ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 5, May 2015

PV Array Fed SEPIC and MCSPWM Based RV Inverter Topology for Single Phase Induction Motor

Anupama Gupta[1], Shimi S.L.[2]

ME Scholar, EE, NITTTR, Chandigarh, India[1]

Assistant Professor, EE, NITTTR, Chandigarh, India[2]

ABSTRACT: This paper presents a simulation Modelling of SEPIC converter and MCSPWM based RV topology for single phase induction motor using solar energy as a source. The large numbers of drives used for commercial, industrial, residential and utility application are induction motor drive. To run such kind of load energy is required as an input source but due to energy crises solar energy is used as an input energy. To run induction motor with PV source DC-DC converter and inverter is used as an interface circuit. For efficient utilization of solar power SEPIC converter with the P &O MPPT controller is used. The boosted output from SEPIC converter use as an input for inverter. The inverter converts the DC input voltage to AC output voltage for the induction motor. To minimize the harmonic from the inverter output voltage, various types of MCSPWM techniques use to generate the firing pulse for the switches of the inverter. In this paper comparative analysis of Cascaded H bridge inverters and RV topology is also presented for the induction motor. The simulation work of these SEPIC converter and RV inverter fed induction motor circuits have been done using SIMULINK and MATLAB software.

KEYWORDS: P & O MPPT, SEPIC, Cascade Multi Level Inverter, New RV Topology, Total Harmonic Distortion, number of carriers.

I.INTRODUCTION

The large numbers of drives used for commercial, industrial, residential and utility application are induction motor drive due to its high robustness, easy build, cheaper in cost due to the absence of brushes, commutators, and slip rings and satisfactory efficiency.

To run such kind of load, energy requires as input. In the world energy crisis is one of the major problems. To overcome this problem, renewable energy resources are used as an energy source. These resources are clean, pollution free and abundantly available in nature. Among them solar energy is one of the most important green energy resources due to its environmental sustainability and inexhaustibility.

As the photovoltaic (PV) cell exhibits the nonlinear behavior, while matching the load to the photovoltaic modules, DC-DC power converters are needed. There are several converter configurations such as Buck, Boost, Buck-Boost, SEPIC, ĆUK, Fly-back, etc. Buck and Boost configurations can decrease and increase the output voltages respectively.

P-V and I-V characteristics of photovoltaic module indicates that the maximum power generation capability is available only on one specific operating condition called maximum power point. So it is necessary to operate the PV module at its maximum power point at all irradiance and temperature condition, for this purpose maximum power point controller is designed. The maximum power point controller tracks the output voltage and current from the solar photovoltaic cell and determines the operating point that will deliver the maximum power and increase the efficiency of solar cell. According to the MPPT (Maximum Power Point Tracking) output the duty cycle of SEPIC (Single Ended Primary Converter) is changed and the output voltage of SEPIC converter is controlled according to load requirement.

In this paper SEPIC converter and Inverter work as an interface circuit between PV source and induction motor. So boosted output voltage from the SEPIC converter is converted in AC voltage for induction motor by using a voltage source inverter. To improve the output voltage, efficiency various types of multilevel inverter are used like Diode clamped multilevel inverter also known as Neutral Point Clamped (NPC) Inverter, the flying capacitors Multilevel Inverter (MLI) and cascaded multilevel inverter. Among these multilevel topologies, cascaded multilevel inverter has preferred over FCMLI and DCMLI because it requires the least number of components and increases the number of

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ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

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Vol. 4, Issue 5, May 2015

levels in the inverter without requiring high ratings on individual devices and the power rating of the CCMLI is also increased [1]. The cascaded multilevel control method is very easy when compare to other multilevel inverter because it doesn't require any clamping diode and flying capacitor. However, it has some disadvantages as complicated PWM controlling technique, increased number of components, complex power bus structure in approximate topologies, and voltage balancing problem. Each active semiconductor added requires associated gate drive circuits and adds further complexity to the converter. To remove all this disadvantage a new RV topology is used in this paper. The comparative analysis of seven levels cascaded inverter and RV inverter for induction motor is presented with FFT analysis.

II.PV FED SEPIC CONVERTER

A solar cell (also called a photovoltaic cell) is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect. PV cell is made of special material called semiconductor material and composed of pn junction. To utilize these electricity for industrial application, we required DC-DC converter. This converter may be used to increase or decrease the solar cell voltage. For maximum power utilization duty cycle of SEPIC converter is controlled by the MPPT Controller.

