

# **A Modified Seven Level Inverter for Dynamic Varying Solar Power Generation System**

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**ABSTRACT:** In this paper we composed of a new solar power generation system and it consists of a dc/dc power converter and a new seven-level inverter. The fly back boost converter is integrated with dc to dc converter and a transformer to convert the output voltage of the solar cell panel array into dc voltage sources. This modified seven-level inverter is configured using a capacitor selection circuit of converter capacitor and a full single H-bridge power inverter, is cascaded. The capacitor selection circuit converts the three output voltage sources of dc–dc power converter into a three-level dc voltage, and the full bridge inverter further converts this three-level dc voltage into a seven-level ac voltage. Some of the advantage of this paper, it has reduced switches and the dynamic varying conditions of solar system will be eliminated by front end DC-DC converter with closed loop control.

**KEYWORDS:** Multilevel inverter, pulse-width modulated (PWM) inverter, flyback boost converter

## **I. INTRODUCTION**

The extensive use of coal and fuels leads to the generation of power using solar radiations. Nowadays solar power is more preferred than fossil fuel because it is pollution free system. Whereas the fossil fuel are one of the main source for greenhouse gas emission and it's not abundantly available in the earth. The solar radiation is available on the earth till sun exists in the universe. The solar radiation is nothing but the rays coming from the sun to the earth. These rays are collected through photovoltaic panel that is heat or radiation is converted to electricity through this panel, they are further converted to pure dc through converter and so it can boost the output voltage to match DC bus voltage of the inverter.

Multilevel inverters provide a better sinusoidal output-voltage waveforms, output current with good harmonic profile, with low emphasizing of electronic elements because of decreased voltages, switching losses are lower than that of conventional two-level inverters, a reduced filter size, and it have a lesser EMI, this thing make a multilevel inverter cheaper, light weight , and more compact in size. Various topologies for multilevel inverters have been proposed over the years. Common ones are diode-clamped, flying capacitor or multicell cascaded H-bridge, and modified H-bridge multilevel [1]. Introduction of a multilevel inverter in PV power system enables each PV source to be controlled separately. Among all types of multilevel inverters, the “cascaded H-bridge inverter” is most commonly used due to its different structure arrangement. The power of each PV source can be increase to maximum level by allocating a maximum power point tracking (MPPT) algorithm for each PV source. This approach has been implemented only in an experimental model where each PV source was emulated by a series connection of dc source and resistance. This representation does not reflect the proper behavior of the PV source, especially under partial shading [2].

Modulation methods for multilevel inverters can be classified according to switching frequencies methods working with low switching frequencies include the multilevel selective harmonic elimination, the multilevel space vector control, the optimal-combination modulation and the staircase modulation In low-switching frequency applications,

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the staircase modulation is very popular, particularly for the cascade multilevel inverters. In the cascade multilevel inverter, the basic idea of the staircase modulation is to connect each cell of the inverter at specific angles to generate the multilevel output waveform, producing only a minimum of necessary commutation [3].

For a single-phase seven-level inverter, 12 power electronic switches are required in both the diode-clamped and the flying-capacitor topologies. Asymmetric voltage technology is used in the cascade H-bridge multilevel inverter to allow more levels of output voltage[4] , so the cascade H-bridge multilevel inverter is suitable for applications with increased voltage levels. Two H-bridge inverters with a dc bus voltage of multiple relationships can be connected in cascade to produce a single-phase seven-level inverter and eight power electronic switches are used. More recently, various novel topologies for seven-level inverters have been proposed. For example, a single-phase seven-level grid-connected inverter has been developed for a photovoltaic system [5]. This seven-level grid-connected inverter contains six power electronic switches. However, three dc capacitors are used to construct the three voltage levels, which results in that balancing the voltages of the capacitors is more complex. In a seven-level inverter topology, configured by a level generation part and a polarity generation. This paper consists of a modified seven level inverter and converter configuration for varying solar power generation.

