Performance Analysis of Soft Switched Seven Level Inverter for Photovoltaic System

R.Dinesh kumar and P.Karuppusamy

Abstract — The PV power generation have low efficiency due to the various constrains. This thesis gives a proposed method to reduce the THD using soft switching technique. The PV cell is connected to Multi-Level Inverter (MLI).In order to improve the efficiency. The project proposes an advanced H-bridge multilevel inverter which varies from the conventional one from the number of power devices used. The proposed seven level multilevel inverter has minimum number of power devices compare than conventional. MLI have emerged as attractive high power medium voltage converter to the reduce harmonic component in the output current due to filter. A novel PWM technique is used to generate the PWM signal for inverter switch and to reduce the THD level using soft switching technique.

Keywords — MLI , PWM, PV Array, soft switching, Total harmonic distortion.

I. INTRODUCTION

The demand for renewable energy has increased significantly over the years because of shortage of fossil fuels and the greenhouse effect. The different types of renewable sources such as solar and wind energy are nowadays popular and also it is more demand due to advancement in power electronics techniques [1]. Photo-Voltaic (PV) sources are used today in many applications as they have the advantages of being maintenance and it is free from pollution. The demand for solar-electric energy is increased consistently by 20%–25% per annum over the last 20 years, which is mainly because of reducing costs. This decline has been driven by the following factors: 1) an increasing efficiency of solar cells 2) manufacturing technology improvements and 3) economics of scale.[2]

Multilevel inverter is the heart of a Photovoltaic system. The DC power which is obtained from PV modules are converted into AC power with the help of multilevel inverter, then it is fed into the grid.

The harmonic content is reduced by improving the output waveform of the inverter, hence, the size of the filter used and the level of electromagnetic interference (EMI) generated by switching operation of the inverter. In the recent years, multilevel inverters have become more popular for researchers and manufacturers due to their advantages over conventional three-level inverters [5] ,They offer improved output waveforms, smaller filter size, lower EMI and lower total harmonic distortion (THD).

II. PROPOSED SCHEME

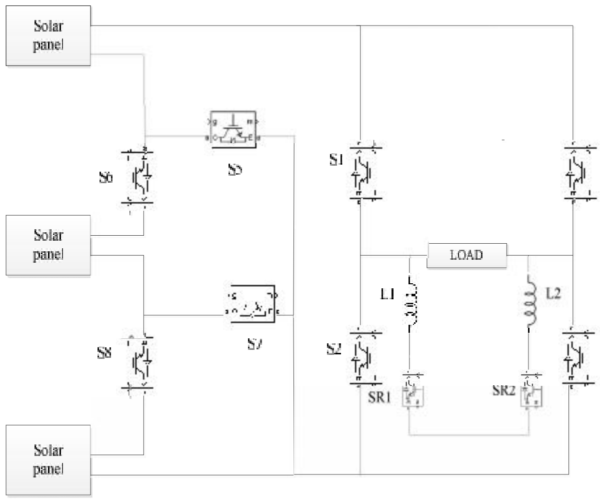

Fig 1 . Proposed topology

The proposed single-phase seven-level inverter was developed from the five-level inverter. It comprises a single-phase the modified H-bridge topology is significantly advantages over other topologies, such as less power switch, power diodes, and less capacitors for inverters of the same number of levels. Photovoltaic (PV) arrays were connected to the inverter and the output of inverter applied to the load. Proper switching of the inverter can produce seven output-voltage levels (Vdc, 2Vdc, 3Vdc,0 ,-Vdc,-2Vdc,-3Vdc) from the dc supply Voltage.

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Table 1.Comparison table for proposed topology

Configurations	Diode Clamped	Capacitor Clamped	Cascaded	Noval Multilevel
Main Switching Devices	12	12	12	8
Main Diodes	12	12	12	0
Clamping Diodes	30	0	0	0
DC Bus Capacitors	6	6	3	0
Balancing Capacitors	0	15	0	0

Compared with the best of the other configurations, it requires only six controlled switches instead of the thirty six required by the other configurations (83% reduction), only twelve diodes instead of the thirty six required by the capacitor clamped or the asymmetric cascade configurations (66% reduction), and only three capacitors instead of the nine required by the asymmetric cascade configuration (66% reduction). In the other hand, the proposed configuration is at a disadvantage when the required voltage ratings are compared: in the new configuration the main power switches are required to block one half of the main supply voltage and the auxiliary switches one third the main supply voltage, as opposed to 1/7 of the main supply voltage in the other configurations.

