MPPT Based Solar Power Generation System with Seven Level Inverter

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Abstract: Solar energy is a renewable energy that is found abundantly in nature. It is green energy that can be utilized throughout day, therefore maximum energy has to capture from the panel. MPPT algorithm is incorporated to capture maximum energy. Multilevel inverter (MLI) technologies become a incredibly main choice in the area of high power medium voltage energy control. Though multilevel inverter has a number of advantages it has drawbacks in the vein of higher levels because of using more number of semiconductor switches. This may leads to vast size and price of the inverter is very high. So in order to overcome this problem the new multilevel inverter is proposed with reduced number of switches. In this paper proposes a MPPT based solar power generation system with, which consist a seven level inverter and DC-DC converter with less number of switches. the seven level inverter has six switches in the main circuit and one high frequency switch for switching at any time to generate seven level output. This reduces overall Total Harmonic Distortion, switching loss and improves the output power and efficiency and here MOSFET using as a switching device.

I. INTRODUCTION

The extensive use of fossil fuels has resulted in the global problem of greenhouse emissions. Moreover, as the supplies of fossil fuels are depleted in the future, they will become increasingly expensive. Thus, solar energy is becoming more important since it produces less pollution and the cost of fossil fuel energy is rising, while the cost of solar arrays is decreasing. In particular, small-capacity distributed power generation systems using solar energy may be widely used in residential applications.

The power conversion interface is important to grid connected solar power generation systems because it converts the dc power generated by a solar cell array into ac power and feeds this ac power into the utility grid. An inverter is necessary in the power conversion interface to convert the dc power to ac power. Since the output voltage of a solar cell array is low, a dc–dc power converter is used in a small-capacity solar power generation system to boost the output voltage, so it can match the dc bus voltage of the inverter. The power conversion efficiency of the power conversion interface is important to insure that there is no waste of the energy generated by the solar cell array. The active devices and passive devices in the inverter produce a power loss. The power losses due to active devices include both conduction losses and switching losses. Conduction loss results from the use of active devices, while the switching loss is proportional to the voltage and the current changes for each switching and switching frequency. A filter inductor is used to process the switching harmonics of an inverter, so the power loss is proportional to the amount of switching harmonics.

The voltage change in each switching operation for a multilevel inverter is reduced in order to improve its power conversion efficiency and the switching stress of the active devices. The amount of switching harmonics is also attenuated, so the power loss caused by the filter inductor is also reduced. Therefore, multilevel inverter technology has been the subject of much research over the past few years. In theory, multilevel inverters should be designed with higher voltage levels in order to improve the conversion efficiency and to reduce harmonic content and electromagnetic interference (EMI).

Conventional multilevel inverter topologies include the diode clamped, the flying-capacitor, and the cascade H-bridge types. Diode-clamped and flying capacitor multilevel inverters use capacitors to develop several voltage levels. But it is difficult to regulate the voltage of these capacitors. Since it is difficult to create an asymmetric voltage technology in both the diode-clamped and the flying capacitor topologies, the power circuit is complicated by the increase in the voltage levels that is necessary for a multilevel inverter. 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, 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. 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. a seven-level inverter topology, configured by a level generation part and a polarity generation part, is proposed. There, only power electronic switches of the level generation part switch in high frequency, but ten power electronic switches and three dc capacitors are used. A modular multilevel inverter with a new modulation method is applied to the photovoltaic grid-connected generator. The modular multilevel inverter is similar to the cascade H-bridge type. For this, a new modulation method is proposed to achieve dynamic capacitor voltage balance. a multilevel dc-link inverter is presented to overcome the problem of partial shading of individual photovoltaic sources that are connected in series. The dc bus of a full-bridge inverter is configured by several individual dc blocks, where each dc block is composed of a solar cell, a power electronic switch, and a diode. Controlling the power electronics of the dc blocks will result in a multilevel dc-link voltage to supply a full-bridge inverter and to simultaneously overcome the problems of partial shading of individual photovoltaic sources.

Solar power generation system is composed of a dc/dc power converter and a seven-level inverter. The seven-level inverter is configured using a capacitor selection circuit and a full-bridge power converter, connected in cascade. The seven-level inverter contains only six power electronic switches, which simplifies the circuit configuration. Since only one power electronic switch is switched at high frequency at any time to generate the seven-level output voltage, the switching power loss is reduced, and the power efficiency is improved. The inductance of the filter inductor is also reduced because there is a seven-level output voltage.

