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SVPWM Techniques Used for Controlling Three-Phase Induction Motor Energized by Renewable Energy Source

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ABSTRACT: Energy becomes an essential requirement for the economic development and human life's need. In each and everywhere demands of energy becomes high. Generation of electricity using fossil fuels, nuclear power, coal and natural gas greatly affects human health and causes climate changes and global warming. It is available in limited amount not in a wide range. Also it takes lot of time to produce. Integration of renewable energy sources with power grid can help to overcome these problems. In recent year, Among renewable energy sources uses of solar energy increases day by day because of its better power quality, high reliability, transportability, easy structure and availability in wide range. The output voltage generated from the solar panel depends on solar irradiance level and temperature. A battery bank is connected at the common DC bus of the three-phase induction motor which acts as buffer storage for exchange of energy. The system is designed for complete automation operation taking consideration of all practical considerations. A two stage circuit topology is proposed wherein; the first stage is a boost converter (DC-DC converter) which serves for maximum power point (MPP) tracking and second stage is a grid tied VSC (voltage source converter), which not only feeds extracted solar photovoltaic energy into the three-phase Induction motor but also serves for harmonics mitigation, high torque and good speed regulation using SVPWM. This paper is mainly focuses on MATLAB/SIMULINK model of Carrier based Space Vector Controlled Three-Phase Induction Motor using Solar cell Array. This paper presents a grid supported solar energy conversion system with a three-phase Induction motor using Carrier based SVPWM for controlling the speed of Induction motor. Speed of Induction motor is showing in terms of torque, speed and rotor current.

KEYWORDS: SVPWM, Solar Panel, Solar Irradiance, Inverter, Induction Motor Drive, Boost DC Converter.

I.INTRODUCTION

With an increase in development, Renewable energy sources gaining popularity due to its lots of advantages [1]. A Renewable energy sources such as solar energy is available in wide range; it has become the most economical source of renewable energy [2]. It is a type of energy that is free from greenhouse effect and known as most clean i.e. pollution free energy. With recent development in technology advances the solar panel manufacturing which enables the improved performance of panels. The higher cost of fuels plays a key role of utilization of this energy [3]. With an increase in demand of electricity throughout the world, it is become necessary to certain implementation in new form of power generation using renewable energy resources such as solar because of its lots of advantages over other form of energy. The photovoltaic energy can be used as a DC power source or can be integrate into the utility grid through a voltage source inverter for AC applications [4]. With continuous development and modification, these technologies will help to produce better quality and flexibility of data and utilities respectively as it also increases the opportunity to improve relationships with customers by offering better services. This paper mainly emphasis on the uses of solar energy and how we can use it more effectively. This paper presented a speed control of three-phase induction motor drive supplied by photovoltaic array which has good dynamic response. The objective of this paper is to operate an Induction Motor using the power from photovoltaic panel and control the speed of an Induction motor using Carrier based SVPWM. This paper mainly focuses on the usage of solar energy which supplied the power to Three-phase Induction motor drive to control the speed and to obtain ripple free torque and good speed regulation by varying the

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frequency [5]. Block diagram of solar energy system with three-phase induction motor drive feeding SVPWM is shown in Fig. 1.