A. PV CELL

The direct conversion of solar radiation into electricity is called as a photovoltaic (PV) energy conversion because it is based on the photovoltaic effect. The photovoltaic effect means the generation of a potential difference at the junction of two different materials in response to visible or other radiation. In order to use solar electricity for practical devices, which require a particular voltage or current for their operation, a number of solar cells are connected together to form a solar panel, also called a PV module.
A photovoltaic module is formed by connecting many solar cells in series and parallel. Considering only a single solar cell. This model is based on mathematical equations and is described through an equivalent circuit including a photocurrent source, a diode, a series resistor and a shunt resistor [1,2]. This model is known as a single diode model of solar cell.

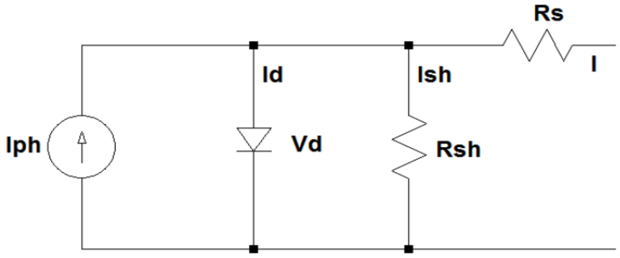

Fig.1 Single Diode Model of Solar Cell

Mathematical equation for PV cell

$$I = I_{ph} - I_s\left(exp\frac{q(V+R_sI)}{NKT} - 1\right) - \frac{(V+R_sI)}{R_{sh}} \quad (1)$$

$$I_{ph} = [I_{sc} + K_i(T - 298)]\frac{\beta}{1000} \quad (2)$$

$$I_s(T) = Is\left(\frac{T}{T_{nom}}\right)^3 exp\left[\left(\frac{T}{T_{nom}} - 1\right)\frac{E_g}{N.V_t}\right] \quad (3)$$

I_{ph} = Photocurrent
I_s = Reverse saturation current of diode
q = Electron charge
V = Voltage across the diode
K = Boltzmann's constant
N = Ideality factor of the diode
R_s = Series resistance of cell
R_{sh} = Shunt resistance of cell

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K_i = Current temperature coefficient
β = Solar radiation (W/m^2)
T_{nom} = Nominal temperature
E_g = Energy gap
V_t = Terminal voltage

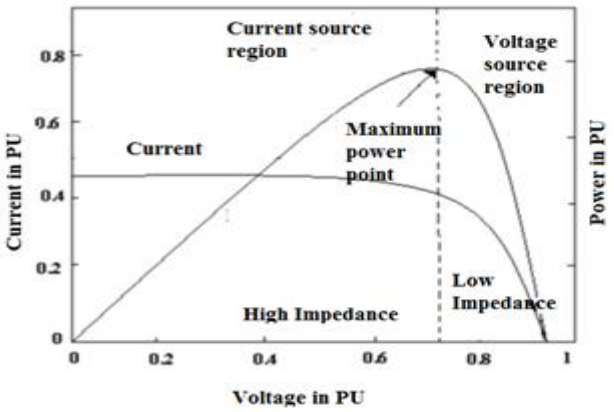

Fig.2 PV Module I-V and P-V Characteristics

Form the output characteristics of solar cell as shown in fig .2 it can be seen that, there is a unique point on the V-I or V-P curve, called the Maximum Power Point (MPP), at which the entire PV system (array, converter, etc.) operates to obtain the maximum efficiency of PV module and produces its maximum output power. So MPPT controller is needed to obtain maximum efficiency.

B. P & O MPPT CONTROLLER

The load on the PV solar cell generator may be a dynamic or a static load. A dynamic load has varying characteristics all over the operating range, whereas the static load has stable characteristics all over the operating range. A resistive load is static and linear characteristics all over the operating range. When a PV module is directly coupled to a load, the PV module's operating point will be at the intersection of its I–V curve and the load line. If the load line intersects the PV characteristic curve at the maximum power point, the matching is 100% between the load and the PV generator. But with varying operating conditions such that varying insolation level or temperature, or varying load resistance, the matching no longer exists as shown in Fig. 3.