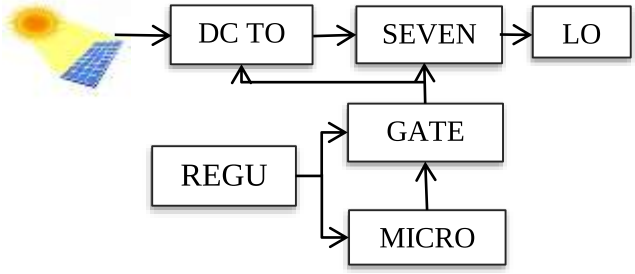

Figure 1: Block diagram of proposed system.

The gate driver circuit acts just like a pulse generator and these are electronic circuits that apply correct power levels to MOSFET. The MOSFET requires 10-15volts supply to operate. The micro-controller circuit is used to give pulse to MOSFET circuit. It can give the pulse up to 5volts. The microcontroller acts as MPPT. A MPPT is an electronic dc-dc converter that optimizes a match between the solar array and the battery bank or utility grid. The power point tracker is a high frequency dc-dc converter. The converter a high voltage dc output from the solar panels down to the lower voltage need to charge batteries.

II. CIRCUIT CONFIGURATION

Fig. 2 shows the configuration of the proposed solar power generation system is composed of a solar cell array, a dc–dc power converter, and a new seven-level inverter. The solar cell array is connected to the dc–dc power converter, and the dc–dc power converter is a 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 two independent voltage sources with multiple relationships, which are supplied to the seven-level inverter. This new seven-level inverter is composed of a capacitor selection circuit 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 utility voltage and is fed into the utility, which produces a unity power factor. As can be seen, this new seven-level inverter contains only six power electronic switches, so the power circuit is simplified.

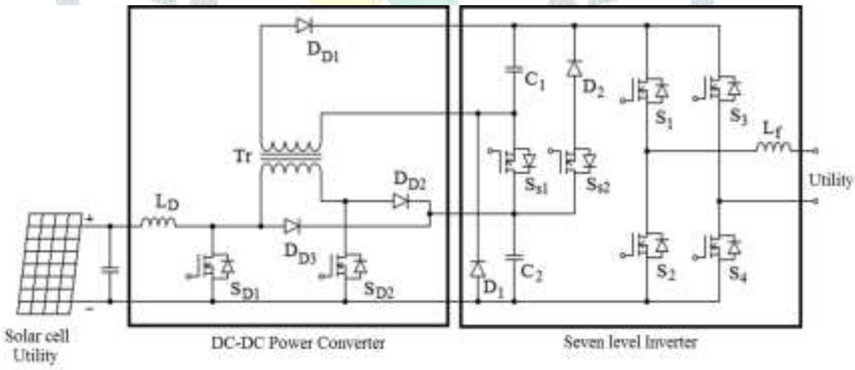

Figure 2: Circuit diagram of MPPT based solar power generation system with a seven-level inverter.

2.1 DC-DC Power Converter

As seen in Fig. 2, the DC–DC power converter incorporates a boost converter and a current-fed forward converter. The boost converter is composed of an inductor *LD*, a power electronic switch *SD*1, and a diode, *DD*3. The boost converter charges capacitor *C*2 of the seven-level inverter. The current-fed forward converter is composed of an inductor *LD*, power electronic switches *SD*1 and *SD*2, a transformer, and diodes *DD*1 and *DD*2. The current-fed forward converter charges capacitor *C*1 of the seven-level inverter. The inductor *LD* and the power electronic switch *SD*1 of the current-fed forward converter are also used in the boost converter.

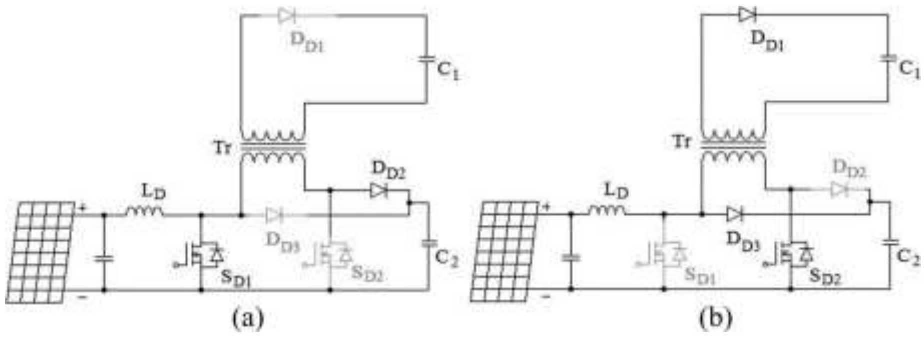

Figure 3: Operation of dc–dc power converter: (a) SD1 is on and (b) SD1 is off.

