to the direction of the incremented power.

IV. BOOST CONVERTER

The boost is a called step up DC-DC converter since its output voltage is stepped to a higher value. To achieve MPPT of the PV panel, the dc-dc boost converter topology is used. The pulse generated from the MPPT algorithm is fed to the switch of the converter. Thus the impedance between the supply side and load side is kept equal, hence maximum power flow happens.

Boost circuit consist of a inductor, high frequency switching MOSFET, diode and a filter across load as shown in the figure.

The relation between the load and supply voltage are shown below:

$$V_o = \frac{V_s}{(1-D)}$$ (5)

$$D = \frac{T_{ON}}{T}$$ (6)

The output voltage of the boost converter depends on the source voltage and duty cycle.

Where, V_o, D= duty cycle and T_{ON}=total time interval.

V. SPWM INVERTER

SVPWM technique is slightly complex than SPWM, but since it reduces the THD, switch losses, SVPWM have many other advantages, it is chosen is here [7].

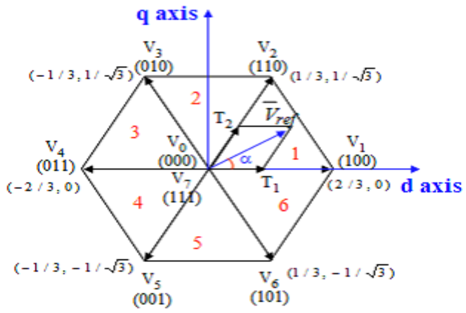

Fig.4.Sector

Step 1: Determine Vdo,Vqo,Vref, and angle (α)

From Fig. 7, the V_{do}, V_{qo}, V_{ref}, and angle (α) can be determined as follows:

$$V_{do} = V_{an} - V_{bn}.cos60 - V_{cn}\,cos60 \quad (7)$$

$$V_{qo} = 0 + V_{bn}\,cos30 - V_{cn}\,cos30 \quad (8)$$

$$|V_{ref}| = \sqrt{V_{do}^2 + V_{qo}^2} \quad (9)$$

$$\alpha = tan^{-1}\frac{V_{qo}}{V_{do}} \quad (10)$$

Step 2: Determine time duration T_1, T_2, T_0

Switching time duration at any Sector can be calculated from the equation given below.

$$T_1 = \frac{\sqrt{3}*T_Z*|V_{ref}|}{V_{dc}}\left(\sin\frac{\pi}{3} - \alpha + \frac{n-1}{3}\pi\right) \quad (11)$$

$$T_2 = \frac{\sqrt{3}*T_Z*|V_{ref}|}{V_{dc}}\left(\sin(\alpha - \frac{n-1}{3}\pi\right) \quad (12)$$

$$T_0 = T_Z - T_1 - T_2 \quad (13)$$

Where, n = 1 through 6 (that is, sector 1 to 6) for $0 \leq \alpha \leq 60$ and T_z is sampling time.

Step 3: Determine the switching time of each switches (S1 to S6)

Table I Switching Time Calculation at Each Sector

Sector	Upper Switch (S_1,S_3,S_5)	Lower Switch (S_4,S_6,S_2)
1	$S_1=T_1+T_2+T_0/2$ $S_3=T_2+T_0/2$ $S_6=T_0/2$	$S_4=T_0/2$ $S_6=T_1+T_0/2$ $S_2=T_1+T_2+T_0/2$
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	$S_1=T_0/2$ $S_3=T_1+T_0/2$ $S_5=T_1+T_2+T_0/2$	$S_4=T_1+T_2+T_0/2$ $S_6=T_2+T_0/2$ $S_2=T_0/2$
5	$S_1=T_2+T_0/2$ $S_3=T_0/2$ $S_5=T_1+T_2+T_0/2$	$S_4=T_1+T_2$ $S_6=T_1+T_2+T_0/2$ $S_2=T_0/2$
6	$S_1=T_1+T_2+T_0/2$ $S_3=T_0/2$ $S_5=T_1+T_0/2$	$S_4=T_0/2$ $S_6=T_1+T_2+T_0/2$ $S_2=T_2+T_0/2$

By using a above table SVPWM is simulated in MATLAB.

VI. INDUCTION MOTOR

Induction motor is one of the most commonly used motor. About 90 % of motor produced in market is induction motor and cost is moderate.

The synchronous speed of the motor can be control by using controlling the frequency of the stator voltage. Here V/f

Control is use to control the speed of induction motor. The open loop V/f control of an induction motor is the most common method of speed control because of its simplicity and these types of motors are widely used in industry. Traditionally, induction motors have been used with open loop 50Hz power supplies for constant speed applications. For adjustable speed drive applications, frequency control is natural. In V/f speed control technique V/f ratio is to be kept constant so that flux remains constant.

VII. SIMULATION RESULT

The simulation is carried out in the MATLAB.

The fig.5 shows the boot converter connected to the PV panel of 3.5KW. A resistive load is connected to show the variation of the output voltage, power and duty cycle corresponding to the variation of the irradiation. The temperature is considered to a constant.