## II. CIRCUIT CONFIGURATION

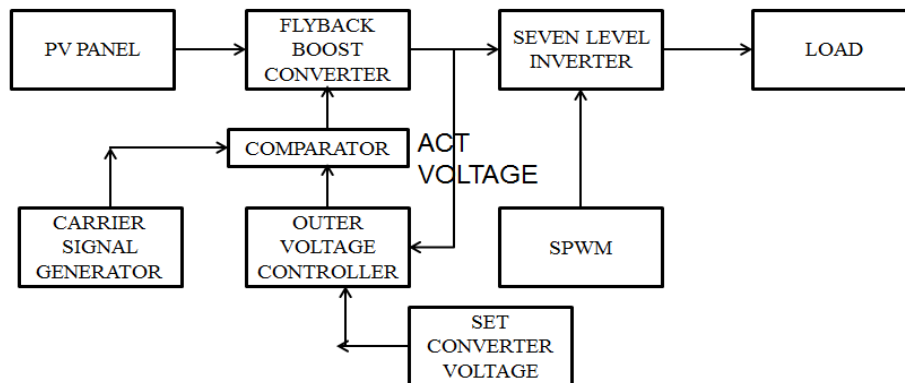


Fig .1 Block diagram of the proposed solar power generation

Fig. 1 shows block diagram the proposed solar power generation system. The solar power generation system consists of solar photovoltaic panel, a dc-dc power converter and a modified seven level inverter. The solar cell array is connected to the dc-dc power converter, and the dc-dc power converter is a flyback boost converter that incorporates a transformer with a turn ratio of 2:1. The dc-dc power converter converts the output power of the solar cell array into independent voltage sources with closed loop control, which are supplied to the seven-level inverter. Fig. 2, shows the circuit diagram of proposed model.

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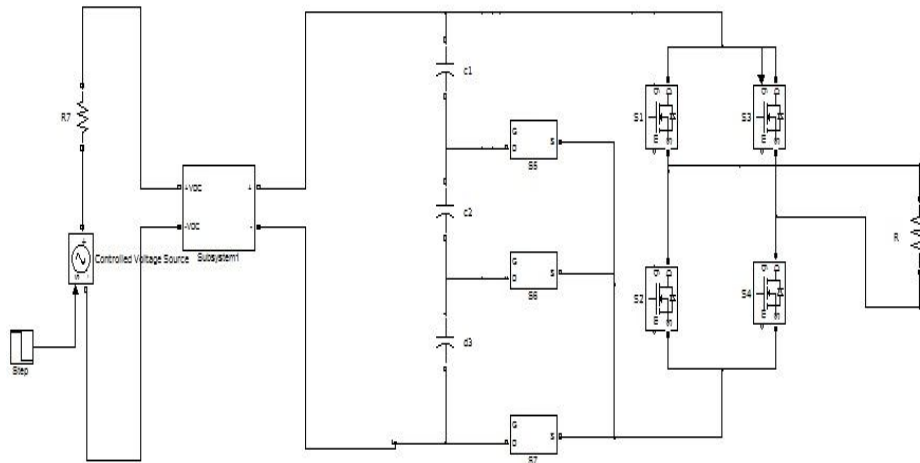


Fig. 2 .configuration of the proposed solar power generation system

Within the specified value which is considered as double the rated current in this work. A rate limiter is introduced in the reference voltage to limit the starting current of the motor as well as the charging current of the dc link capacitor[10-12].

This modified seven-level inverter is composed of a capacitor selection circuit which means converter capacitor and a full-bridge power converter, connected in a cascade. The power electronic switches of capacitor selection circuit determine the discharge of the two capacitors while the two capacitors are being discharged individually or in series. Because of the multiple relationships between the voltages of the dc capacitors, the capacitor selection circuit outputs a three-level dc voltage. The full-bridge power converter further converts this three-level dc voltage to a seven-level ac voltage that is synchronized with the utility voltage. In this way, the proposed solar power generation system generates a sinusoidal output current that is in phase with the load. As can be seen, this new seven-level inverter contains only six power electronic switches, so the power circuit is simplified and using front end dc-dc power converter dynamic varying condition are eliminated.

### III. DESIGN OF DC-DC POWER CONVERTER

The flyback boost DC-DC converter is formulated from the simple buck-boost converter. The conversion ratio for this converter is given by,

$$V_{out}/V_{in} = (n \cdot D / 1 - D) \quad (1)$$

From the above equation, the flyback boost converter ratio is similar to that of the buck-boost converter with an included factor of n, which is the turn's ratio of the flyback transformer[13].