Fig. 3(a) shows the operating circuit of the dc–dc power converter when *SD*1 is turned ON. The solar cell array supplies energy to the inductor *LD*. When *SD*1 is turned OFF and *SD*2 is turned ON, its operating circuit is shown in Fig. 3(b). Accordingly, capacitor *C*1 is connected to capacitor *C*2 in parallel through the transformer, so the energy of inductor *LD* and the solar cell array charge capacitor *C*2 through *DD*3 and charge capacitor *C*1 through the transformer and *DD*1 during the off state of *SD*1. Since capacitors *C*1 and *C*2 are charged in parallel by using the transformer, the voltage ratio of capacitors *C*1 and *C*2 is the same as the turn ratio (2:1) of the transformer. Therefore, the voltages of *C*1 and *C*2 have multiple relationships. The boost converter is operated in the continuous conduction mode (CCM). The voltage of *C*2 can be represented as

$$\mathrm{Vc2} = \frac{1}{1-\mathrm{D}}\mathrm{V}s \tag{1}$$

Where *VS* is the output voltage of solar cell array and *D* is the duty ratio of *SD*1. The voltage of capacitor *C*1 can be represented as

$$\mathrm{Vc1} = \frac{1}{2(1-\mathrm{D})}\mathrm{Vs} \tag{2}$$

It should be noted that the current of the magnetizing inductance of the transformer increases when *SD*2 is in the ON state. Conventionally, the forward converter needs a third demagnetizing winding in order to release the energy stored in the magnetizing inductance back to the power source. However, in the proposed dc–dc power converter, the energy stored in the magnetizing inductance is delivered to capacitor *C*2 through *DD*2 and *SD*1 when *SD*2 is turned OFF. Since the energy stored in the magnetizing inductance is transferred forward to the output capacitor *C*2 and not back to the dc source, the power efficiency is improved. In addition, the power circuit is simplified because the charging circuits for capacitors *C*1 and *C*2 are integrated. Capacitors *C*1 and *C*2 are charged in parallel by using the transformer, so their voltages automatically have multiple relationships.

2.2 Seven Level Inverter

As seen in Fig. 2, the seven-level inverter is composed of a capacitor selection circuit and a full-bridge power converter, which are connected in cascade. The operation of the seven level inverter can be divided into the positive half cycle and the negative half cycle of the utility. For ease of analysis, the power electronic switches and diodes are assumed to be ideal, while the voltages of both capacitors *C*1 and *C*2 in the capacitor selection circuit are constant and equal to *V*dc/3 and 2*V*dc/3, respectively. Since the output current of the solar power generation system will be controlled to be sinusoidal and in phase with the utility voltage, the output current of the seven-level inverter is also positive in the positive half cycle of the utility. The operation of the seven-level inverter in the positive half cycle of the utility can be further divided into four modes, as shown in Fig. 4.

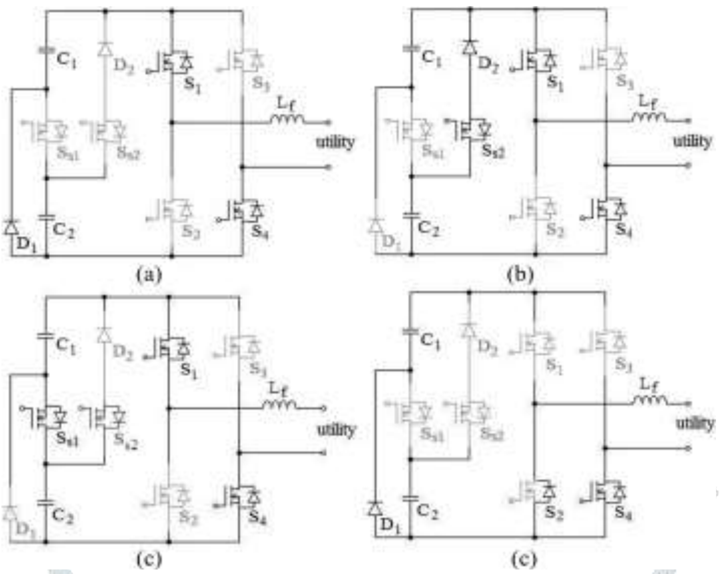

Figure 4. Operation of the seven-level inverter in the positive half cycle,
(a) Mode 1, (b) Mode 2, (c) Mode 3, and (d) Mode 4.

