ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Three-Phase SVPWM Inverter controlled Induction Motor Drive Fed from Photovoltaic Panel

K. Bharat Babu
M.Tech, PE&ED,
Department of EEE,
BITS Engineering College,
A.P, India.

M.Sai Ganesh
Assistant Professor,
Department of EEE,
BITS Engineering College,
A.P, India.

ABSRACT:

The usage of Induction Motor has been growing in rapid pace and its applications had proven to be widespread in several industrial, domestic and commercial domains. Therefore, the main intention of this project is to integrate an Induction Motor to a PV system by use of three phase SVPWM inverter. To absorb maximum power from the panel, Perturb and Observe (P&O) algorithm of Maximum Power Point Tracking (MPPT) technique is used. Also, a DC-DC Push-Pull converter is used to the step-up the panel voltage to the voltage level required by the inverter. In addition, a closed-loop speed control is implemented to regulate the motor within the desired speed limits. Sinusoidal PWM technique is widely used to obtain the output line voltages of an inverter. When compared with SPWM, Space Vector Pulse Width Modulation (SVPWM) technique utilizes the dc voltage more effectively and generates less harmonic distortion. Therefore, the overall objective of this project is by implementing SVPWM inverter, an Induction Motor is effectively drived and controlled in speed, feeding power from PV panel by using dc-dc push-pull converter along with the application of MPPT. The simulation results are presented by using Matlab/Simulink software.

Keywords:

Photovoltaic; Power Electronics; DC-DC Push-Pull Converter; Maximum Power Point Tracking; SPWM; Three-Phase Inverter; Induction Motor.

I. INTRODUCTION:

Renewable energy source become one of the most widely studied electric power applications since fossil fuels are decreasing and oil prices and global warming are increasing. Hydrogen energy, wind turbines and photovoltaic cells are the most popular renewable sources.

A photovoltaic system has advantages such as being static and quite since it has no moving parts. So that, it has little operation and maintenance costs. The output characteristic of photovoltaic cells depends on parameters as temperature, the solar insulations and output voltage [1]. Inverters are power electronics devices which converter DC power to AC power [2]. In many power electronic applications, it is desired to control output frequency and voltage level. AC voltage can be produced at desired output frequency and voltage level by using inverters. Recently, developments in power electronics and semiconductor technology have lead improvements in power electronic systems [3]. The waveform of the output voltage depends on the switching states of the switches used in the inverter. Major limitations and requirements of inverters are harmonic contents, the switching frequency, and the best utilization of dc link voltage. Pulse width modulation (PWM) inverters are studied extensively during the past decades. In this method, a fixed dc input voltage is given to the inverter and a controlled ac output voltage is obtained by adjusting the on and off periods of the inverter components. The most popular PWM techniques are the sinusoidal PWM and space Vector PWM. With the development of DSPs, space-vector modulation (SVM) has become one of the most important PWM methods for three-phase voltage source inverters. In this technique, Space-vector concept is used to compute the duty cycle of the switches. It is simply the digital implementation of PWM modulators. Most advanced features of SVM are easy digital implementation and wide linear modulation range for output line-to-line voltages.

II. METHODOLOGY:

A. Photovoltaic Panel:

PV array is a p-n junction semiconductor, used to convert sunlight into electrical energy. When the incoming solar energy exceeds the band-gap energy of the module, photons are absorbed by materials to produce electricity.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

The cells in the PV array are tied in series or parallel and the electrical power of the PV array depends upon the solar irradiance, panel temperature and the operating current and voltage relationship. The current voltage relationship, which is the I-V characteristic of the PV array is a complex and non-linear function. The following exponential model is used to describe and predict the behavior of our proposed photovoltaic module. According to this model, maximum power, Pmax equals [8]:

$$P_{\max} = \frac{V_{op} * I_{sc}}{1-\exp\left(-1/b\right)} * \left[1-\exp\left(\frac{V_{op}}{b.V_{oc}} - \frac{1}{b}\right)\right] \quad (1)$$

$$b = \frac{\left(\frac{V_{op}}{V_{oc}} - 1\right)}{\ln\left[1 - \frac{P_{\max}}{V_{op} * I_{sc}}\right]} \quad (2)$$

$$R_{op} = \frac{V_{op} - V_{op} * \exp\left(\frac{-1}{b}\right)}{I_{sc} - I_{sc} * \exp\left(\frac{V}{b.V_{oc}} - \frac{1}{b}\right)} \quad (3)$$