In a flyback converter, when the current ramps up in the primary, energy formed in the transformer core. When the switch is in off condition, the energy is passed into the secondary side of transformer. This makes the current flow current to flow in the secondary, so the primary current reduced to zero. This effect made to rise a current in the secondary side of a transformer, after that the current in the secondary side goes down linearly as it discharges voltage from the capacitor to the load. When the switch is in off condition the secondary side is equal to the peak value of the primary and is determined by the turn's ratio.

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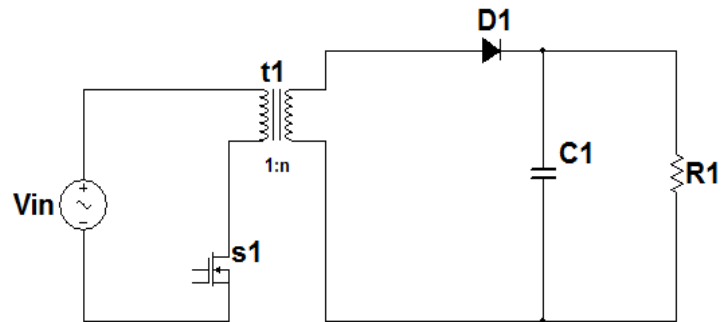


Figure 3. Basic Topology of a Flyback Converter

As seen in Fig.3, the DC-DC power converter incorporates a flyback boost converter and a current-fed forward converter. The flyback boost converter is composed of a power electronic switch S1. The boost converter charges capacitor C1 of the seven-level inverter. The current-fed forward converter is composed of power electronic switches S1, a transformer, and diodes D1 and C1. The current-fed forward converter charges capacitor C1 of the seven-level inverter. And the power electronic switch S1 of the current-fed forward converter is also used in the boost converter [14-16].

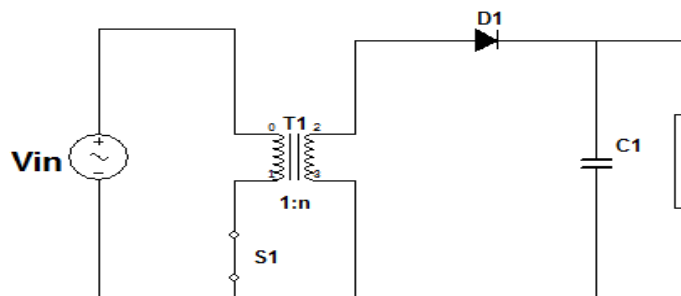


Fig.4. operation of dc-dc converter :( a).S1 is ON

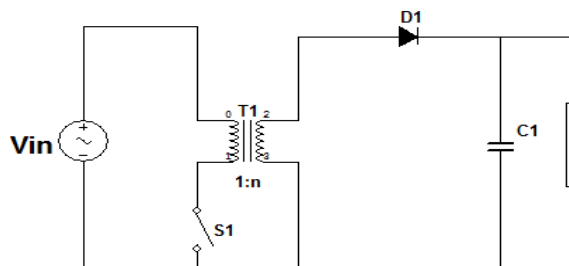


Fig.4. operation of DC-DC converter :(b) S1 is OFF

The behaviour of most transformer-isolated converters can be adequately understood by modelling the physical transformer with a simple equivalent circuit consisting of an ideal transformer in parallel with the inductance. The magnetizing inductance behaves in a way of all the inductor behaves; in particular, volt-second balance must hold when the circuit operates in steady-state. The average voltage given across every winding of the transformer must be zero.

Let us replace the transformer of Fig. 3 with the equivalent circuit described above. The circuit of Fig. 4(a) is then obtained. The magnetizing inductance  $L_M$  functions in the same manner as inductor L of the original buck-boost converter of Fig. 3. When switch S1 start to conduct, energy from the dc source  $V_{dc}$  is stored in  $L_M$ . When diode D1

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start to conduct, the energy stored in the capacitor is transferred to the load, with the inductor voltage and current is measured according to the turn's ratio of the transformer.