Mode 1: SS1 and SS2 of the capacitor selection circuit are OFF, so C1 is discharged through D1 and the output voltage of the capacitor selection circuit is Vdc/3. S1 and S4 of the full-bridge power converter are ON. At this point, the output voltage of the seven-level inverter is directly equal to the output voltage of the capacitor selection circuit, which means the output voltage of the seven-level inverter is Vdc/3 and it's shown in fig 4 (a) mode 1.

Mode 2: SS1 is OFF and SS2 is ON, so C2 is discharged through SS2 and D2 and the output voltage of the capacitor selection circuit is 2Vdc/3. S1 and S4 of the full-bridge power converter are ON. At this point, the output voltage of the seven-level inverter is 2Vdc/3 and it's shown in fig 4 (b) mode 2.

Mode 3: SS1 is ON. Since D2 has a reverse bias when SS1 is ON, the state of SS2 cannot affect the current flow. Therefore, SS2 may be ON or OFF, to avoiding switching of SS2. Both C1 and C2 are discharged in series and the output voltage of the capacitor selection circuit is Vdc. S1 and S4 of the full-bridge power converter are ON. At this point, the output voltage of the seven-level inverter is Vdc and it's shown in fig 4 (c) mode 3.

Mode 4: SS1 and SS2 of the capacitor selection circuit are OFF. The output voltage of the capacitor selection circuit is Vdc/3. Only S4 of the full-bridge power converter is ON. Since the output current of the seven-level inverter is positive and passes through the filter inductor, it forces the anti parallel diode of S2 to be switched ON for continuous conduction of the filter inductor current. At this point, the output voltage of the seven-level inverter is zero and it's shown in fig 4 (d) mode 4.

Therefore, in the positive half cycle, the output voltage of the seven-level inverter has four levels: *V*dc, 2*V*dc/3, *V*dc/3, and 0.

Table 1: States of power electronic switches for a seven level inverter

Positive half cycle						
	Ss1	Ss2	S1	S2	S3	S4
Vdc/3	0	0	1	0	0	1
2Vdc/3	0	1	1	0	0	1
Vdc	1	1	1	0	0	1
Negative half cycle						
-Vdc/3	0	0	0	1	1	0
-2Vdc/3	0	1	0	1	1	0
-Vdc	1	1	0	1	1	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. 5. A comparison with Fig. 4 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 *S*2 and *S*3 of the full-bridge power converter are ON during modes 5, 6, and 7, and *S*2 is also ON during mode 8 of the negative half cycle. Accordingly, the output voltage of the capacitor selection circuit is inverted by the full-bridge power converter, so the output voltage of the seven-level inverter also has four levels: −*V*dc, −2*V*dc/3, −*V*dc/3, and 0.

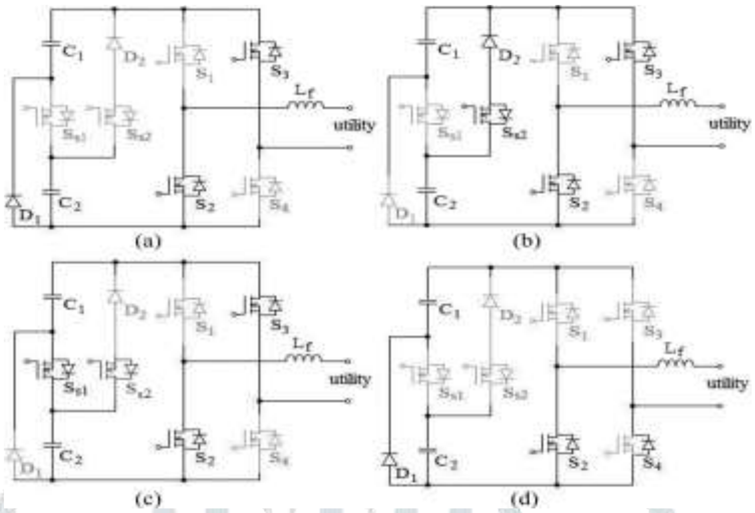

Figure 5: Operation of the seven-level inverter in the negative half cycle:
(a) mode 5, (b) mode 6, (c) mode 7, and (d) mode 8.

In summary, the output voltage of the seven-level inverter has the voltage levels: *V*dc, 2*V*dc/3, *V*dc/3, 0, −*V*dc/3, −2*V*dc/3, and −*V*dc.