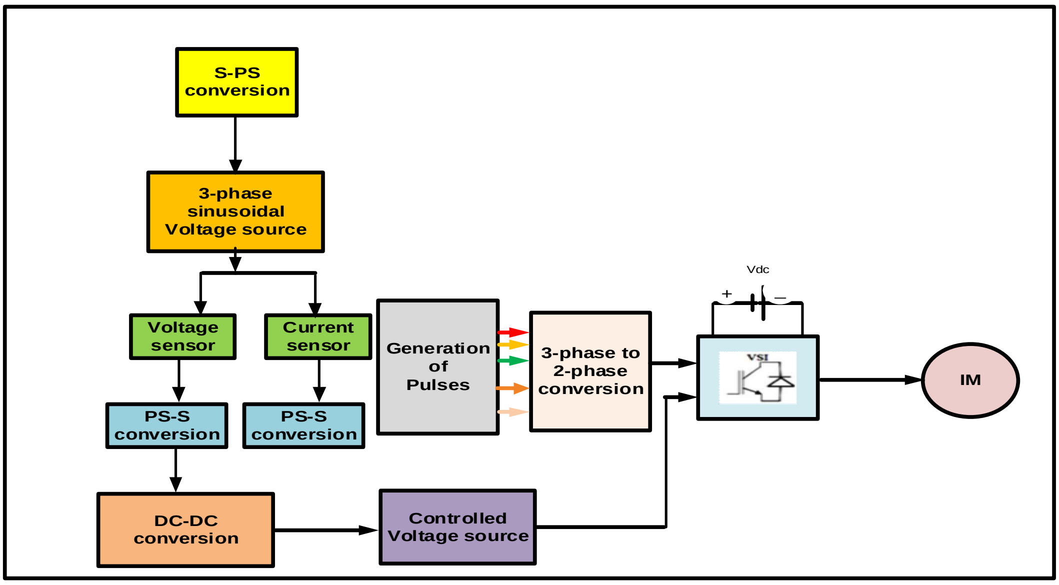

Fig. 1 Block diagram of 3-phase Induction motor drive feeding SVPWM

In this model we are using solar energy as a source. The solar irradiance subsystem consist 72 solar cells. In this each solar cell represented as a resistance that is connected in series with a parallel combination of the elements such as current source, two exponential diodes, parallel resistor Rp. 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 DCDC converter. The positive terminal of solar irradiance connected to the both current and voltage sensor. The current sensor converts current into a physical signal proportional to the current. Connections + and – of current sensor are electrical conserving ports through which the sensor is inserted into the circuit. Further, a DC to DC converter is connected because voltage frequency drives (VFD) need a power section that converts AC power into DC power. This is called the converter bridge. Sometimes the front end of the VFD, the converter is commonly a three-phase, full-wave-diode bridge. A DC bus is also used in this model. The DC bus is the true link between the converter and inverter sections of the drive. Any ripple must be smoothed out before any transistor switches "on". If not, this distortion will show up in the output to the motor. The DC bus voltage and current can be viewed through the bus terminals.The DC link is an important section of the drive as it provides much of the monitoring and protection for the drive & motor circuit. It contains the base-drive fusing and pre-charge capacitor network, which assures steady voltage DC voltage levels prior to the inverter bridge and allows a path for over-voltage dissipation. The inverter section is made up primarily of modules that are each made up of a transistor and diode in combination with each other which inverts the DC energy back to AC.By switching the inverter-transistor devices on and off many times per half cycle, a pseudosinusoidal current waveform is approximated as shown in fig.2

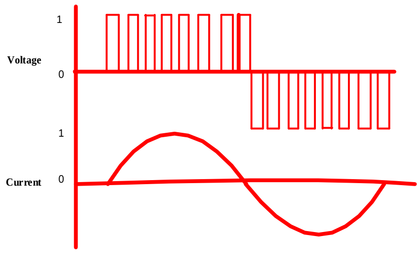

Fig. 2 Pulse-width-modulated voltage and current waveforms

The Inverter changes the DC energy into three channels of AC energy that an AC induction motor can use to function properly. Inverters are classified as voltage-source, current-source of variable-voltage types. This has to do with the

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form of DC that the inverter receives from the DC bus. The main objective of the Inverter is to vary the speed of the motor while providing the closest approximation to a sine wave for current (while pulsing DC voltage to the motor). The PWMs drive ability to maintain the AC levels through all types of load conditions at given speeds is the factor which separates one drive manufacturer from the other.

II.MODELLING OF SOLAR CELLS

A solar cell is used to convert solar energy into electricity. Numbers of solar cells are connecting in series to form photovoltaic array. In this paper we are using 72 solar cells which are connected in series to form photovoltaic module. A block diagram of solar cell represents that parallel combination of current source, two diodes and a parallel resistor R_p in series with resistance R_{sh} as shown in Fig. 3.

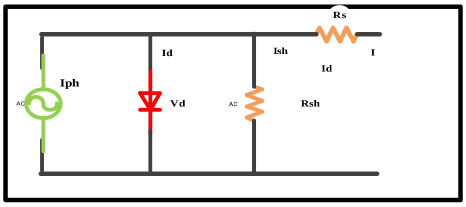

Fig. 3. Block diagram of solar cell

The characteristic equation for a photovoltaic cell is given by

$$I = Iph - Io\left[\exp\left\{q * \frac{V + I * Rs}{n * K * T}\right\} - 1\right] - \frac{V + I * Rs}{Rsh} \quad (1)$$

$$I=(I_{ph}*N_p)-Id-I_{sh} \quad (2)$$

$$Vt = \left(\frac{K * Top}{q}\right) \quad (3)$$

$$Io = Ior * \left(\frac{Top}{Tr}\right)^3 * [\exp\{q * Ego * \frac{\frac{1}{Tref}-\frac{1}{Top}}{n*K} \quad (4)$$

$$I_{ph} = \{I_{sc} + K_i*(Top-25)\}*I_{rr} \quad (5)$$

$$Is = \frac{V + (I * Rs)}{Rp} \quad (6)$$

$$Irs \frac{Isc}{e^{\left(\frac{q*Voc}{K*c*Top*n}\right)} - 1} \quad (7)$$

$$Id = Io * Np\{e^{\left(\frac{\frac{Vs}{Ns}+\frac{I*Rs}{Ns}}{n*Vt*c}\right)} - 1\} \quad (8)$$

I &V : solar cell output current and voltage;
Io : solar cell reverse saturation current;
T : Solar cell temperature (in Celsius);
k : Boltzmann's constant (1.38 * 10^{-19} J/K);
q : Electron charge (1.6*10^{-23} C);

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K_i : Short circuit current temperature coefficient (I_{scr});
Lambda or Irr : Solar irradiation (W/m^2);
I_{sc} : Short circuit current at (25 ℃;
I_{ph} : Light-generated current;
E_g : Band gap for silicon;
n :Ideality factor;
T_{ref} : Reference temperature;
I_{rs} : Cell saturation current (T_{ref});
R_{sh} : Shunt resistance;
R_s : Series resistance;

The characteristics equation of solar panel depends on the how much cells connected in parallel and series. We can clearly see by the experimental results that the current variation is less dependent on the shunt resistance and is more dependent on the series resistance.

$$I = Np * Iph - Np * Io \left[\exp\left\{ q * \frac{\frac{V}{Ns} + I * \frac{Rs}{Np}}{A * K * T} \right\} - 1 \right] - \frac{V * \left(\frac{Np}{Ns}\right) + I * Rs}{Rsh} \quad (9)$$

By P-V and I-V curves in Fig. 4. we can see cell operates as a constant current source at less values of operating voltages and constant voltage source at less values of operating current.