Where ISC is the short circuit current, VOC is the open circuit voltage, IOP is the optimal current and IOP is the optimal voltage. Solving equation (1) for b and taking into account that b is very small; b can be estimated by equation (2). This value is distinct and unique for every solar panel and does not fluctuate with changes in irradiance and solar cell temperature. Thus for a particular irradiance level and cell temperature, if ISC, VOC, IOP and Vop are found for a given solar panel, the value of b can be achieved. By using the value of b in the exponential model, an accurate representation of the voltage and current characteristics of the panel can be obtained. Using the value of b, the optimal resistance Rop can also be found, which is the load resistance at which the photovoltaic panel transfers Pmax to the load.

B. Maximum Power Point Tracking (MPPT):

Maximum Power Point Tracking (MPPT) is very important in solar power system because it minimizes the solar array cost by decreasing the number of solar modules required to achieve the desired output power. MPPT is a device that looks for the maximum power point of a source and keeps it operating in that point. Since, the PV is not always operating in its maximum power point, but with the use of an MPPT it is possible to force the PV to extract the maximum power at the given irradiance level. We used P&O MPPT algorithm due to its simplicity and easy of implementation [2]. This technique is easily implemented by an algorithm using the power-voltage characteristics of the PV module. Knowing that at the right and the left of the maximum power point the power decrease, the converters duty cycle is changed depending on the last change in power and if the duty cycle was increased or decreased. To implement the P&O the power needs to be read at a time U, afterwards the voltage is changed. Next the power in time U+ I is read, if this power is incrementing we increment the duty ratio and by consequence the voltage in the PV. In the case that the power in the U+1 is lower than in the U time we decrement the duty ratio and by consequence the voltage. This technique operates in the boundaries of the MPP. The MPPT algorithm developed for this application is responsible for deploying the necessary adjustment in the Push-Pull Converter's duty cycle so that the optimum voltage is achieved, thus allowing maximum power delivery to the load [3]. Fig. 1 shows the P&O, MPPT algorithm varying the push-pull converter duty cycle to obtain the maximum power delivered by PV panel.

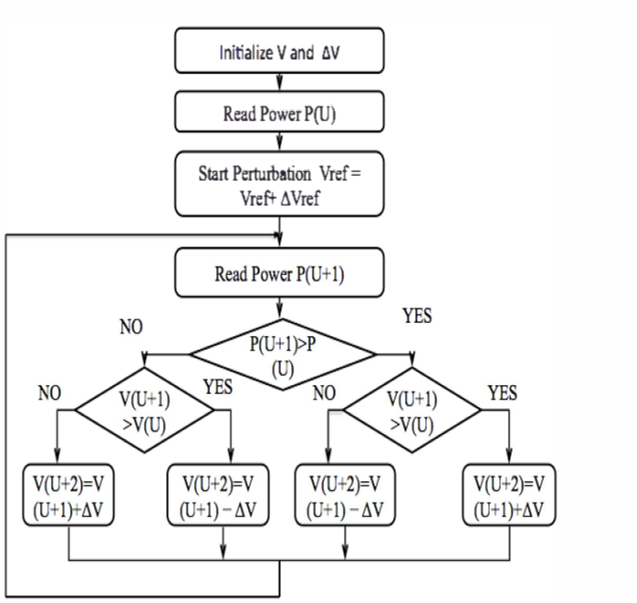

Fig.1 MPPT, P&O algorithm flow chart.