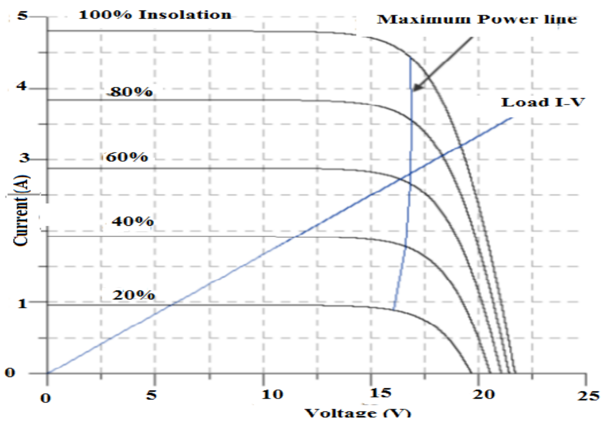

Fig.3 Mismatching of I-V Curves MPP and Load Line for PV Generator

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ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

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So we need to transfer the load resistance to another value to be seen from the PV generator side as 100% matching in all operating conditions. The operating point is different at the PV module's MPP, thus it is not producing the maximum power. To solve this problem, various types of a maximum power point tracker (MPPT) can be used to maintain the PV module's operating point at the MPP. The controller changes the output voltage level of DC-DC converter by changing the duty cycle of the pulse width modulated (PWM) signal, which tracks the reference signal. The reference signal is used to compare the SEPIC's output to achieve the maximum power.
P&O based MPPT controller is most common and simplest MPPT controller [4]. In this MPPT method very less number of sensors required to track the maximum power point. In P&O techniques MPPT tracker move in the direction in which output power obtained from the PV system increases. In this algorithm a slight perturbation is introducing. This perturbation changes the power of solar cell. If a change in the power of solar cell given by equation 4 is positive, then the perturbation is continues in the same direction. If the change of power (ΔP) is negative, the tracker will change the direction of perturbation in the opposite direction.

$$\Delta P = P_K - P_{K-1} \qquad (4)$$

After the peak power is reached the power at the next instant decreases and hence after that the perturbation reverses. When the steady state is reached the algorithm oscillates around the peak point. In order to keep the power variation small the perturbation size is kept very small.

C. SEPIC CONVERTER

Single-ended primary-inductor converter (SEPIC) acts as a buck-boost converter, where it changes its output voltage according to its duty cycle. The SEPIC converter output voltage may be either higher or lower than the input voltage. Unlike the conventional buck-boost converter, the SEPIC converter has a non-inverted output and it uses a series capacitor to isolate input from output. SEPIC Converter has minimum ripple current, comparing to buck-boost converter [5].
The working of the converter is performed under the following assumptions,
i. All the components of the converter are assumed ideal.
ii. The capacitances C1 and C2 are large enough so that the voltages across them are constant and the efficiency of the structure is considered equal to 100%.
The SEPIC converter works in two modes: mode 1 where the switch is ON and in the mode 2 switch is OFF.
Mode 1: (0<t<DT) as shown in Fig. 4 at t=0, the switch is turned on. The energy from the source V_{in} is stored in the inductance L1 and the capacitor C1 transfers its energy to the L2. The capacitor C1 voltage is considered constant and equal to V_{in}. The currents I_1 and I_2 increases linearly. During this stage diode D is reverse biased and kept blocked and the capacitor C2 supplies energy to the load.
Mode2: (DT<t<T) as shown in Fig. 4 at t=DT, the switch is turned off and the diode D is forward biased and turned on, transferring the inductor stored energy to the load. The currents I_1 and I_2 decreases linearly.
From mode 1 and mode 2 the average voltage across inductor in one cycle is zero

$$\text{Vin DT} - \text{Vo}(1 - D)T = 0 \qquad (5)$$

$$\text{Vin D T} = \text{Vo}(1 - D)T \qquad (6)$$

$$\frac{\text{Vo}}{\text{Vin}} = \frac{D}{(1 - D)} \qquad (7)$$

From the equation 7 it is concluded that the SEPIC converter work as step up and step down DC to DC converter by varying the duty cycle D.

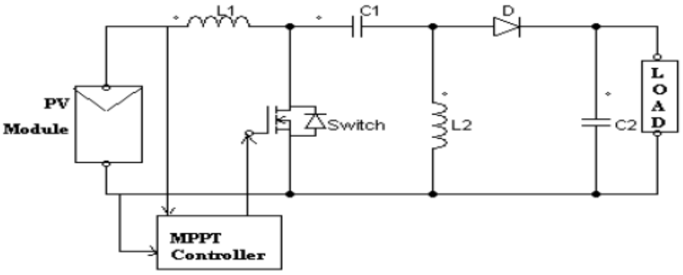

Fig. 4. SEPIC Converter with PV Module and MPPT Controller.