Table 2.Inverter output voltage during various switching conditions

Voltage level	S1	S2	S3	S4	S5	S6	S7	S8
Vdc	1	0	1	0	1	0	0	0
+2Vdc	1	0	1	0	0	1	1	0
+3Vdc	1	0	1	0	0	1	0	1
0	0	0	0	0	0	0	0	0
-Vdc	0	1	0	1	1	0	0	0
-2Vdc	0	1	0	1	0	1	1	0
-3Vdc	0	1	0	1	0	1	0	1

III. MODELING OF THE SOLAR CELL

The diode in parallel with current source is simplest equivalent circuit of a solar cell. The light falling on the cell which is equal to output of the current source. At the time of darkness the solar cell works as a diode. It does not produce current and voltage. Then it is connected to an external source (large voltage) it generates a current ID, called diode (D) current or dark current. The diode determines the I-V characteristics of the cell.

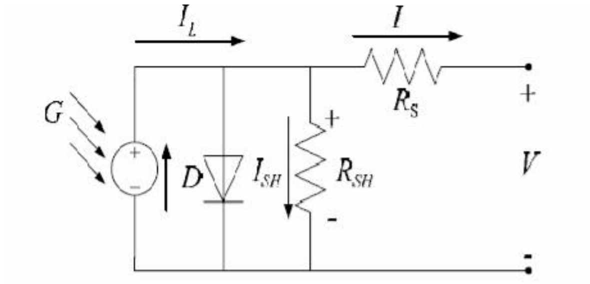

Fig 2 .Circuit diagram of the PV model

Increasing sophistication, accuracy and complexity can be introduced to the model by adding in turn Temperature dependence of the diode saturation current I0. Temperature dependence of the photo current IL. Series resistance R s s, which gives a exact shape between the open circuit voltage and maximum power point. At the time of current flow there is some internal losses. The diode parallel with the shunt resistance R_{sh} this corresponds to the leakage current to the ground and it is commonly neglected. Either allowing the diode quality factor n to become a variable parameter (instead of being fixed at either 1 or 2) or introducing two parallel diodes with independently set saturation currents.
The output current (I) from the PV cell is found by applying the Kirchoff's current law (KCL) on the equivalent circuit is shown.

$$I=I_{sc}-I_d \quad (1)$$

The photon generated current is equal to the short circuit current I_{sc} and I_d is the current shunted through the intrinsic diode.
From shockley's diode equation the diode current I_d is given below:

$$I_d=I_o(e^{qV_d/KT}-1) \quad (2)$$

Where: Io is the reverse saturation current of diode (A), q is the electron charge (1.602×10-19 C), Vd is the voltage across the diode (V), k is the Boltzmann's constant (1.381×10-23 J/K), T is the junction temperature in Kelvin (K).
Replacing Id of the equation (3) by the equation (4) gives the current-voltage relationship of the PV cell [5].

$$I_d=I_o(e^{qV_d/KT}-1) \quad (3)$$

V represents voltage across the Photo voltaic cell, and I is the output current from the cell.
The reverse saturation current of diode (Io) is constant under the constant temperature and found by setting the open-

circuit condition as shown. Using the equation (5), let I = 0 (no output current) and solve for Io.

$$I_{sc} = I_o (e^{qV_d/KT} - 1) \quad (4)$$

$$I_{sc} = I_o (e^{qV_d/KT} - 1) \quad (5)$$

$$I_o = I_{sc} / (e^{qV_d/KT} - 1) \quad (6)$$

To a very good approximation, I_{sc} Which is equal to photon generated current is directly proportional to the irradiance, the intensity of illumination of Photo voltaic cell; From the data sheet I_{sc} value is taken, under the standard test condition, Go=1000W/m2 at the air mass (AM) = 1.5, then the photon generated current at any other irradiance, G (W/m2), is given by [5,11]:

$$Isc_G = \left(\frac{G}{G_0} \right) Isc_{G0} \quad (7)$$

The PV cell output is both limited by the cell current and the cell voltage, and it can only produce a power with any combinations of current and voltage on the I-V curve. It also shows that the cell current is proportional to the irradiance.