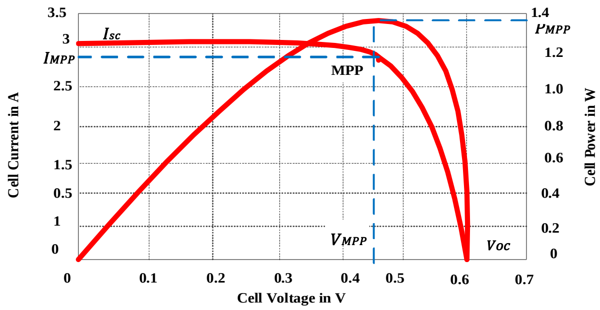

Fig. 4 P-V and I-V curve of a solar cell at given temperature and solar irradiation

III.DC-DC CONVERTER

The DC-Dc converters are highly used in DC power supplies and in photovoltaic applications. The output of the solar irradiance is non-regulated DC supply therefore it will fluctuate due to changes in irradiance on the photovoltaic panels. By switching of DC-DC inverters are used to transform this non-regulated Dc output of solar panel into controlled DC output. Basically converters are of three types i.e. buck converter(also known as step-down converter), boost converter(also known as step-up converter) and buck-boost converter. In this paper we are using boost converter according to the requirement. Boost converter is a DC-DC converter that is used to step-up the voltage output of solar irradiance to a high level while stepping down current. Circuit diagram of boost converter is as shown in Fig. 5. In this system output of solar array is 23.75V and output of DC-DC converters is 45.66V. It consist of minimum 2 semi conductors (a diode and transistor) and minimum one energy storage element i.e. capacitor, inductor or two in combination. To reduce voltage ripples, filters are connected to both input (source) and output (load) side of the converter. The output voltage of converter is controlled by switch ON/OFF time of duty cycle. At constant switching frequency, adjusting the ON and OFF time duration of the switch is called pulse width modulation (PWM) switching technique. The switching duty cycle, k is defined as the ratio of ON time to the total switching time period. The output voltage of the boost converter is

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

where k is duty cycle

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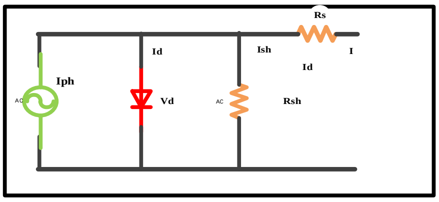

Fig. 5 Circuit diagram of Boost converter

IV.INVERTER

Today's generation of electricity mainly depends on renewable energy source. But this energy is in form of AC but it is transformed into DC by using photovoltaic cell. But most of the load demands AC power supply. So to fulfil their demands we need to transform this DC power into AC power. Inverter is a device which converts DC power into AC power and supply to the various loads. There is various methods for generation of pulses according to the requirement. Here in this paper we are using solar energy system driving a three-phase Induction motor. For proper functioning of Induction motor we need to control the speed. There are various control techniques that is used to control the speed of Induction motor feeding with inverter. Space vector pulse width modulation is one of them which is used to generation of pulses that is require to control the speed.

The topology of three-phase voltage source inverter based space vector pulse width modulation is as shown in Fig. 6. Six out of these eight states produce nonzero output voltage. Since energy is supplied from the source to the motor during these states are known as nonzero switching states or active states. Whereas two states produce zero output voltages since no energy is supplied from the source to the motor are known as zero switching states or inactive states. In this methodology switching state "1" indicate the conduction of upper switch and inverter terminal voltage is +ve i.e. $+\ dc$ while "0" indicates the conduction of lower switch. In this voltage source, inverter can assume only eight states because input lines must never be shorted and the output current must always be continuous. These states are as shown in Fig. 7. Among the 8 switching states [000] and [111] are zero states and others are active states are show in table 1.