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International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

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SEPIC converter with PV module and MPPT controller use as an input source for the cascaded and RV inverter.

III.CASCADED H BRIDGE INVERTER

The concept of this inverter is based on connecting H-bridge inverters in series to get a sinusoidal voltage output. The output voltage is the summation of the output voltage of each H- bridge [6,7]. The number of output voltage levels is 2n+1, where n is the number of H- bridges. The switching angles can be chosen in such a way that the total harmonic distortion is minimized. For this Phase Disposition, Altenative Phase Opposition Disposition, Phase Opposition disposition method is used to generate the firing pulses for the H- bridge switches and minimized the harmonic from the output voltage level. Among these Carrier disposition method Phase disposition method is preferred as this method has low THD value.

IV.RV INVERTER

In conventional cascaded multilevel inverters, a combination of power semiconductor, switches are used to produce a high-frequency output voltage level in positive and negative polarities, but in RV topology all the switches are not used for generating bipolar levels. This topology is a hybrid multilevel topology which separates the output voltage into two parts. One part is named as level generation part and it is responsible for generating the output voltage level in positive polarity. This part requires high-frequency switches to generate the required levels. The other part is called polarity generation part and it is responsible for generating the polarity of the output voltage, which is the low-frequency part operating at line frequency [8,9]. The connecting diagram and block diagram of seven level RV inverter is shown in fig.5 and fig.6.

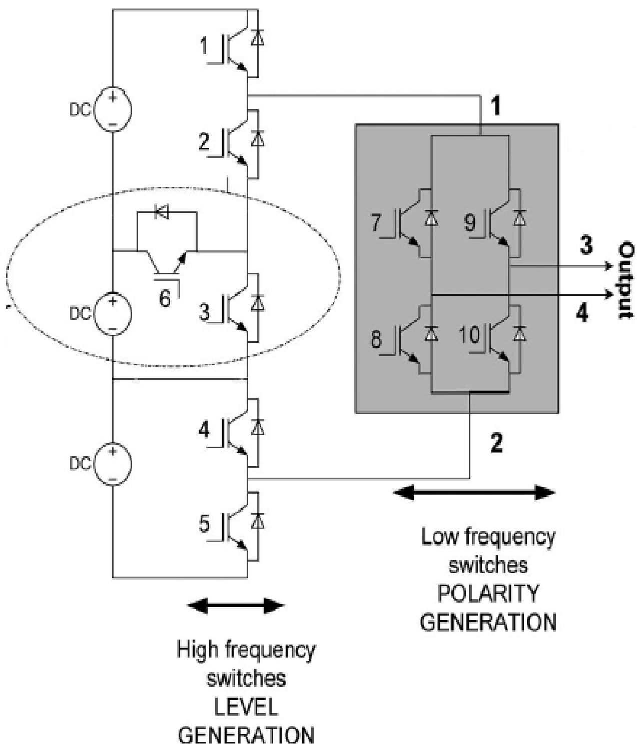

Fig.6 Connecting Diagram of Seven Level RV Inverter

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ISSN (Online): 2278 – 8875

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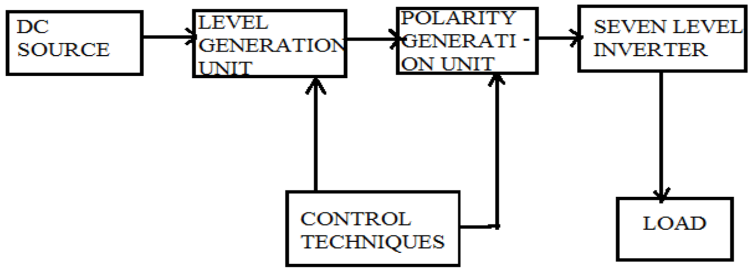

Fig. 5 Block Diagram of RV Topology

A new RV topology requires fewer components in comparison to conventional inverters. Another advantage of the topology is that it just requires half of the conventional carriers for SPWM controller. SPWM for seven-level conventional converters consists of six carriers, but in this topology, three carriers and one modulating signal are sufficient [10,11]. The reason is that, according to Fig.6, the multilevel converter works only in positive polarity and does not generate negative polarities. A Full bridge inverter is used to generate the polarity.