Then the VI relationship of Photo voltaic cell is written as:

$$I = I_{sc} - I_o (e^{q\left[\frac{V+IR_s}{nKT}\right]} - 1) - \left[\frac{V+IRs}{Rp}\right] \quad (8)$$

Since it does not include the effect of parallel resistance (Rp), letting Rp =∞ in the equation (10) gives the equation (11) that describes the current-voltage relationship of the PV cell, and it is shown in equation 9.

$$I = I_{sc} - I_o (e^{q\left[\frac{V+IR_s}{nKT}\right]} - 1) \quad (9)$$

Where: I is the cell current (the same as the module current), V is the cell voltage = {module voltage} ÷ {# of cells in series},

T is the cell temperature in Kelvin (K).

IV. NEW PWM MODULATION

Different types of pulse width modulation techniques are possible for multilevel inverters (MLI). This paper uses multi-level triangular wave's generation as derived in. It can be a useful solution for pulse generation for this topology. This technique in is called carrier redistribution (CR) technique. This technique is derived from the triangular carrier and has individually the lowest switching frequency among the multi-level PWM methods.

V. CONTROL ALGORITHM

The proposed inverter utilizes the Incremental conductance algorithm. Incremental conductance (IC) is good for conditions of rapidly varying irradiance. However, noise may cause continuous searching so some amount of noise reduction may be needed. The incremental conductance algorithm is based on the fact that the slope of the curve power vs. voltage (current) of the PV module is zero at the MPP, positive (negative) on the left of it and negative (positive) on the right.

- $\Delta V/\Delta P = 0(\Delta I/\Delta P = 0)$ at the MPP
- $\Delta V/\Delta P > 0(\Delta I/\Delta P < 0)$ on the left
- $\Delta V/\Delta P < 0(\Delta I/\Delta P > 0)$ on the right

The output of the MPPT is the duty-cycle function. As the dc-link voltage Vdc was controlled in the dc–ac seven level Pulse Width Modulation inverter, the change of the duty cycle, it will changes the voltage at the output of the Photo Voltaic panels.

VI. SOFT SWITCHING TECHNIQUE

The multilevel inverter to increasing the levels to reduce the ripples and get better output voltage and without increasing the levels to reduce the THD level that is solution for the proposed system. To using the soft switching technique reduced the THD. Turn ON and Turn OFF the switches at time of zero crossing .and ZVS (zero voltage switching) and ZCS (zero current switching) these are some types of soft switching on that to use ZVS RSI (zero voltage switching resonant snubber inverter)soft switching to reduce the harmonic content of the system

VII. SIMULATION RESULTS

Generally, it is important that the harmonic components of output voltage produced by inverter itself should be reduced to alleviate the output current ripple and the core loss of inductor. For this purpose, simulations are performed in advance to prove availability of the proposed single-phase seven-level PWM inverter. The PWM switching patterns were generated by comparing three reference signals (Vref1, Vref2, and Vref3) against a triangular carrier signal (see Fig. 2) One leg of the inverter operated at a high switching rate that was equivalent to the frequency of the carrier signal, while the other leg operated at the rate of the fundamental frequency(i.e., 50 Hz). Switches S5 and S6 also operated at the rate of the carrier signal. Fig. 13 shows the simulation result of inverter output voltage V_{inv}.