C. DC-DC Push-Pull Converter

To achieve maximum power point tracking of the photovoltaic panel, the DC-DC push-pull converter topology is implemented in this project [3]. Switch mode DC-DC converters efficiently convert an un-regulated DC

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

input voltage into regulated DC output voltages. Compared to linear power supply, switching power supply offers much more efficiency and power density. Switching power supply includes solid-state devices such as transistors and diodes to operate as a switch: either completely turn-on or completely turn-off. The basic push-pull converters consist of inductors, capacitors, diodes, transistors and transformer to step-up or step-down a voltage input.

The Fig. 2 shows the push-pull converter circuit. When designing a push-pull converter, it is convenient to select the transformer turns ratio n such that duty cycle D does not vary in wide range [4]. At the same time, high values for n should be avoided to ensure that the SPWM voltage inverter operates with low modulation index. The push-pull input voltage is the MPPT panel array voltage. Thus given the motor output power, it is possible to numerically search the push-pull input voltage. The push-pull output voltage (E) depends on the input voltage (V), the duty cycle (D), and the high frequency transformer turns ratio (n), [5],

$$E = \frac{n}{1-D} V \quad (4)$$

$$D = \frac{t_{on}}{T} \quad (5)$$

Where, D defines the duty cycle and ton corresponds to the total time interval when both switches conduct (ton= D7). Thus, our design we implemented a DC-DC push-pull converter, that successfully steps-up PV arrays 24V DC output voltage into 312V DC in case of steady environmental condition.

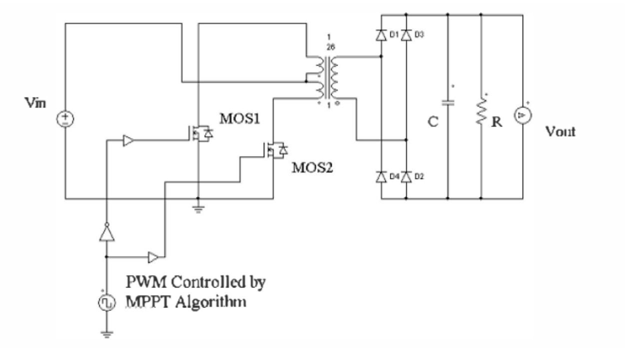

Fig.2. Push-Pull Converter Circuit

D.Sinusoidal Pulse Width Modulation (SPWM):

PWM technique is most commonly used in conventional inverter switching, which suffers from various drawbacks such as low fundamental output voltage, higher THD level and contains excessive amount of harmonics at inverter output waveform. However, an alternatives modulation technique such as SPWM is used in order to mitigate this problem. In SPWM switching control, for three-phase inverter; three sinusoidal modulation signals (called as reference signals) of 50Hz are generated that are delayed by 120 degree with respect to each other [6].

Then it is compared with high frequency triangular wave in order to get the resulting switching gate pulses for inverter MOSFET switch [7]. Fig. 4 shows the schematic diagram of SPWM control circuit. However, the two key factors that influence the performance of the three-phase inverter, one of them is modulation index Ma that is defined by the ratio between reference signal (sine wave), Vref and the carrier signal (triangular wave), Vcarrier and another one is frequency modulation, Ma defined by the ratio between the frequency of carrier signal and reference signal.Thus, these two terms are also described by following mathematical equations,

$$M_a = \frac{V_{ref}}{V_{carrier}} \quad (6)$$

$$M_f = \frac{f_{triangular}}{f_{ref}} \quad (7)$$

The value of Ma is important to find output voltage of inverter though theoretically if Ma decreases inverter AC voltage increases. From equation (6) Ma should be less than 1, in order to achieving high voltage gain with fewer harmonics content at inverter output. So filter design is easy if Ma is in between 0.9 and 1. For Ma greater than 1, the harmonics will decrease and this condition is known as over modulation. Fig.5 shows the reference signal of each phase with the carrier signal.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

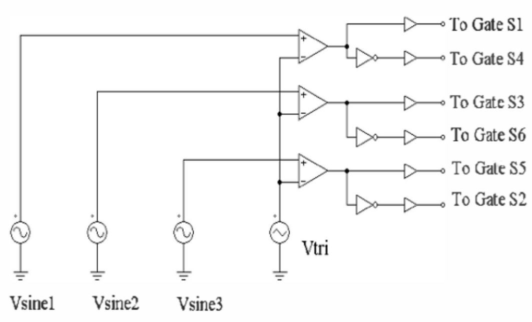

Fig.3. Control circuit of SPWM technique.