Fig. 4(a) shows the operating circuit of the dc-dc power converter when S1 is turned ON. The solar cell array supplies energy to the primary side transformer. When S1 is turned OFF and C1 supplies its energy to the load. Its operating circuit is shown in Fig. 4(b). This paper propose a different arrangement of converter, here three flyback converters are used. The capacitor C1 is connected to capacitor C2 and C3 in parallel through the secondary transformer and it is placed outside of the subsystem. . Since capacitors C1, C2 and C3 are charged in parallel by using the transformer, the voltage ratio of capacitors C1, C2 and C3 is the same as the turn ratio (1:1) of the transformer. Therefore, the voltages of C1, C2 and C3 have multiple relationships. The boost converter is operated in the continuous conduction mode (CCM). The voltage of C1 can be represented as

$$V_{C1} = (1 / (1-D)) V_s \tag{2}$$

Where  $V_s$  is the output voltage of solar cell array and D is the duty ratio of S1. Here, C2 and C3 capacitors are connected in parallel to C1. The voltage drop in each parallel capacitor is same, then the voltage  $V_{C2}$  and  $V_{C3}$  have the same voltage as  $V_{C1}$  respectively.

The switches S5, S6 and S7 are connected in parallel with the C1,C2 and C3 capacitors .Here, the three levels are converted to seven levels by varying switching operations of S5,S6 and S7, which is given to the inverter as an input.

Here dynamic varying condition is eliminated by using front end dc/dc converter. This is obtained by giving pulse to the switch by comparing output voltage of converter with the reference voltage.

In addition, the power circuit is simplified because the charging circuits for capacitors C1, C2 and C3 are integrated. Capacitors C1, C2, C3 are charged in parallel by using the transformer, so their voltages automatically have multiple relationships. The control circuit is also simplified.

## IV. SEVEN LEVEL INVERTER

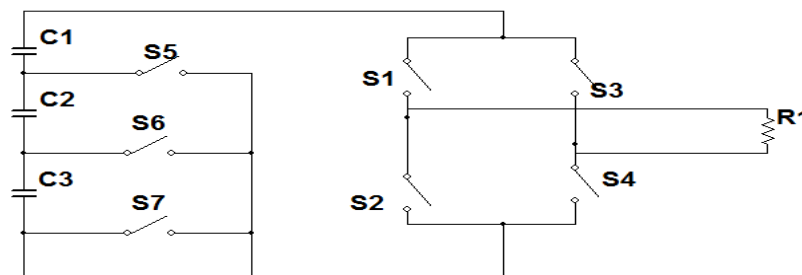


Fig .6 inverter circuit diagram

As seen in Fig. 6, the seven-level inverter is consists of a capacitor from converter and a full-bridge power converter, which are connected in cascade. Here converter itself acts as a capacitor selection circuit. The operation of the seven level inverter can be divided into the positive half cycle and the negative half cycle to the load. For ease of analysis, the power electronic switches and diodes are assumed to be ideal, while the voltages of three capacitors C1, C2 and C3 in the capacitor selection circuit are constant and equal to  $V_{dc}$  and  $2V_{dc}$  and  $3V_{dc}$ , respectively. Since the output current of the solar power generation system will be controlled to be sinusoidal and in phase with the inverter bus voltage, the output voltage and current of the seven-level inverter is also positive in the positive half cycle of the load. The operation of the seven-level inverter in the positive half cycle can be further divided into four modes. In the positive half cycle the switch S1 and S4 will be in on condition.

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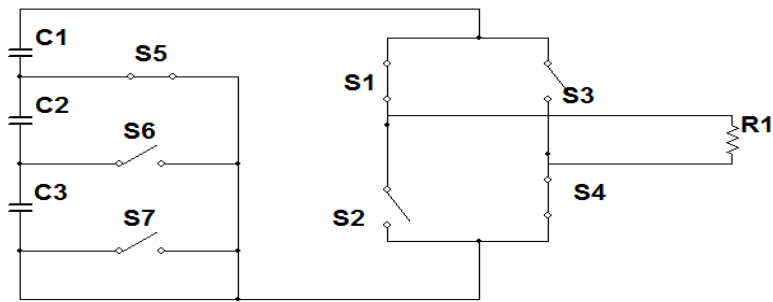


Fig. 7: when S5 is ON

Mode 1: The operation of mode 1 is shown in Fig. 7, when pwm pulse is given to S1 and S4 of the full bridge inverter, it will turn ON and starts to conduct from capacitor C1. And the current flow direction is from S1 to the load and from the load to the switch S4 then it return back to the capacitor C1 through the switch S5. Here S5 is turned ON by the PWM pulse given, and it is generated by the voltage level of sinusoidal waveform compared with the carrier waveform. S6 and S7 of the capacitor selection circuit are in OFF state, because voltage pass through the switch S5. At this point, the output voltage of the seven-level inverter is directly equal to the output voltage of the capacitor selection circuit C1, which means the output voltage of the seven-level inverter is  $+V_{dc}$ .