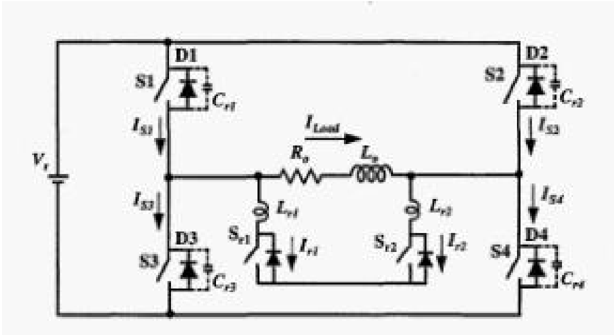

Fig 3. A Single Phase Version of the Proposed Soft Switched Inverter

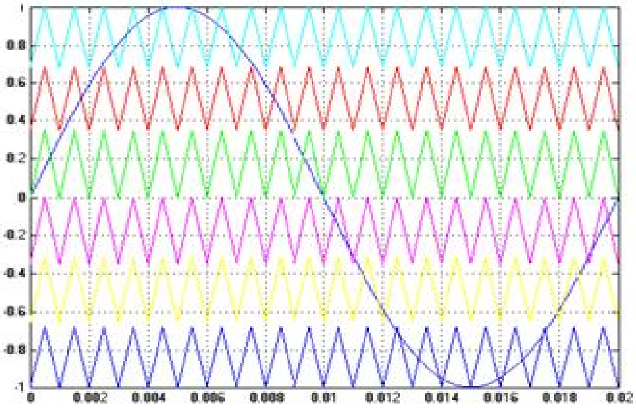

Fig 4.Pulse generation

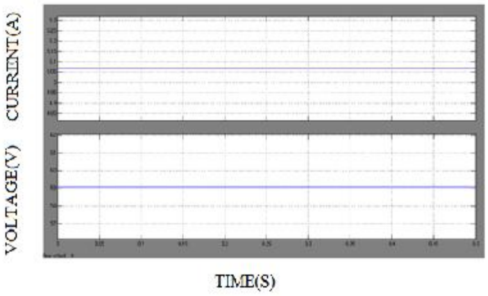

Fig 5 . Input voltage for proposed system

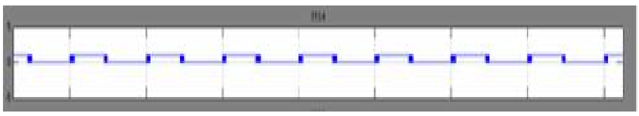

Fig 6. PWM signal for S1 and S4

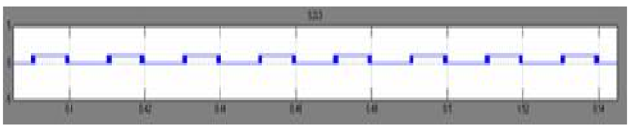

Fig 7. PWM signal for S2 and S3

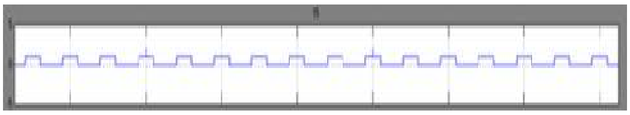

Fig 8. PWM signal for S5

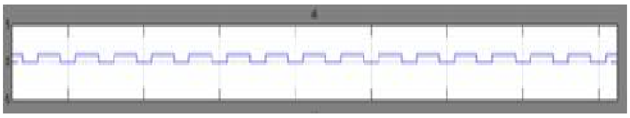

Fig 9. PWM signal for S6

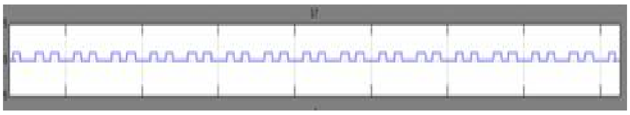

Fig 10. PWM signal for S7

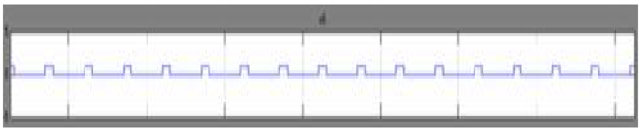

Fig 11. PWM signal for S8

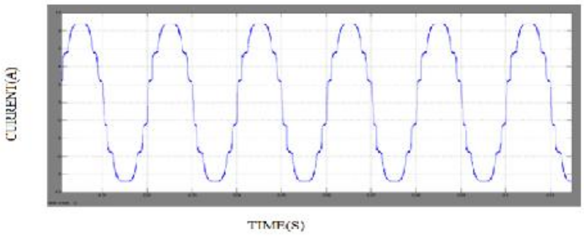

Fig 12 . Simulation result of 7-level Multilevel inverter Output current

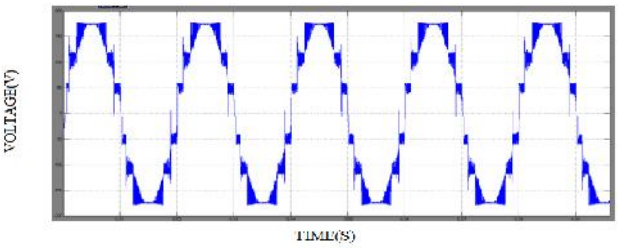

Fig 13.Simulation result of 7- Level Multilevel inverter output voltage

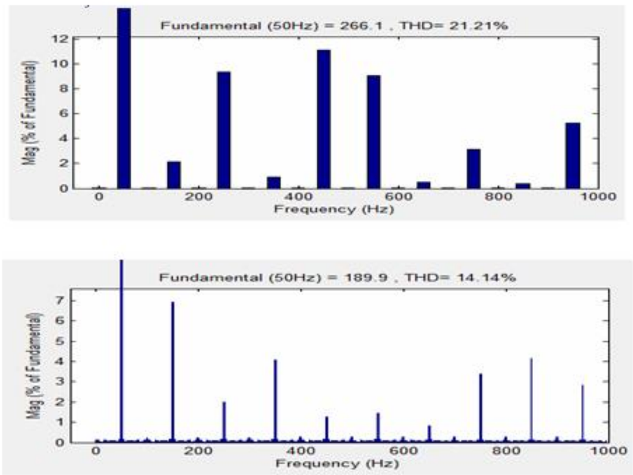