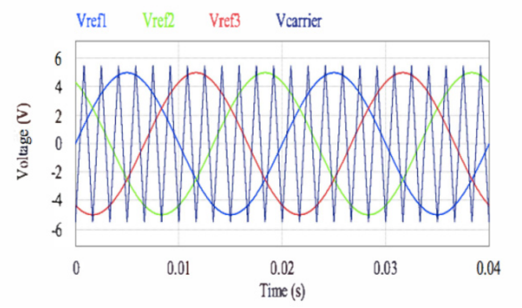

Fig.4.Carrier signal vs. reference voltage.

E.DC-AC Three-Phase Inverter

Inverter is a device used to convert direct current to alternate current. By using proper switching and control technique the alternate current can be any required voltage or frequency. The three-phase inverter is commonly used to transform direct current to alternate current in high power application. This inverter consists of three half-bridge units; the upper and lower switches are controlled complementarily, which means that when the upper one is turned on, the lower one must be turned off and vice versa [6]. Gating signals are delayed by 120 degrees with respect to each other for three phase inverters.

A common type of control signals (SPWM) used to switch the six transistors in three-phase inverter is the ISO-degree conduction mode. In a cycle six modes of operation exist and each has duration of 60 degrees. Each gate signal is shifted by 120 degrees between each phase and respective complementary signals. Thus as a result the three phase voltages lag by 120 degrees. However, the output of an inverter, when it is not connected to a transformer, is a square waveform due to the on/off states of the switches. Later it is converted to sine waveform by employing low pass LC filter.

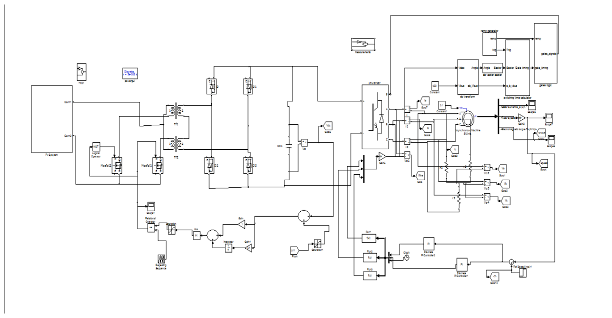

Fig.5. Complete schematic diagram of proposed design in MATLAB.

III. INDUCTION MOTOR (IM):

An induction motor is an example of asynchronous AC machine, which consists of a stator and a rotor. This motor is widely used because of its strong features and reasonable cost. A sinusoidal voltage is applied to the stator, in the induction motor, which results in an induced electromagnetic field. A current in the rotor is induced due to this field, which creates another field that tries to align with the stator field, causing the rotor to spin. A slip is created between these fields, when a load is applied to the motor. Compared to the synchronous speed, the rotor speed decreases, at higher slip values. The frequency of the stator voltage controls the synchronous speed. The frequency of the voltage is applied to the stator through power electronic devices, which allows the control of the speed of the motor. The research is using techniques, which implement a constant voltage to frequency ratio. Finally, the torque begins to fall when the motor reaches the synchronous speed. Thus, induction motor synchronous speed is defined by following equation,

$$n_s = \frac{120 f}{P} \tag{8}$$

Where f is the frequency of AC supply, n, is the speed of rotor; p is the number of poles per phase of the motor. By varying the frequency of control circuit through AC supply, the rotor speed will change.