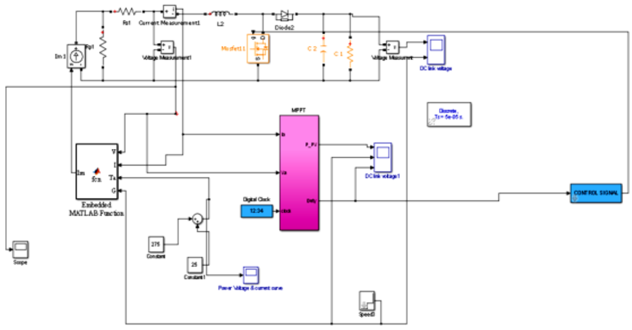
Fig.5.Boost converter fed from PV panel.

The fig.6 shows the variation of the output voltage with changing irradiation. Since the irradiation changes the output power from the PV panel also changes. The irradiation is varied at 3 sec to 500 W/m2 from 200 W/m2 and then to 1000 W/m2 at 6 sec. The change in irradiation cause change in output voltage.

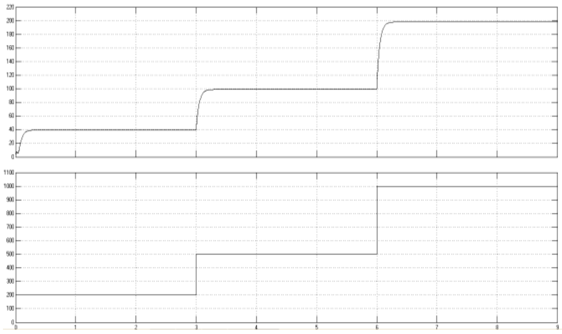

Fig.6.(a) Voltage across Load (b) Irradiation

Since we are using P & O MPPT, the maximum power is tracked. In the fig 7 (a) shows the tracking of the power with different irradiation. The fig 7 (b) shows the change in irradiation. The fig 7 (c) show the duty cycle generated from the P&O algorithm in order to track maximum power at different irradiation.

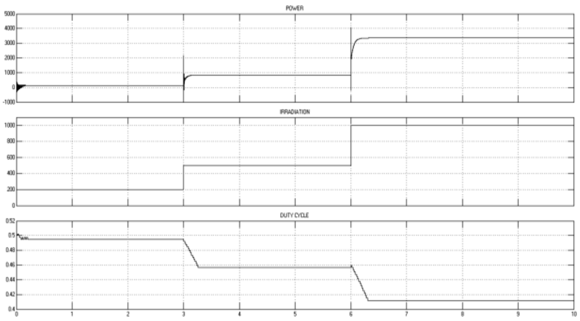

Fig.7.(a)Power (b)Irradiation (c)Duty cycle

The fig 8 shows the PV panel fed induction motor(400V,1500rpm,50Hz) using SVPWM inverter. The SVPWM inverter is used because of higher utilization of DC supply voltage and higher harmonics.

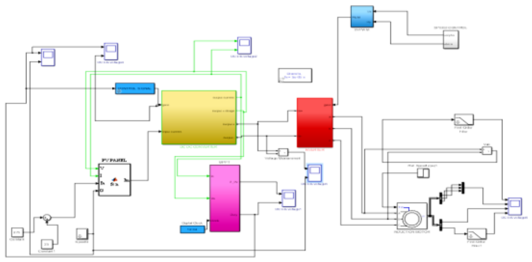

Fig.8. Induction motor fed from PV panel.

The simulation is done for a constant irradiation 800W/m^2

In fig 8 (c) change in the speed from 150rps to 50rps at 1sec. Since open loop speed control is implemented the loading can affect in the speed reduction of the motor. Here the load torque is considered as zero fig 8 (d). As the speed is decreased at 1 sec the voltage input to the motor is decreased to make V/f constant. The fig 8 (b) show the current I_{abc}.

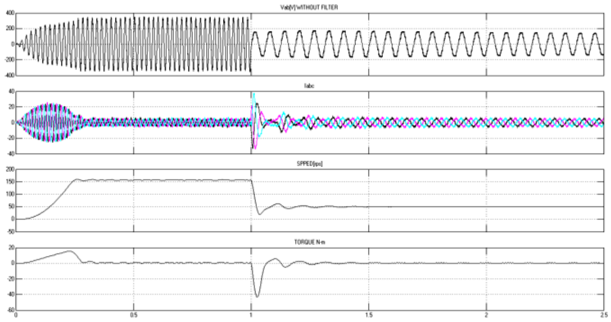

Fig.8.(a)Input voltage (b)I_{abc} (c)Speed (d)Torque

The fig 9 show the THD as less as 1.13%.

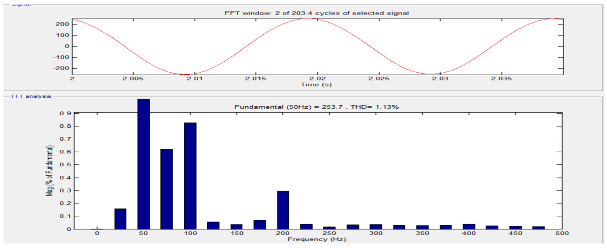

Fig.9.THD analysis.

VIII. CONCLUSION

Simulation is carried out in MATLAB and the results are checked. P&O algorithm is implemented to extract maximum power from the PV panel and different irradiation condition. The boost converter is used to step up the PV panel voltage. Open loop speed control is implemented so speed can be set to a desired value. SVPWM inverter is used so the THD can be reduced to a lower value. Thus overall efficiency of the system is increased.

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