Fig 14. Voltage THD of 7-level multilevel inverter with soft switching technique

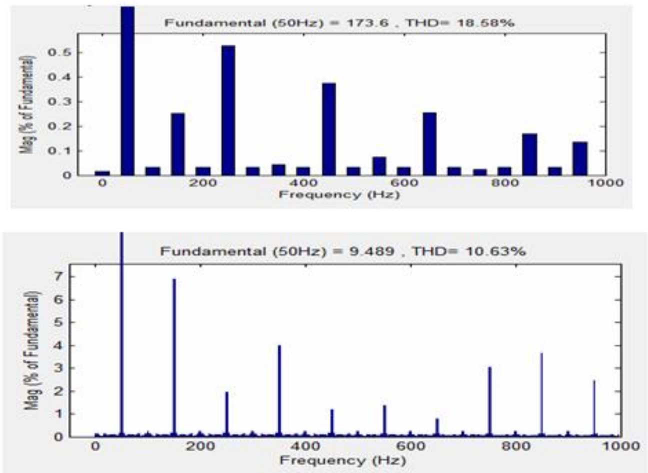

Fig 15. Current THD of 7-level multilevel inverter with soft switching technique

The THD measurement of the waveform corresponds to seven-level inverter shown and to apply the soft switching technique to reduce the THD level of the system

VIII. EXPERIMENTAL RESULTS

This chapter describe about hardware description of seven level multilevel inverter for PV application .which chapter consist of controller circuit ,driver circuit, circuit ,inverter circuit ,Soft switching Solar energy is observed by the PV cell. The output of the PV cell is given to multilevel inverter. And soft switching technique also applied to the multilevel inverter. Soft switching to reducing the switching losses so THD level will be reduced. The output of the PV cell and soft switching are given to multilevel inverter which converts DC to AC. PWM pulses are generated by using PIC18f4331and it is given to inverter switches.