A. Control Strategy of Induction Motor:

Power electronics interface such as three-phase SPWM inverter using constant closed loop Volts/Hertz control scheme is used to control the motor. According to the desired output speed, the amplitude and frequency of the reference (sinusoidal) signals will change.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

In order to maintain constant magnetic flux in the motor, the ratio of the voltage amplitude to voltage frequency will be kept constant. Hence a closed loop Proportional Integral (PI) controller is implemented to regulate the motor speed to the desired set point. The closed loop speed control is characterized by the measurement of the actual motor speed, which is compared to the reference speed while the error signal is generated. The magnitude and polarity of the error signal correspond to the difference between the actual and required speed. The PI controller generates the corrected motor stator frequency to compensate for the error, based on the speed error.

IV. SVPWM:

The spaced vector PWM is an alternative to multilevel PWM as it minimizes the total harmonic distortions in both current and voltage waveforms with least number of commutations. To solve the complexity simple generalized space vector algorithms are used.

A. Principle of space vector:

To implement space vector modulation a reference signal Vref is sampled with a frequency fs(Ts = 1/fs). The reference signal may be generated from three separate phase references using the αβλ transform. The reference vector is then synthesized using a combination of the two adjacent active switching vectors and one or both of the zero vectors. Various strategies of selecting the order of the vectors and which zero vector(s) to use exist. Strategy selection will affect the harmonic content and the switching losses.

This requirement may be met by the complementary operation of the switches within a leg. This leads to eight possible switching vectors for the inverter, V0 through V7 with six active switching vectors and two zero vectors. All possible switching vectors for a three-leg inverter using space vector modulation is shown in the above table. An example Vref is shown in the first sector. Vref_MAX is the maximum amplitude of Vref before non-linear over modulation is reached.

V.MATLAB/SIMULINK RESULTS

Case 1: Performance of Proposed System by Using SPWM Controller

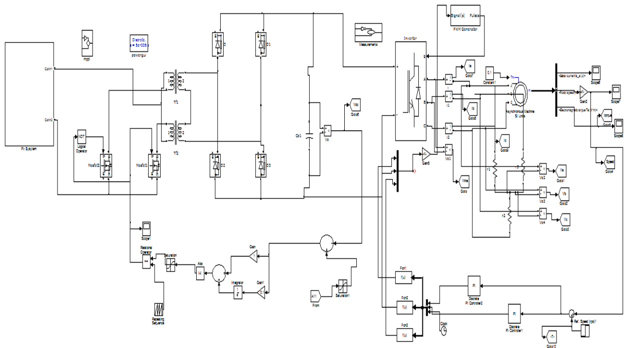

Fig.6.Simlink Circuit for Proposed System by Using PI Controller.

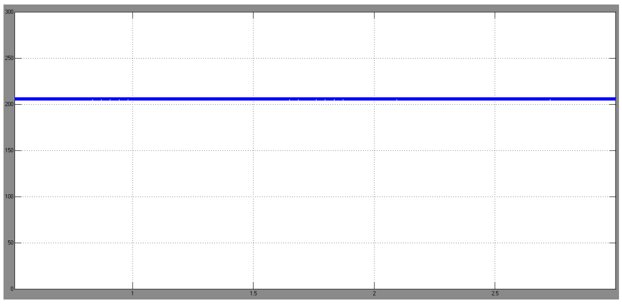

Fig.7.Simulation Result for Output Power Of Solar Cell

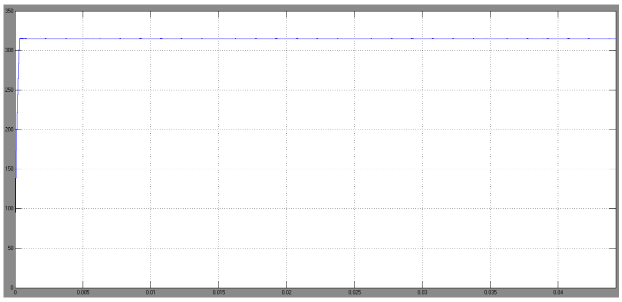

Fig.8.Simulation Result For Output Voltage Of Push-Pull Converter.