V. FLOW CHART OF PROPOSED WORK

The proposed work for PV fed SEPIC Converter and MCSPWM based VSI for Single Phase Induction Motor will be carried out by the steps shown in flow chart.

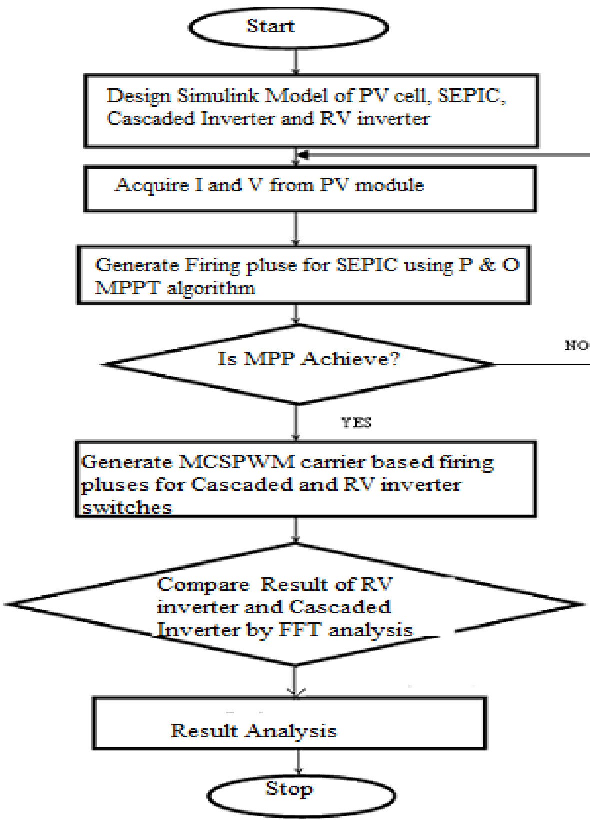

Fig.7 Flow Chart of Proposed work

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ISSN (Online): 2278 – 8875

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VI.SIMULATION RESULT

Fig. 8 - 11 shows the Output voltage and THD of PD based seven levels Cascaded Inverter and RV inverter. In this case total harmonic distortion For Cascaded inverter is 17.8% and for RV inverter is 19.92 % for modulation index 0.8.

Peak output voltage and rms voltage for Seven level Cascaded inverter are 103.7 volts and 73.5 and for RV inverter peak and rms voltage are 109.8 V and 77.67 V as shown in Fig. 8 and Fig.9. Peak and rms voltage of RV inverter is high compare to the PD fed cascaded inverter. So if higher output voltage required RV inverter Topology is preferred over H- Bridge cascaded Inverter.