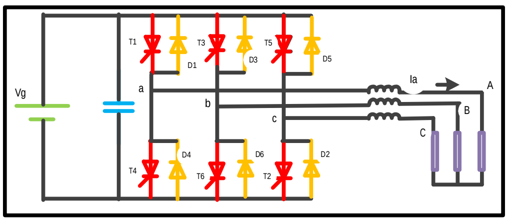

Fig. 6.Topology of three phase inverter

Switching states (three phases)	On-state switch
(000)	S_4, S_6, S_2
(100)	S_1,S_6, S_2
(110)	S_1,S_3, S_2
(010)	S_4, S_3, S_2
(011)	S_4, S_3, S_5
(001)	S_4, S_6, S_5
(101)	S_1, S_6, S_5
(111)	S_1,S_3, S_5

Table 1. Eight switching states

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The relationship between the switching variable vector and line to line potential vector are as

$$\begin{bmatrix} V_{ab} \\ V_{bc} \\ V_{ca} \end{bmatrix} = V_{dc} \begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ -1 & 0 & 1 \end{bmatrix} \begin{bmatrix} a \\ b \\ c \end{bmatrix} \qquad (10)$$

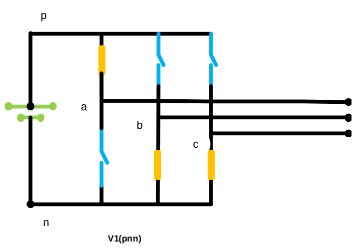
Also the relationship between the switching variable vector and the phase potential vector are as follows

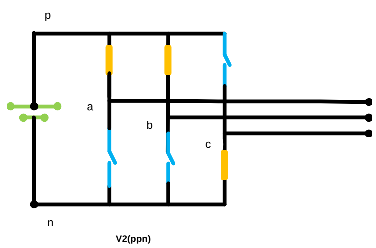
$$\begin{bmatrix} V_{an} \\ V_{bn} \\ V_{cn} \end{bmatrix} = \frac{V_{dc}}{3} \begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix} \qquad (11)$$

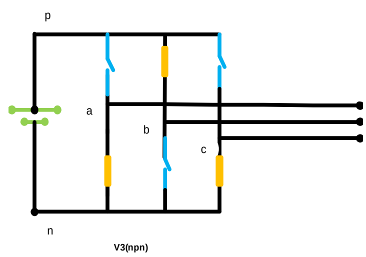
According to equation 1 and 2, 8 switching vectors output line to phase voltages and output line to line voltages are shown in Table 2.

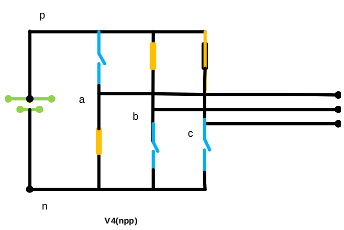
Potential Vectors	Switching Vectors			Line to neutral potential			Line to line potential		
	A	b	c	V_{an}	V_{bn}	V_{cn}	V_{ab}	V_{bc}	V_{ca}
V_0	0	0	0	0	0	0	0	0	0
V_1	1	0	0	$2/3$	$-1/3$	$-1/3$	1	0	-1
V_2	1	1	0	$1/3$	$1/3$	$-2/3$	0	1	-1
V_3	0	1	0	$-1/3$	$2/3$	$-1/3$	-1	1	0
V_4	0	1	1	$-2/3$	$1/3$	$1/3$	-1	0	1
V_5	0	0	1	$-1/3$	$-1/3$	$2/3$	0	-1	1
V_6	1	0	1	$1/3$	$-2/3$	$1/3$	1	-1	0
V_7	1	1	1	0	0	0	0	0	0
Note : the respective voltage should be multiplied with V_{dc}									

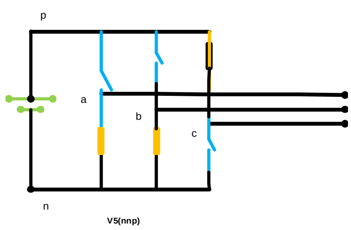
Table 2. Switching vectors, phase voltages, line to line voltages

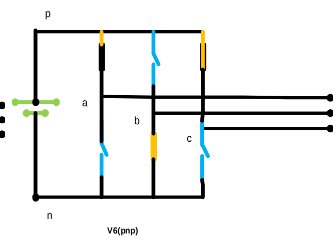












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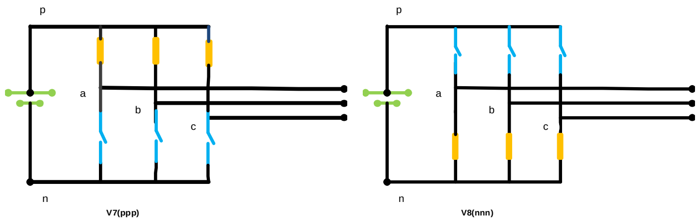

Fig. 7. Eight switching state topologies of a voltage source inverter

V.SPACE VECTOR PULSE WIDTH MODULATION

Space vector pulse width modulation (SVPWM) is an algorithm which is applied to the inverter to control the pulses generated from the inverter. It is used for the creation of AC waveforms which is mostly used to drive three-phase motors at different speeds from Dc using multiple class-D amplifiers.In this generation reference signal is sampled in regular bases after each sample, non-zeros active switching vectors adjacent to the reference vector and one or more of the zero switching vectors are selected for the appropriate fraction of the sampling period in order to synthesize the reference signal as the average of the used vectors.

Space vector pulse width modulation can be classified into four types as

a) Sector selection based SVPWM

b) Reduced switching SVPWM

c) Carrier based SVPWM

d) Reduced switching carrier based SVPWM

In this paper we are using Carrier based pulse width modulation.. It allows fast and efficient implementation of SVPWM without sector determination. The techniques is based on duty ratio profiles that SVPWM exhibits (as shown in fig. 7 and fig. 8) by comparing the duty ratio profile with a higher frequency triangular carrier pulses can be generated based on the same argument as the sinusoidal pulse width modulation.