III. SIMULATION RESULTS AND ANYLYSIS

For generating the dc source to the inverter photovoltaic array is used replacement for the dc source by renewable energy source. According to study and mathematical modeling of PV Module Fig. 6 in MATLAB simulation has been implemented.

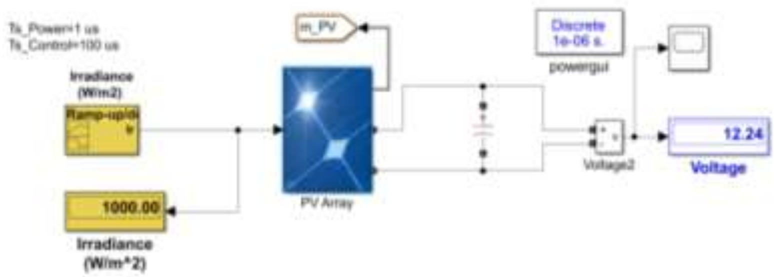

Figure 6: Simulation of PV module.

Figure 7: Output of PV model.

The PV array replaced the dc source as input to the dc-dc converter the. The waveform of output voltage of PV cell is shown in Fig. 7. The voltage waveform of PV cell is constant whereas the current waveform is fluctuating.

MPPT algorithms are necessary because PV arrays have a nonlinear voltage current characteristic with a unique point where the power produced is maximum. This point depends on the temperature of the panels and on the irradiance conditions. Both conditions change during the day and are also different depending on the season of the year. Furthermore, irradiation can change rapidly due to changing atmospheric conditions such as clouds. It is very important to track the MPP accurately under all possible conditions so that the maximum available power is always obtained. The MPPT provides the output in the form of duty cycle, this duty cycle is then provided to DC-DC Boost converter. Boost converter is used to convert the input voltage in compatible magnitude, so that it can be used as source for Multi-Level Inverter. The Simulink Block Diagrams of DC-DC Boost converter with MPPT and PV module is shown in fig 8.

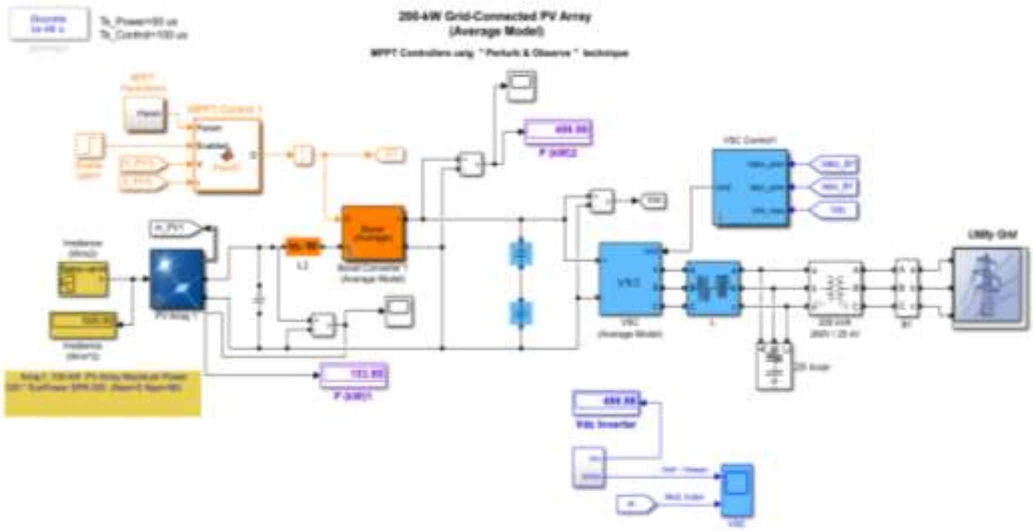

Figure 8: Matlab simulation of dc-dc converter with PV module and MPPT controllers using (P & O) Technique.