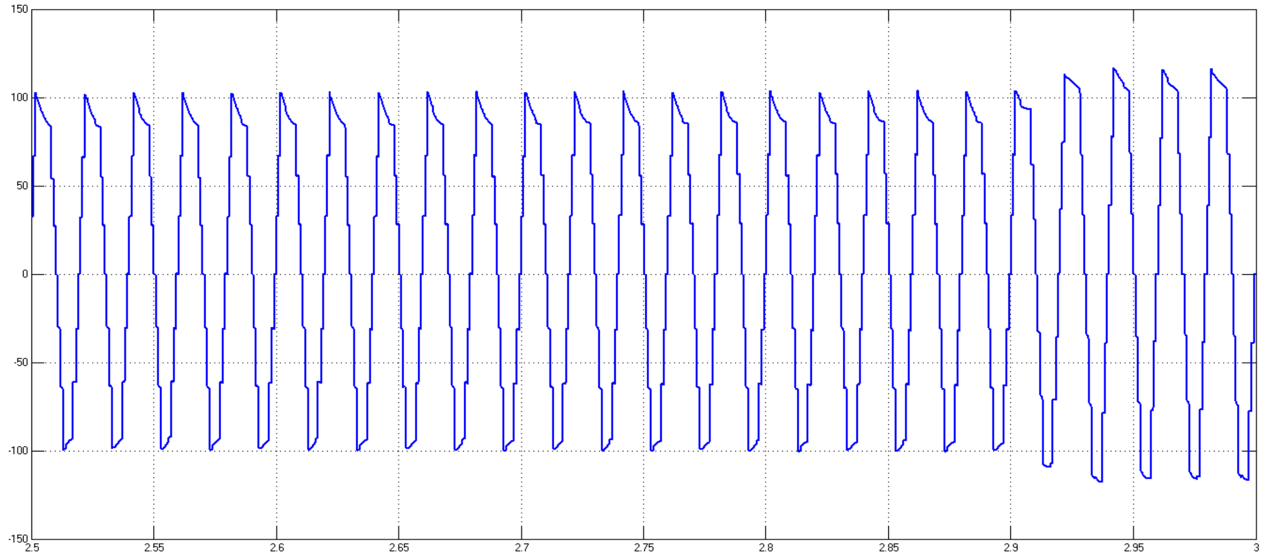

Fig.8 Output Voltage of Single Phase Cascaded Inverter using PD

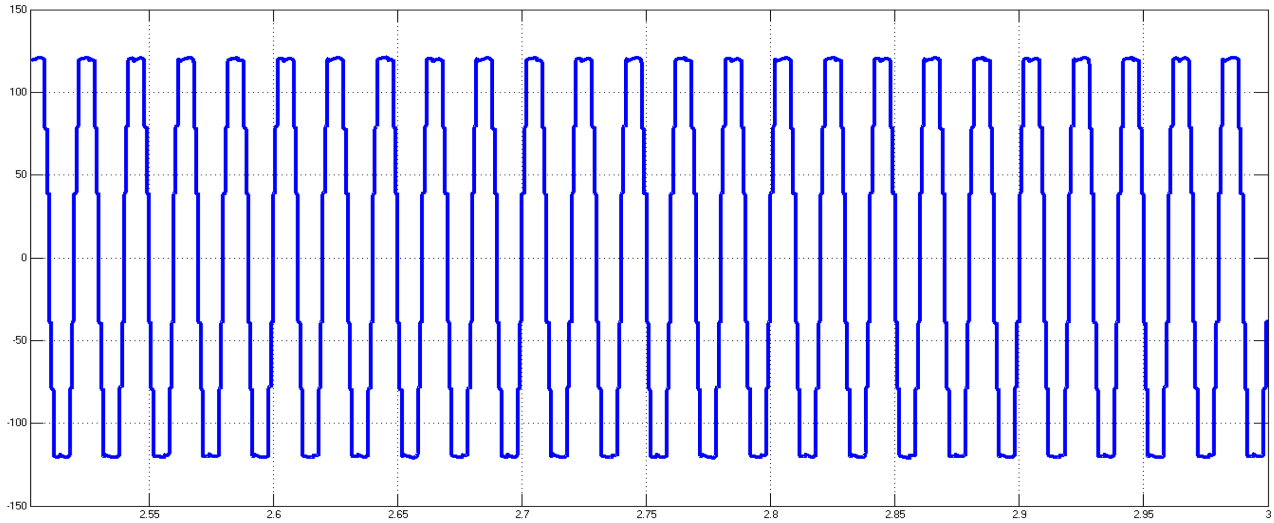

Fig.9 Output Voltage of Single Phase RV Inverter using PD

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ISSN (Online): 2278 – 8875

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(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 5, May 2015