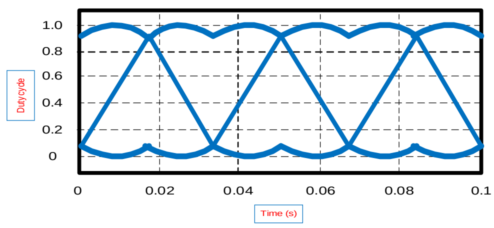

Fig. 8. Obligation ratio profile with standard SVPWM

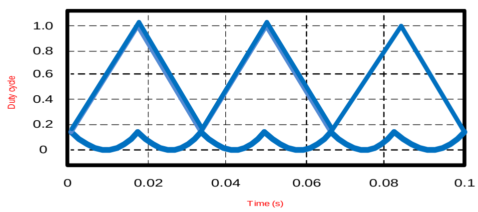

Fig. 9 Obligation ratio profile with reduced switching SVPWM

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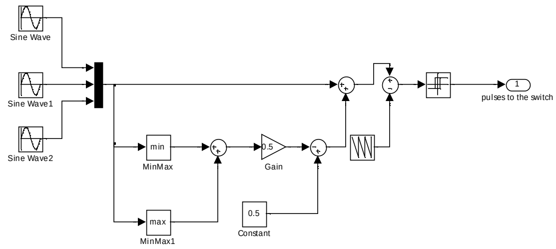

Fig. 10.Carrier based SVPWM based on common mode voltage addition

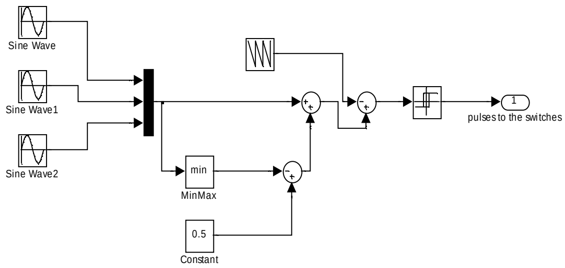

Fig. 11. Reduced switching carrier based SVPWM based on common mode potential addition and unique zero vector utilization

IV. MATLAB SIMULATION OF THREE-PHASE INDUCTION MOTOR DRIVE FED BY SOLAR CELLS

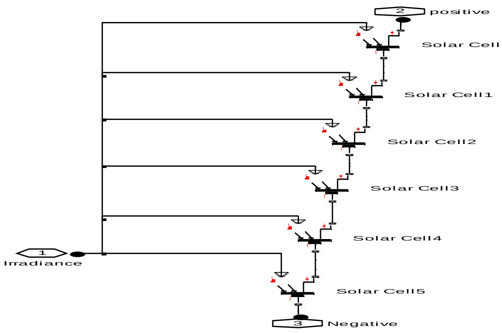

Fig. 12 Simulink model of solar cells

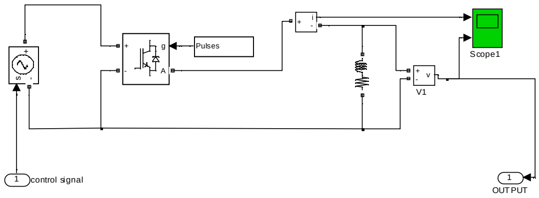

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Fig. 13 Simulink model of converter

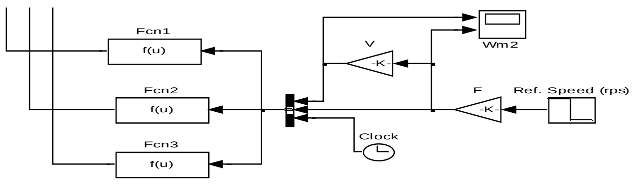

Fig. 14 Simulink model of inverter for generation of pulses

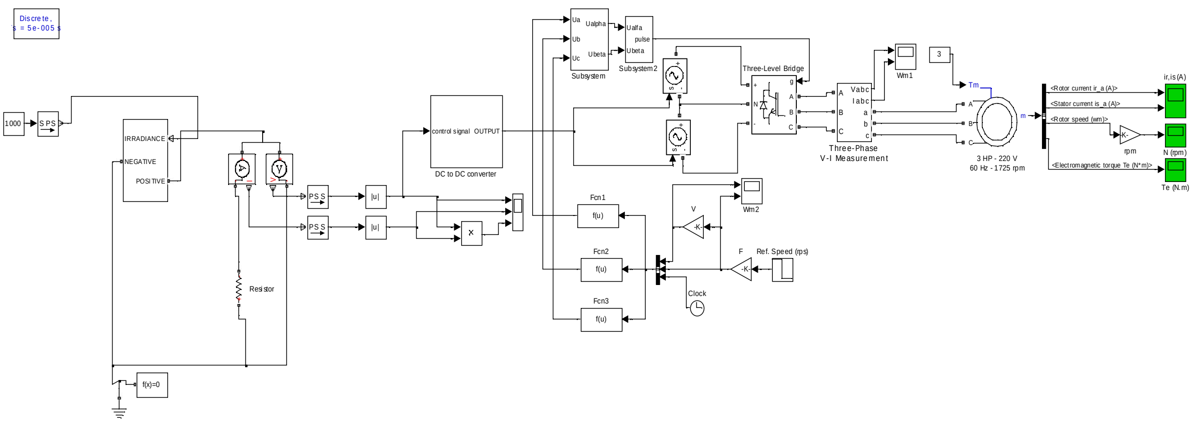

Fig. 15 Simulink model of solar energy system with three-phase Induction motor drive feeding SVPWM by multilevel inverter