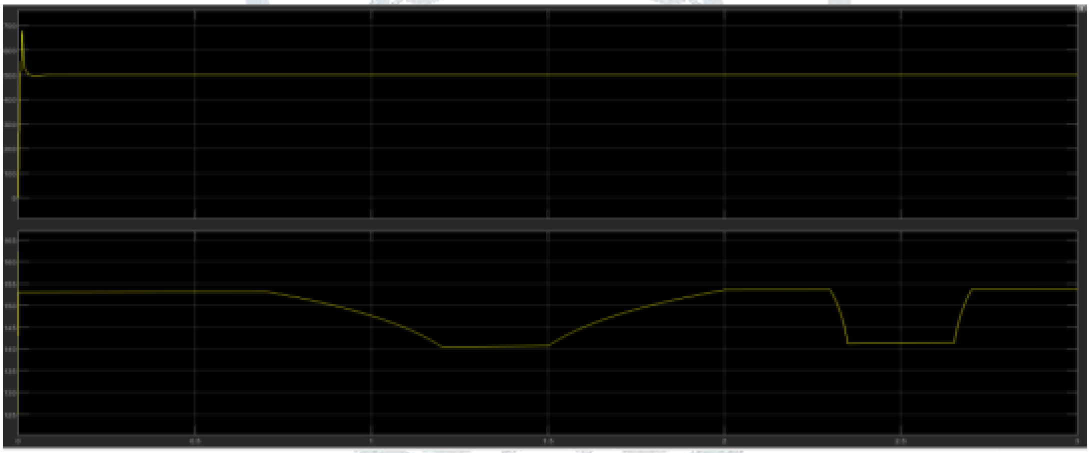

Figure 9: Output Voltages of before and after the simulation of dc- dc power converter with PV module and MPPT controllers using P&O technique.

The simulation of dc to dc boost converter with PV module and MPPT controllers using P&O technique before using the boost converter its voltage is 153V, and after applying dc to dc boost converter its voltage is 499V shown in fig 9 and the Simulink model of the proposed Seven Level Inverter is simulated in MATLAB. The Simulink block diagrams of the proposed topology are shown in Fig.10.

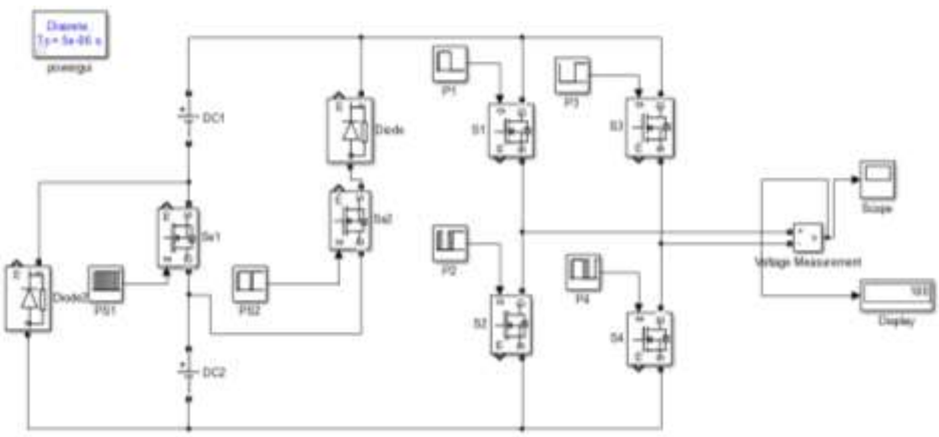

Figure 10: Simulink model of seven level multilevel inverter.

In proposed seven level inverter the control of bridge converter and capacitor selection circuit. Bridge converter is controlled by controlled circuited which gives the pulses to all six switches of bridge converter whereas, the capacitor selection switches pulses are given embedded MATLAB function.

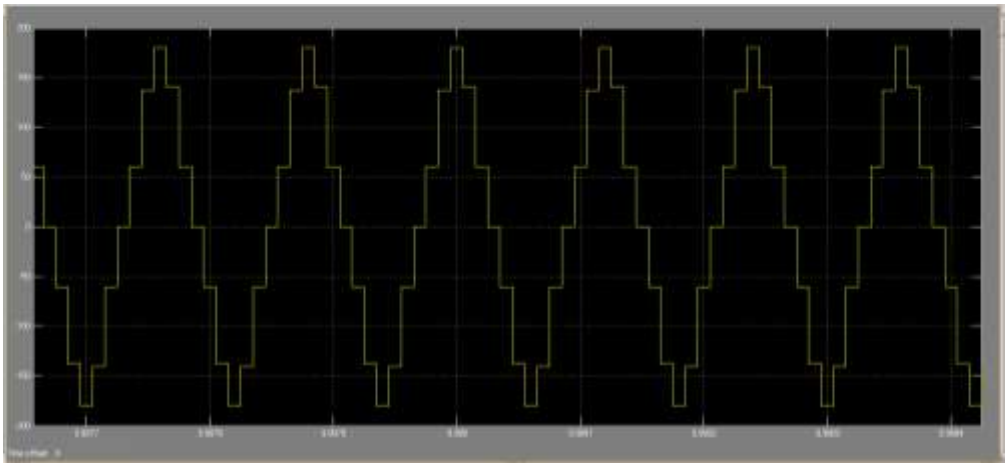

Figure 11: Seven level output voltage of proposed topology inverter.