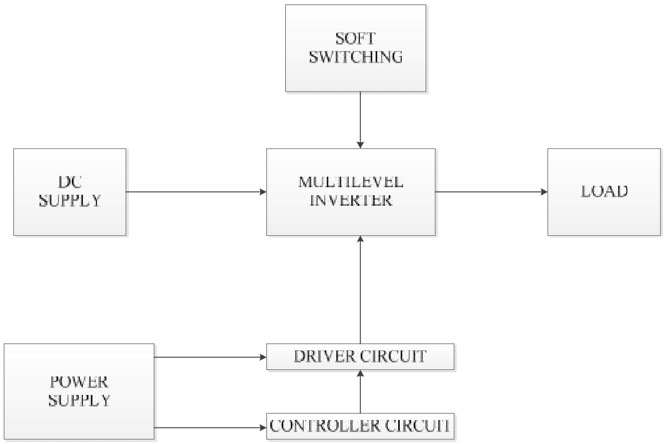

Fig.16.Hardware Block Diagram for seven level inverter

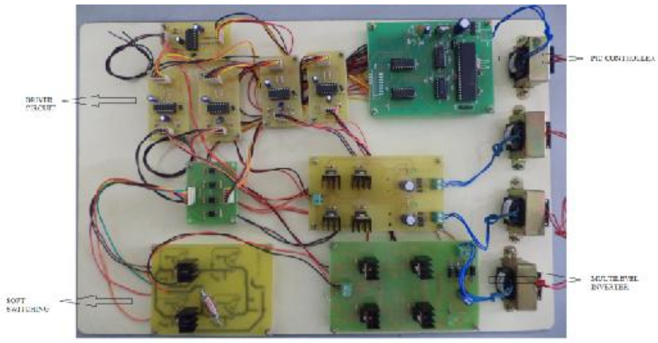

Fig17.Experimental prototype of soft switching multilevel inverter

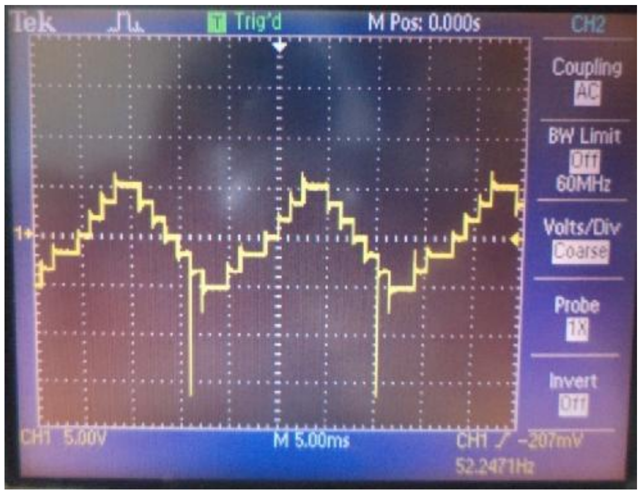

Fig18.Output voltage of soft switching multilevel inverter

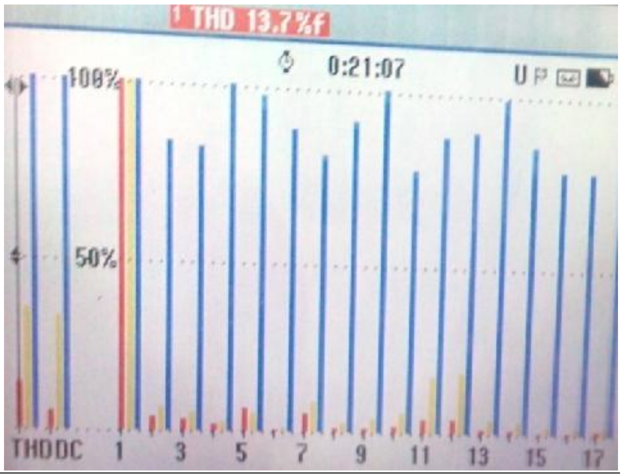

Fig19.THD level for Hardware setup

IX. CONCLUSION

This paper has covered conversion of photovoltaic dc voltage to ac voltage by implementing a novel multilevel inverter. A novel PWM technique is used here. The PWM switching signals are generated by comparing one reference signal against six triangular wave signals. The proposed multilevel inverter is to reduce both voltage & current THD of the inverter using soft switching technique .The proposed topology has minimum number of switches compare than other configuration .Simulation results indicate that the THD of the seven-level inverter.

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