VII. SIMULATION RESULTS

Rotor Type	Squirrel Cage	**Stator Inductance**	0.000004 H
Ref. Frame	Stationary	**Rotor Resistance**	0.000816 ohm
Capacity	3 HP	**Rotor Inductance**	0.000002 H
Speed	1725 rpm	**No. of pole**	4
Voltage	220 V	**Mutual Inductance**	0.000069 H
Line Frequency	60 hz	**Inertia (J)**	0.00089
Stator Resistance	0.000435 ohm	**Simulation Time**	1 s

Table 3. Description of apparatus rating used in simulation model

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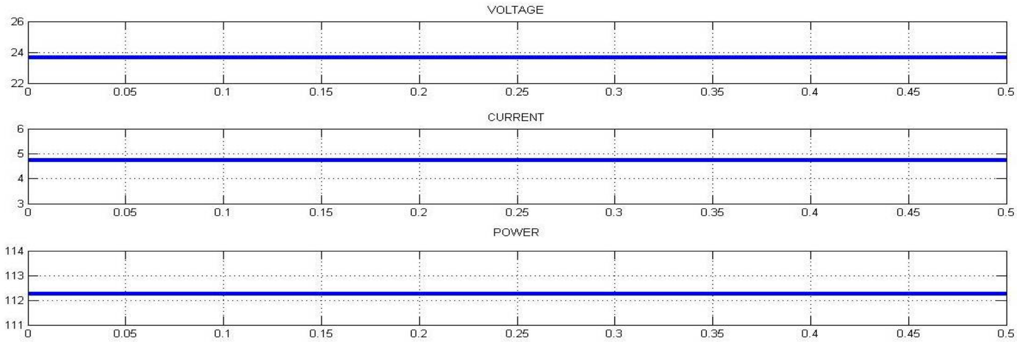

Fig. 16.Voltage, current and power of solar irradiance

Fig. 16. Shows the output of solar irradiance which is applied to DC-DC converter for boosting up voltage and filtered out ripples.

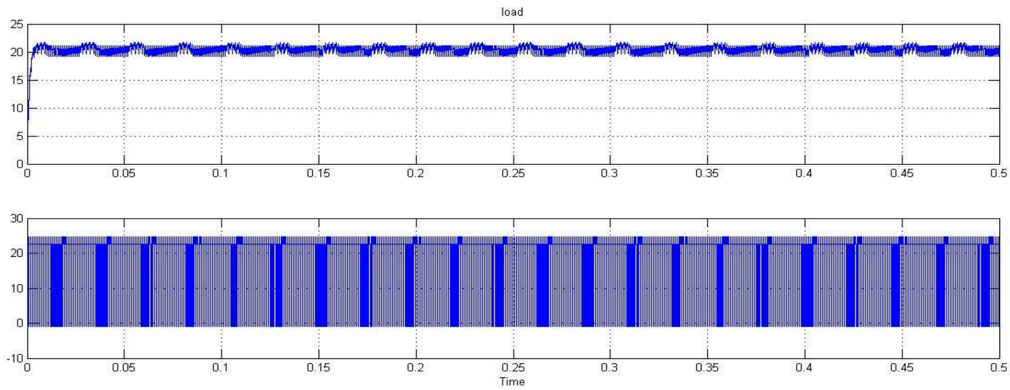

Fig. 17. DC-DC converter

Fig. 17 Shows the output of the DC-Dc converter which is applied to inverter for the conversion of DC to Ac required by the load.

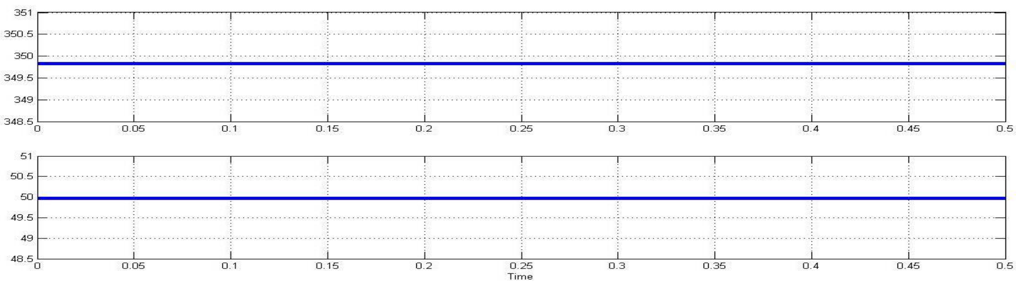

Fig. 18 Generation of pulses by inverter

Fig. 18 Shows the generation of pulses of output of inverter fed with SVPWM which is applied to the three-phase Induction motor for controlling the speed.