The proposed seven level output voltage is shown in figure 11. The output voltage of the seven level inverter has seven voltage levels and output voltage is 180V and Output voltage levels are 60V,120V,180V,0V,-60V,-120V,-180V.

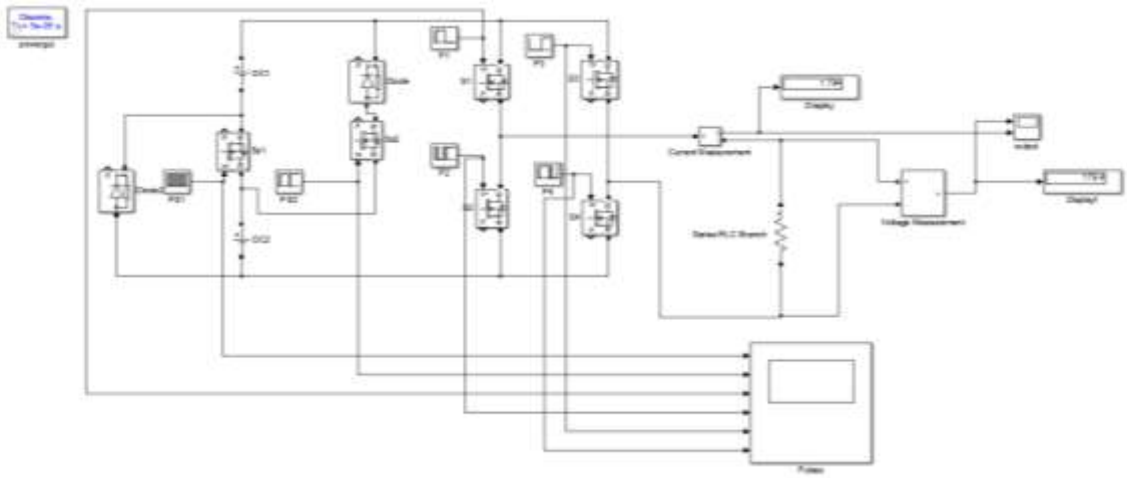

Figure 12: Simulation Circuit for Seven Level Inverter using Single PWM.

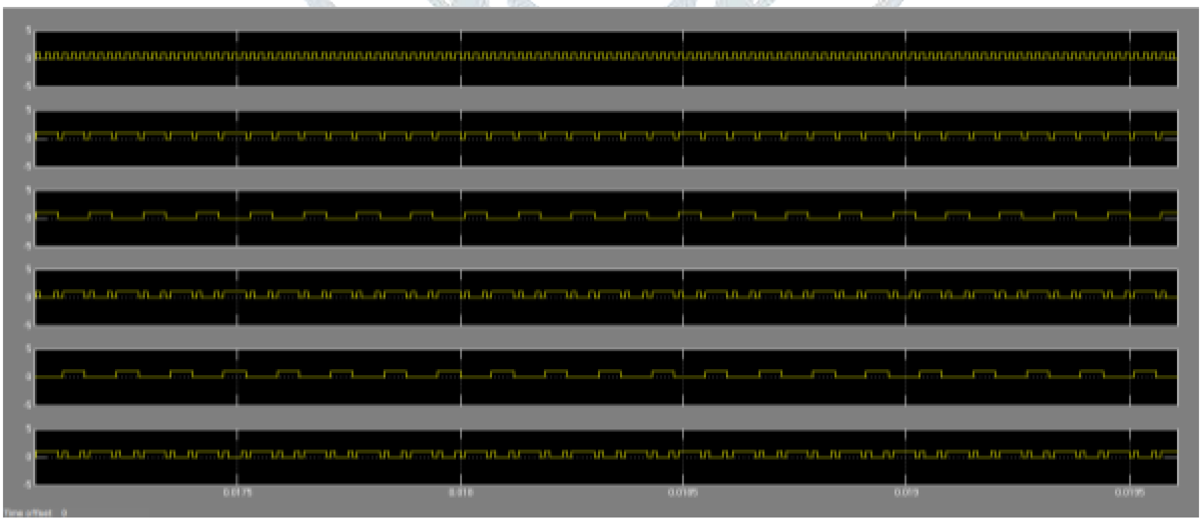

Figure 13: Switching pattern of single phase seven level inverter.