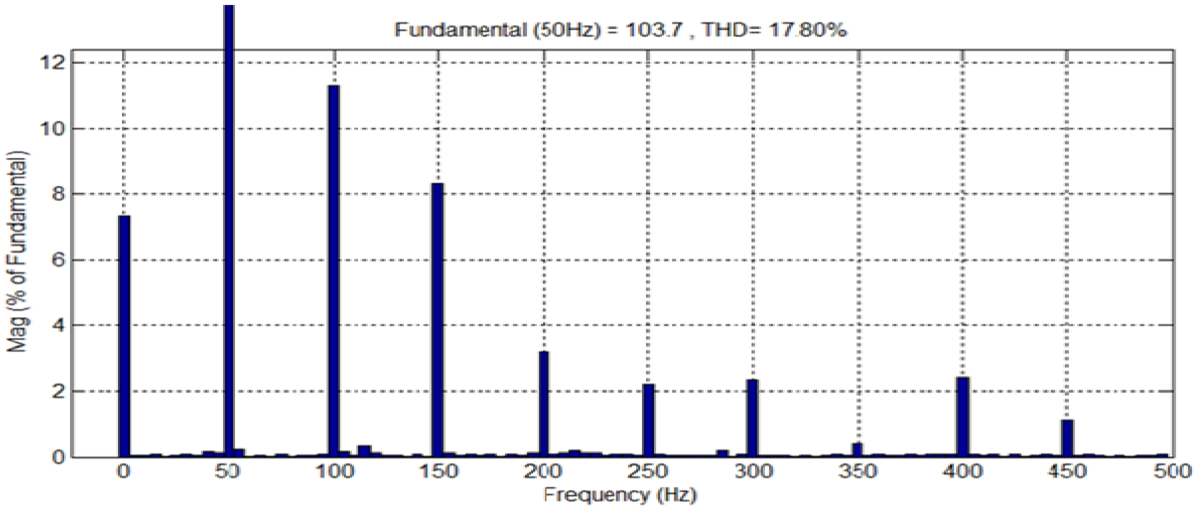
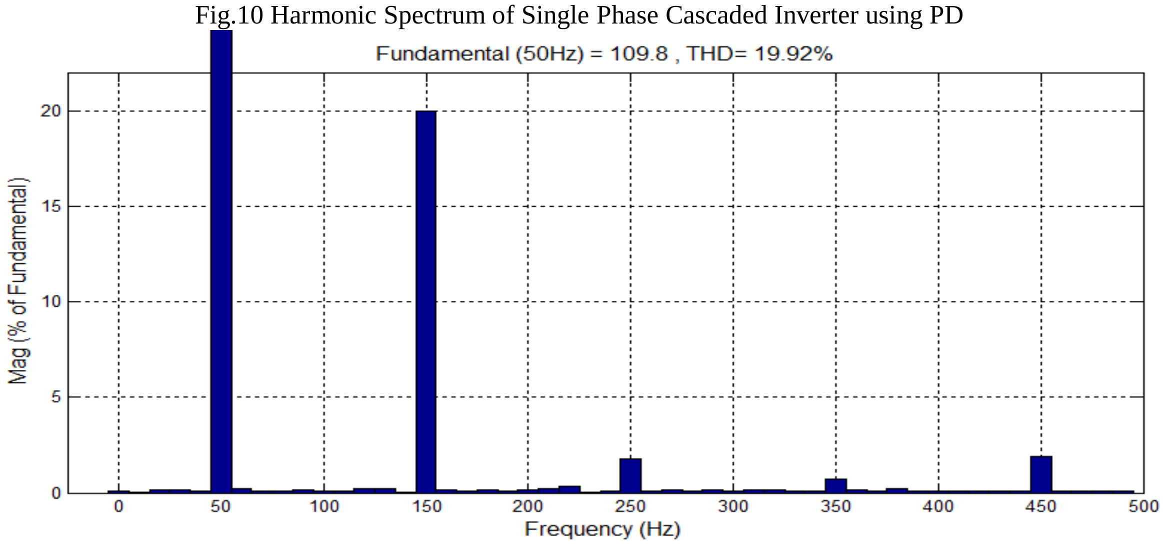


Fig.10 Harmonic Spectrum of Single Phase Cascaded Inverter using PD



Harmonic Spectrum of Single Phase RV Inverter using PD

TABLE 1 Comparative Analysis of Single Phase Cascaded Inverter and RV Inverter

	Cascaded Inverter (PD)	RV Inverter (PD)
THD	17.80%	19.92%
Phase Voltage (RMS)	73.35	77.67
No. of Carrier	N-1	(N-1)/2
Even Harmonic	YES	NO

From the Fig. 8 to 11 and Table 1 We observe that RV inverter is comparable with cascaded inverter in terms of THD, rms voltage, ripple in current and torque, speed and dynamic response, but it required less number of switches and carriers so cost of RV inverter is less and performance of RV inverter is similar to cascaded inverter.

VII.CONCLUSION

Matlab and Simulink model of PV fed SEPIC converter and MCSPWM Based Seven level RV and Cascaded inverter are presented and output voltage and current waveform is observed for induction motor and comparative analysis of cascaded H bridge inverter and reverse voltage inverter topology is presented and found that a reverse voltage

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International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 5, May 2015

balancing topology is comparable with the conventional cascaded H bridge inverter in terms of THD. RV Topology does not contain any even harmonics in output voltage and RV topology is easily extended for higher level so RV topology is simple in construction. RV topology is superior to the conventional cascaded inverter in terms of number of carriers, cost, complexity, control requirement, no of the component.

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