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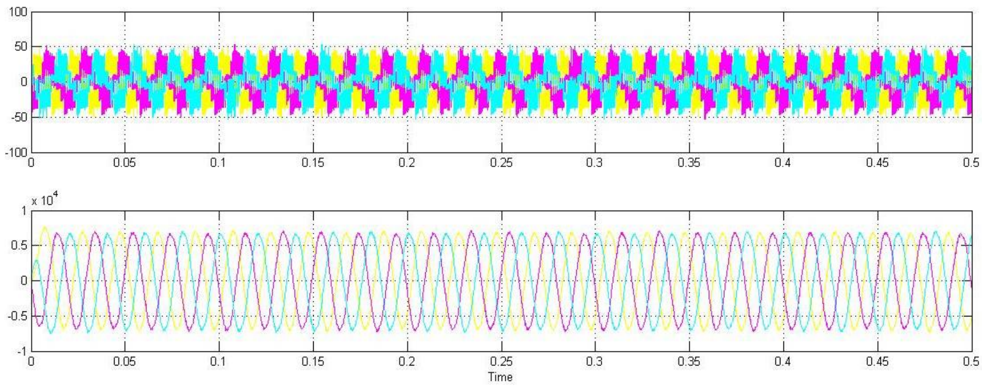

Fig. 19 3-phase voltage-current measurement

Fig. 19 shows the sinusoidal output of three-phase system.

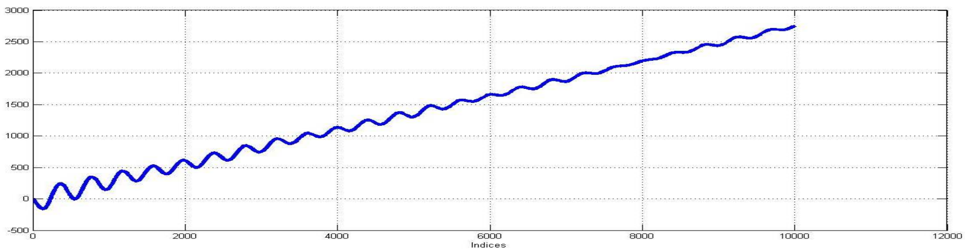

Fig. 20 Induction motor speed

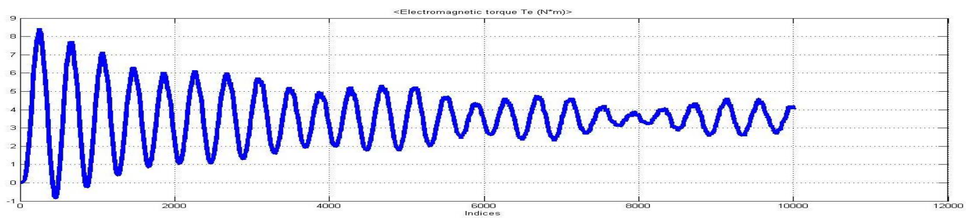

Fig. 21 Electromagnetic torque

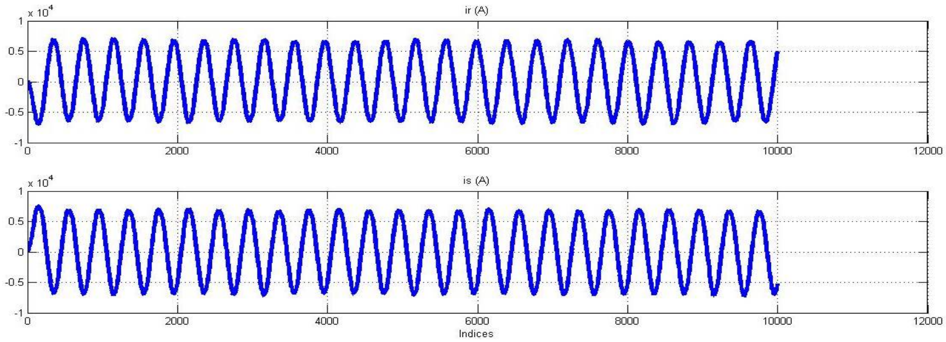

Fig. 22 Induction motor stator current and rotor current

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Fig. 19, 20 and 21 shows the controlled output in form of current, speed and torque by controlling the frequency of the source which is obtained by applying the SVPWM technique to the inverter which generate pulses for controlling the speed of three-phase Induction motor.

VIII. CONCLUSION

In this paper design and control of three-phase Induction motor drive fed by Renewable energy generating sources is presented. By varying frequency of the source speed of Induction motor is controlled. Also a brief description of solar cell, Dc-Dc converter, three-phase Inverter is presented in this paper. By using solar energy as a source it is converted into electrical energy then it is fed into three-phase induction motor and by using SVPWM speed of Induction motor is controlled. Speed of Induction motor is shown in terms of torque, speed and rotor current.