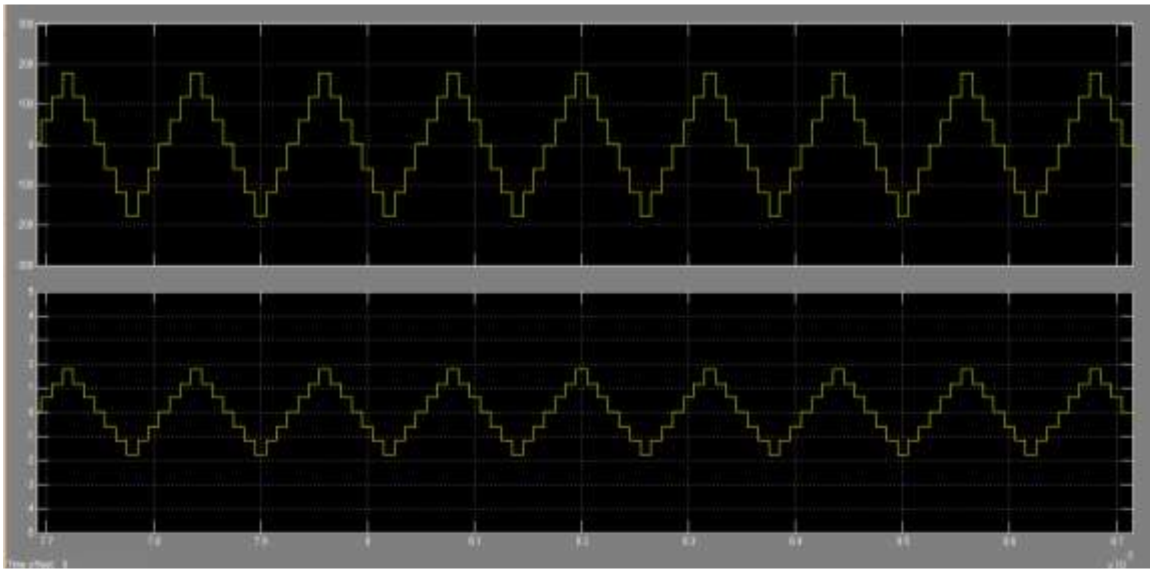

Figure 14: Output Voltage and Current Waveform of Proposed Seven Level MLI using single PWM.

IV. ADVANTAGES

Solar power can be used to generate electricity and these systems are virtually maintenance free and will last for decades. Once installed, there are no recurring costs. They operate silently, have no moving parts, do not release offensive smells and do not require you to add any fuel. More solar panels can easily be added. These solar panels are usually wired in series to produce very high voltages, usually between 200 and 600 volts using Cu wire but nowadays it became a significant expense due to rise in the price of copper. Grid tied inverters are designed to take as input the high DC voltages that are common in the systems. They are also designed such that if the grid goes down for any reason, the will turn off the supply from the solar panels at the utility because the side should not get shocked.

V. APPLICATIONS

It can be used in the solar street light and Solar Lighting Also known as day lighting, this is the use of natural light to provide illumination to offset energy use in electric lighting systems and reduce the cooling load on HVAC systems. Day lighting features include building orientation, window orientation, exterior shading, saw tooth roofs, clerestory windows, light shelves, skylights, and light tubes. Architectural trends increasingly recognize day lighting as a cornerstone of sustainable design. Solar hot water systems use sunlight to heat water. The systems are composed of solar thermal collectors and a storage tank, and they may be active, passive or batch systems. In a solar irrigation system pumps are used for the transport water are equipped with solar cells. The solar energy absorbed by the cells is then converted into electrical energy via a generator which then feeds an electric motor driving the pump.

VI. CONCLUSION

This paper proposes a MPPT based solar power generation system to convert the dc energy generated by a solar cell array into ac energy that is fed into the utility by using single phase PWM technique were developed and it was simulated in MATLAB/ Simulink software. The proposed MPPT based solar power generation system is composed of a dc–dc power converter and a seven-level inverter. The seven-level inverter contains only six power electronic switches, which simplifies the circuit configuration. Furthermore, only one power electronic switch is switched at high frequency at any time to generate the seven-level output voltage. This reduces the switching power loss and THD and improves the power efficiency. The proposed MPPT based solar power generation system generates a seven-level output voltage and output current that in phase with the utility voltage. The proposed solar power generation system can effectively trace the maximum power of solar cell array.

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