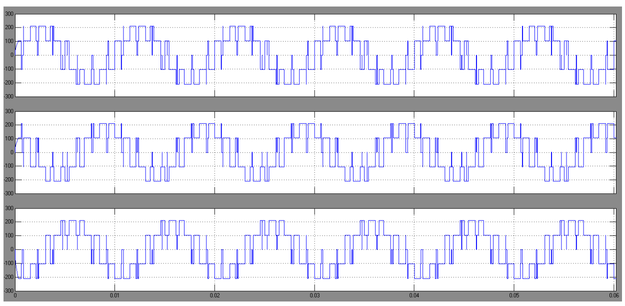

Fig.9.Simulation Result for Three-Phase PWM Output Voltage without Filtering.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

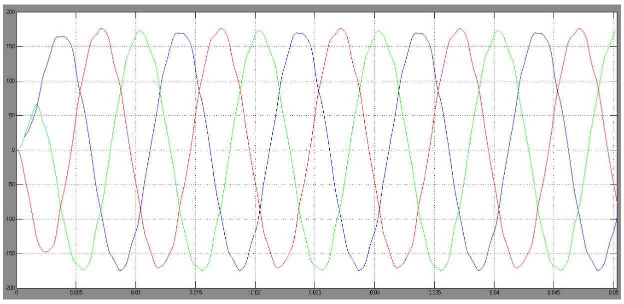

Fig.10.Simulation Result for Inverter Output Voltage.

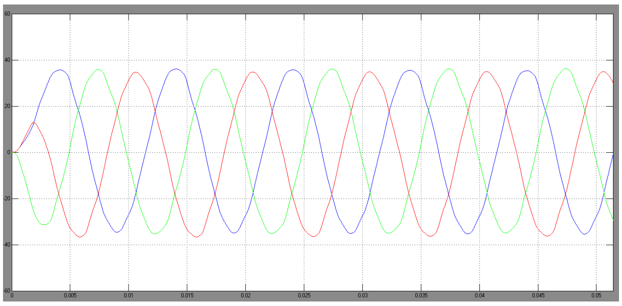

Fig.11.Simulation Result for Inverter Output Current.

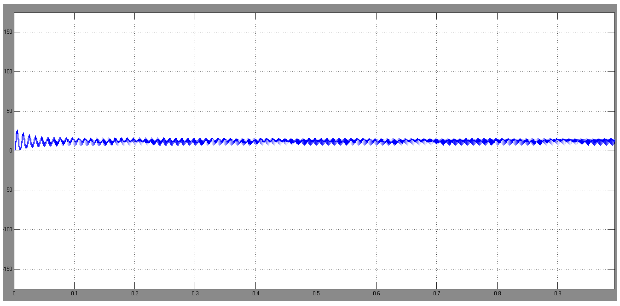

Fig.12.Simulation Result for Electromagnetic Torque of Induction Motor.

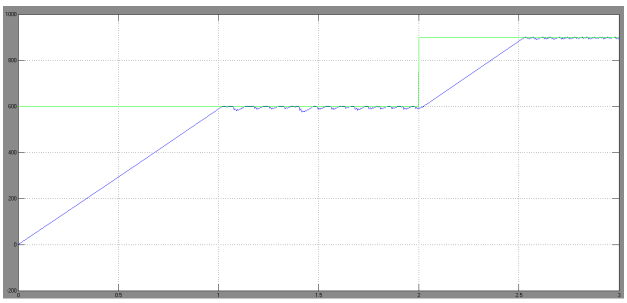

Fig.13.Simulation Result For Actual and Reference Speed of Induction Motor in Closed Loop PI System.