REFERENCES

[1] Mohammed abdul khader aziz biabani and Fazeel Ahmed", International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT),page no. 1614-1620, 2016.

[2] Seemant Chourasiya, Khushboo Gupta and Seema Agarwal," MATLAB Realisation of SVPWM Based Speed Control of Asynchronous Machine Fed From Solar Cell Array" International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol.4 Issue 6, pp 5086-5095, June-2015

[3] Paolo Lazzeroni et. al, "Battery Energy Storage System usage in a Distribution Grid for PV exploitation: a Middle-East Case Study",IEEE, Page no. 1998-2003, 2016.

[4] Udhyami M. B.and Ashna Mohan, "Multiple - Input Bidirectional DC -DC Power Converter with Renewable Energy Source", International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT), page no. 1739-1744,2016.

[5] A.Krama et. al, "Improved Control of Shunt Active Power Filter Connected to a Photovoltaic System Using Technique of Direct Power Control", 8th International conference on Modelling, Identification and Control (ICMIC-2016), page no. 880-885, 2016.

[6] Wachirapong Wareesri and Sakorn Po-Ngam, "A Three-Phase PV-Pump Inverter With Maximum Power Point Tracking (MPPT) Controller", IEEE, pp. 1-4, 2016.

[7] Ravi Raushan et. al, "Operation and Control of Three-Phase Multilevel Inverter with Reduced Component", 3rd International Conference on Recent Advances in Information Technology(RAIT), IEEE, pp. 295-299, 2016.

[8] Semma Agarwal, Seemant Chourasiya, Rakesh Kumar Kumwat and D.K. Palwalia, " Performance Analysis of Standalone hybrid PV-SOFC-Battery Generation system", International Advanced Research Journal in Science, Engineering and Technology (IARJSET), National Conference on Renewable Energy and Environment, pp. 49-53, Vol. 1 special issue 1, May 2015

[9] Mahmoud A.Mossa and Silverio Bolognani, "Effective Model Predictive Direct Torque Control for an Induction Motor Drive", International Symposium on Power Electronics, Electrical Drives, Automation and Motion, IEEE, pp. 746-754, 2016.

[10] Mohammed abdul khader aziz biabani and Syed mahamood ali, "Control of Induction Motor Drive using Space Vector PWM", International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT), IEEE, pp. 3344-3351, 2016.

[11] Abhinav Saxena et. al, "Comparative Analysis of Sensor-Less Speed Control of Three Phase Induction Motor", 3rd International Conference On Computing For Sustainable Global Development (Indiacom), IEEE, pp.1118-1121, 2016.

[12] Aswathi Unni and Mini. V.P, "An efficient solar powered Induction motor drive system", International Conference on Control, Communication & Computing India (ICCC), IEEE, pp. 155-160, 2015.

[13] Hemza Saidi et. al, "Three phase Inverter Using SVPWM Method for Solar Electric Vehicle", 6th International Renewable Energy Congress (IREC)", IEEE, pp. 1-5, 2015.

[14] Bikram Das et. al, "Comparison of Different PWM-VSI Fed 3 Φ IM Based on Modulation Index and Switching Frequency", International Conference On Electrical, Electronics, Signals, Communication And Optimization (EESCO), IEEE, pp. 1-6, 2015.

[15] Suneel Kumar Agrawal and Sumit Ghatak Choudhuri, "Simulation of Vector Controlled Induction Motor drive in MATLAB for various applications: a comparative Study", Michael Faraday IET International Summit (MFIIS), pp. 533-540, September 12 – 13, 2015.

[16] Sy Yi Sim et. al, "Neural Network SVPWM-DTC of Induction Motor for EV Load Model", Electrical Power, Electronics, Communications, Controls, and Informatics Seminar (EECCIS)", IEEE, pp. 23-28, 2014.

[17] Shravni Mathur and Ritika Verma, "Comparative study of total harmonic distortion on the current waveform by PWM fed and Vector controlled Induction Motor drives", Electrical, Electronics and Computer Science(SCEECS), IEEE, pp. 1-6, 2014.

[18] Hung Linh Le et. al, "Speed and flux control of three-phase AC induction motor with uncertain parameters using a speed estimator", International Conference on Robotics and Biomimetics(ROBIO), IEEE, pp. 1578-1583, 2014.

[19] SeHwan Kim et. al, "Induction Motor Control with Small DC-Link Capacitor Inverter fed by Three-Phase Diode Front-End Rectifiers", Energy Conversion Congress And Exposition, IEEE, pp. 3584-3591, 2014.

[20] Ayush Vardhan Goyal et. al, "Three Phase Induction Motor Drive using Single- Phase to Three-Phase Cycloinverter With SVPWM Technique", Students Conference On Engineering And Systems, IEEE, pp. 1-5, 2014.

[21] G. Bhuvaneswari et. al, "Vienna Converter for Three-Level Inverter Fed Induction Motor Drive", 6th IEEE Power India International Conference, pp. 1-6, 2014.

[22] Marco Pruckner, "Modeling the Impact of Electrical Energy Storage Systems on Future Power Systems", *IEEE Electrical Power and Energy Conference (EPEC)*,page no. 978, Vol.1,2016.