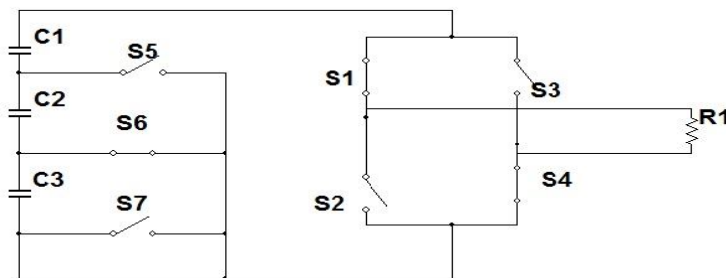


Fig. 8, when S6 is ON

Mode 2: The operation of mode 2 is shown in Fig.8. In the positive half cycle the switch S1 and S4 are in ON state. In the capacitor selection circuit, S5 is turned OFF and S6 will turn ON by pwm pulse. The capacitors are discharged through S1 to the load and goes to the S4 and return back to the capacitor again via through the switch S6. Here the capacitor C1 and C2 are discharged in a series manner. Since current flow direction is always from positive to negative. Now the output voltage of the capacitor selection circuit is  $2V_{dc}$ . At this point, the output voltage of the seven-level inverter is  $+2V_{dc}$ .

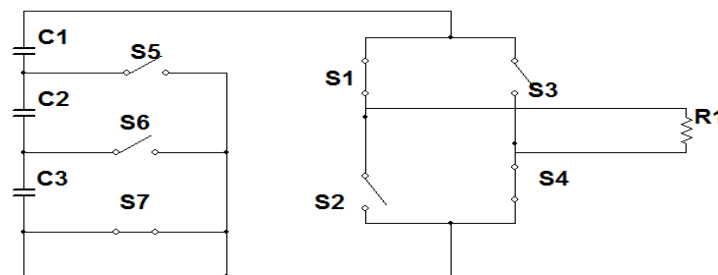


Fig. 9, when S7 is ON

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Mode 3: The operation of mode 3 is shown in Fig. 9. In this mode capacitor selection circuit, S7 is turned ON. And S6 is turned OFF by removing the gate pulse. The capacitors are discharged through S1 to the load and from load to the S4 and then return back to the capacitors via through S7. Here three capacitors are discharged in a series C1, C2 and C3. S1 and S4 of the full-bridge power converter are ON. Now, output voltage of the capacitor selection circuit is  $3V_{dc}$ . At this point, the output voltage of the seven-level inverter is  $+3V_{dc}$ .

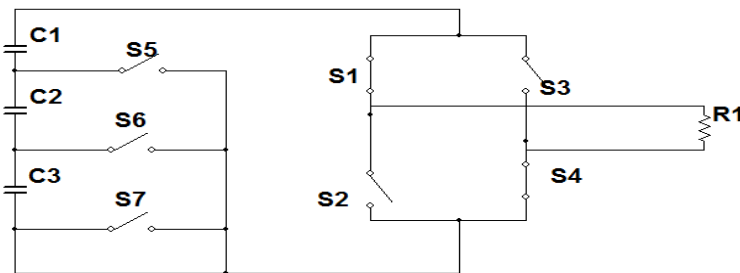


Fig: 10, when all switches are OFF

Mode 4: The operation of mode 4 is shown in Fig.10, S5, S6 and S7 of the capacitor selection circuit are OFF. The output voltage of the capacitor selection circuit is 0. Only S1 and S4 of the full-bridge power converter is ON. At this point, the output voltage of the seven level inverter is zero. Here all the capacitors are charging. Therefore, in the positive half cycle, the output voltage of the seven-level inverter has four levels:  $V_{dc}$ ,  $2V_{dc}$ ,  $3V_{dc}$  and 0.

In the negative half cycle, the output current of the seven-level inverter is negative. The operation of the seven-level inverter can also be further divided into four modes, as shown in Fig. 11. A comparison with Fig. 7 shows that the operation of the capacitor selection circuit in the negative half cycle is the same as that in the positive half cycle. The difference is that S3 and S2 of the full-bridge power converter are ON during modes 5, 6 and 7.