Case 2: Performance of Proposed System by Using SVPWM Controller

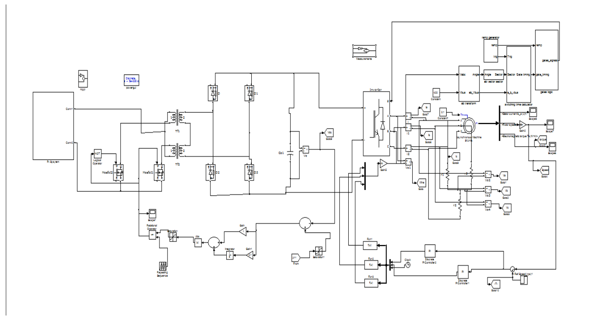

Fig.14.Simulink Circuit for Proposed System by Using SVPWM Controller.

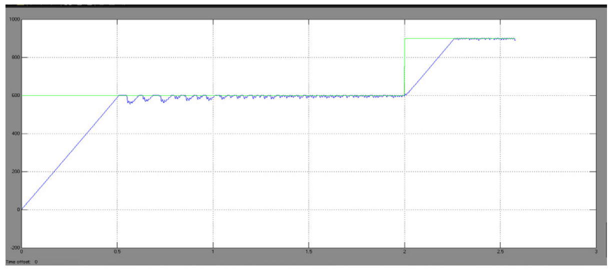

Fig.15. Simulation result of SVPWM inverter for actual and reference speed of induction motor.

VI.CONCLUSION:

The Push-Pull converter proved to be a good interface between panel and load because of the step up and step down properties that provide good impedance matching. The turns ratio of the transformer provided an additional voltage step-up needed to reach higher voltages than a single boost converter could. The space vector technique method has been studied. This method has the advantage of improving the total harmonic distortion over other PWM methods. Also this technique features easy implementation and more importantly, minimum harmonic content in the inverter output voltage and current of the Induction Motor Load. The Modulation Index is higher for SVPWM as compared to SPWM. The current and torque harmonics produced are much less in case of SVPWM. In case of SVPWM the output voltage is about 15% more as compared to SPWM. The SVPWM technique utilizes DC bus voltage more efficiently and generates less harmonic distortion in a three-phase voltage-source inverter. SVPWM is very easy to implement.

REFERENCES:

[1] W. Xiao,F. F. Edwin,G. Spagnuolo,J. Jatsvevich, "Efficient approach for modelling and simulating photovoltaic power system " IEEE Journal of photovoltaics.. vol. 3,no. I, pp. 500-508,Jan. 2013.

[2] N. Femia, G. Petrone, G. Spagnuolo, and M. Vitelli, “Optimization of per-turb and observe maximum power point tracking method,” IEEE Trans. Power Electron., vol. 20,no. 4,pp. 963-973,Jul. 2005.

[3] E.I Ortiz-Rivera, “Maximum power point tracking using the optimal duty ratio for DC-DC converters and load matching in photovoltaic application,” in Proc. IEEE Applied Power Electronics Conference and Exposition (APEC)., Feb 2008.

[4] S. Abe et aI., “ Operation Characteristics of push-pull type series resonant DC-DC converter with synchronous rectifier, “ in Proc. IEEE 341h international Telecommunication Energy Conference (INTELEC), PP. 1-6,Sept.30/0ct.4 2012.

[5] D. Holmes, P. Atmur, C. Beckett, M. Bull, W. Luo, D. Ng, N. Sachchithananthan, P. Su, D. Ware, and P. Wrzos, “ An innovative efficient current-fed push-pull grid connectable inverter for distributed generation systems,” in Proc. IEEE PESC, 2006, pp. 1-7.

[6] M. H. Rashid, Power Electronics, Circuits, Devices, and Applications, 3rd ed. New Delhi: Prentice-Hall of India Private Limited, 2007 pp.253- 256.

[7] N. Mohan, T. M. Undeland,& W. Robbins, Power Electronics, 3rd Ed., Denvers, MA: John Wiley & Sons,Inc.,2006,pp. 211-350.

[8] N. Mendez-Gomez,O. Bousono,R Castaneyra, and E.!. Ortiz-Rivera, “ Development of a low cost induction motor drive system using a PVM, boost converter and three-phase inverter,” Proc. IEEE Photovoltaic Specialist Conference (PVSC), pp. 1348-1351,2012.