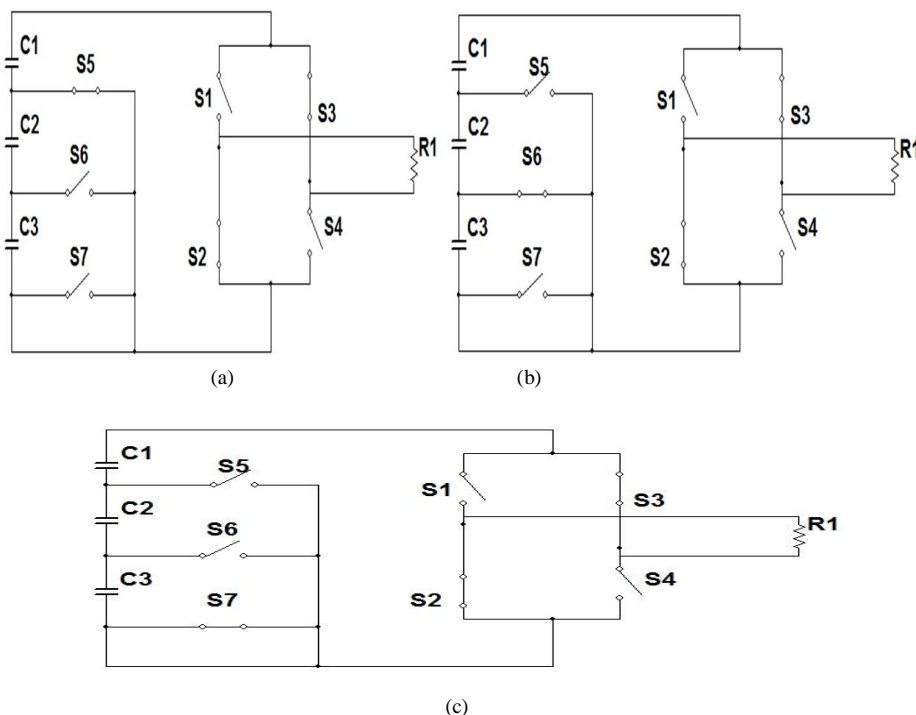


Fig: 11, when switches are ON during negative half cycle (a) Mode 5,(b) Mode 6, (c) Mode 7.

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In the negative half cycle the output voltage of the seven level inverter is  $-V_{dc}, -2V_{dc}, -3V_{dc}$  voltage range. Thus the seven level is obtained from the inverter .S1 is switched in PWM.

TABLE I

Voltage rating (V)	Switching states						
	S1	S2	S3	S4	S5	S6	S7
108.4	1	0	0	1	1	0	0
216.8	1	0	0	1	0	1	0
325.2	1	0	0	1	0	0	1
0	1	0	0	1	0	0	0
-108.4	0	1	1	0	1	0	0
216.8	0	1	1	0	0	1	0
-325.2	0	1	1	0	0	0	1

## V.SIMULATION RESULT

The simulation result shows the output of each system and the output of the solar panel is and their corresponding voltage and current is shown Fig: 12.

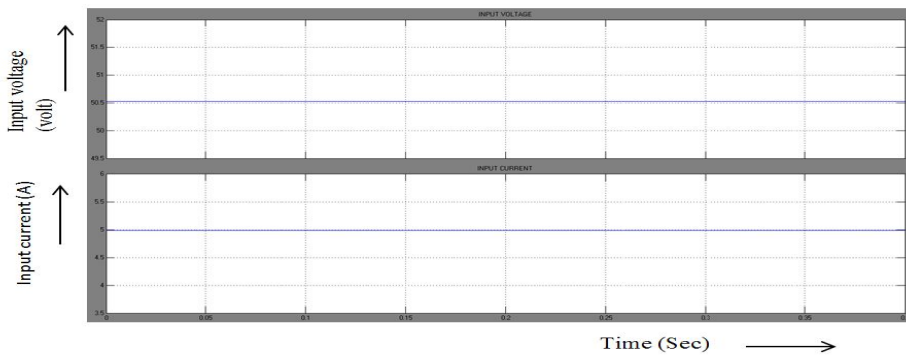


Fig 12: output voltage and current from PV panel

Fig 13: Shows the output voltage of the converter which is divided as a three converter.

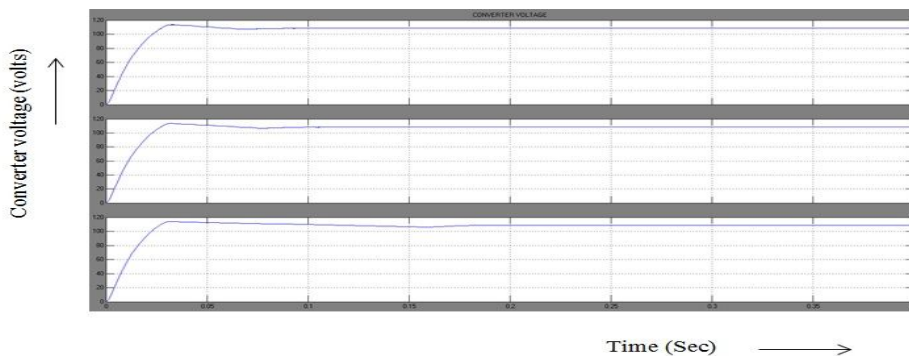


Fig 13: converter output



Fig 14: Shows the output voltage of the inverter which obtain seven level

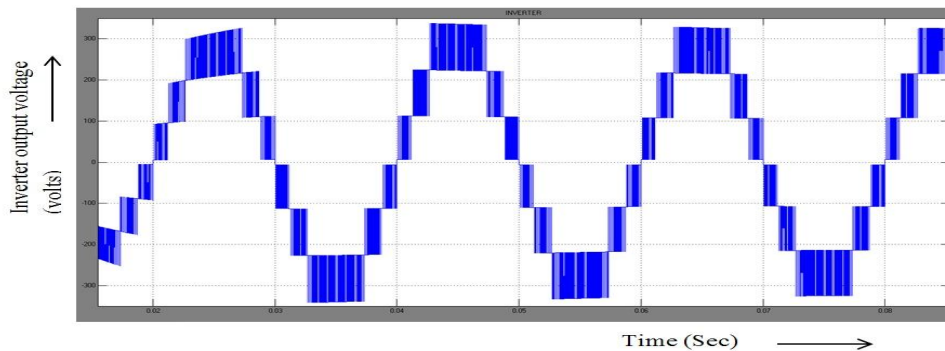


Fig 14: inverter output

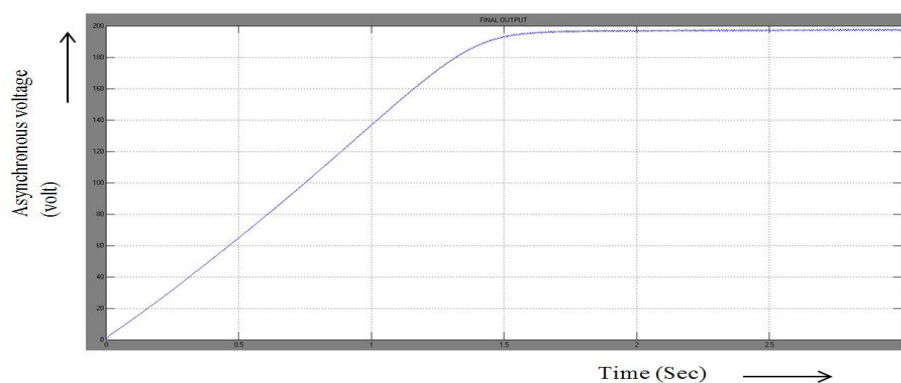


Fig 15: asynchronous machine output

From the simulation results, it shows the separate output for each circuit and the capacitor start single phase asynchronous machine is used as a load and the resultant output voltage is for about 320V. The output voltage is step down using a step down transformer and corresponding output is obtained and it is shown in fig:15.

## VII .CONCLUSION

This paper proposes a solar power generation and power conversion, and it is very important because it converts dc power generated by solar power into ac power, which is given to load to analyse the output and changes occur in the system. Furthermore, here converter acts as a capacitor selection circuit with reduced switches and one switch is operated in high frequency at the inverter. It improves the efficiency and also eliminates dynamic varying conditions using front end dc-dc converter. And multilevel concept are used here in order to achieve a nearer sinusoidal waveform for load purposes.

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