High Boost Converter and Novel Thyristor Clamped H Bridge Inverter for Photovoltaic System

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Abstract— **The utilization of photovoltaic energy becomes an key source of electrical energy with the advancement in power electronic technology. The dc-dc converters is connected to PV system, for connecting the source to the grid or AC load through an inverter. MPPT (Maximum Power Point Tracking) increases the power production of the PV system. The advantages of high step up converters integration with voltage multiplier includes improving voltage gain without using extreme duty ratio, reduction of voltage stress, current ripple and conduction losses are desirable for renewable energy applications. A multilevel hybrid cascaded inverter is connected high step up converter for connecting to the ac load.**

Keywords— **High step up converter, voltage multiplier, renewable energy, photovoltaic system, high gain.**

I. INTRODUCTION

With the development in power electronics technologies the renewable energy sources utilization become an increasing trend for electrical energy. The photovoltaic system is a feasible energy source in research and development work in power system and power electronics. For the better consumption of solar energy a high reliable, low cost, design are required for the PV integrated high step up topologies. High performance dc to dc converter can be obtained with MPPT technique and islanding detection for photovoltaic system are now considered for the interface to the grid or ac utilities [4]. The DC/AC inverters control the output voltage of DC/DC converter and generate a fundamental real power required for the loads.

The conventional boost converter provide step up conversion without high gain due the limitation of conduction losses in the circuit parameters. The gain depends on the I^2R losses in the inductors and the power electronic devices connected. The voltage gain is difficult to obtain with conventional boost topologies because of the parasitic components, which limits the frequency and the system size. A voltage multiplier is a device which converts the low voltage input to a higher voltage by means of capacitors and diodes combined circuit. The voltage multiplier helps in reducing the turns ratio of transformer for better performance.

The conventional boost converters are provided with voltage multipliers to increase the voltage gain without having

high duty cycle and reduce the voltage stress across the switches. The voltage multiplier reduces the peak current flowing through the switch and enhances the dynamic response with the increase of turn OFF period.
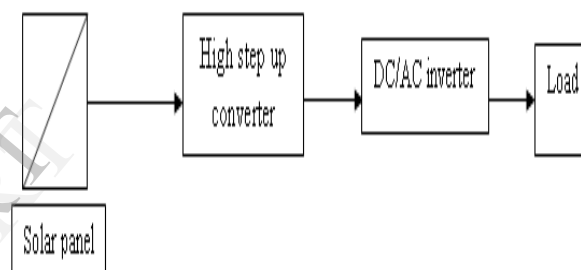

Fig.1. Photovoltaic system.

DC to DC boost converters are applicable for obtaining regulated value of dc output voltage. The regulation is normally achieved by PWM at constant frequency and the switching device used are usually BJT, MOSFET or IGBT. The high step-up converter helps in improving the voltage gain, reduction of voltage stress and current ripple with optimized circuit performance. The effective circuit component determines the efficiency and gain of the converters used in the photovoltaic system. The integration of voltage multiplier reduces the input current ripple, hence the increases the life of PV arrays of the photovoltaic system. The low voltage output of the PV arrays is stepped up to high voltage for the dc-ac inverter with high efficiency step up converters. Usually the output of the parallel connected PV arrays are low of the range of 30-40V. They are to be stepped up to a value of 380-400V for a full bridge operation, for connecting them to the grid or ac loads [3]. They can also connect directly to dc loads without dc-ac inverter. The main factor depends on the selection of the PV array or cells in the photovoltaic system are the cost and efficiency.

The integration of high boost converter with voltage multiplier and thyristor clamped H bridge inverter for better power output is also discussed in the paper. The inverter uses phase disposition principle of PWM

technique. The voltage multiplier aids in increasing the voltage of the boost converter. It consists of diodes and capacitor for charging and discharging of the current to the converter.

II. MODELLING OF PHOTOVOLTAIC CELL

The solar radiations from the sun are converted to electric energy by the photovoltaic effect. The photons from the sun having band gap energy higher than the semiconductor material used, will produce electron-hole recombination, which depends on incident radiation. Electron-hole recombination result in the flow of photocurrent[5].

The PV system depends on the cell temperature and solar insolation have non-linear characteristics for P-V and I-V curves. The equivalent circuit of the PV system is shown in figure 2.
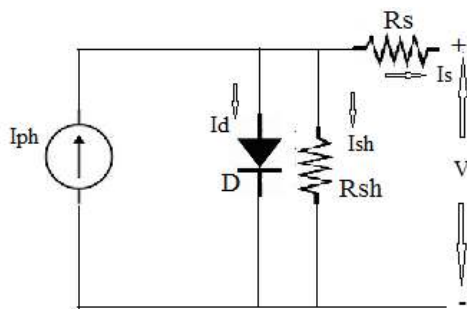
Fig.2. Equivalent circuit of PV cell

The parameters for a PV system are open circuit voltage, Voc and short circuit current, Isc. The reverse saturation current,Irs due to the diffusion of minority carriers at reference temperature is given by

$$I_{RS} = I_{SC}/[\exp\left(\frac{qV_{OC}}{N_S kT_C A}\right) - 1] \tag{1}$$

Where q=1.6 x 10^{-19}C, Ns represents number of cells in series, k represents Boltzmann's constant=1.38x10^{-23}J/K, Tc is the cell temperature in ℃. A is the ideal factor, which is the measure of ideality towards diode equation.

The saturation current is represented by

$$I_S = I_{RS}(T_C/T_{ref})^3 \exp[\frac{qE_g\left(\frac{1}{T_{ref}} - \frac{1}{T_c}\right)}{kA}] \tag{2}$$

Is represents the saturation current, Tref is the reference temperature. Eg is the energy gap of the semiconductor of the solar cell.

The photocurrent is represented by

$$I_{PH} = [I_{SC} + k_i(T_c - T_{ref})]\lambda \tag{3}$$

λ represents the solar insolation, the amount of solar energy reaching the surface of the semiconductor.

The terminal voltage of current and voltage can be represented as

$$I = N_P I_{PH} - N_P I_s [exp[\frac{q(V/N_S + IR_S)/N_p}{kT_c A} - 1] \tag{4}$$

where Np represents the number of parallel cells connected in the PV system. The PV modules can be connected in series and parallel to obtain required value of voltage and current.

III. MODELLING OF MPPT ALGORITHM

Maximum Power Point Tracking (MPPT) technique is to extract maximum power from photovoltaic systems. MPPT maintains the operation of maximum power Efficient MPPT techniques differ in many aspects such as required sensors, complexity, cost, range of effectiveness, convergence speed, correct tracking etc. Hill Climbing Techniques are used for tracking maximum power. Here the PV system uses P & O algorithm because of simplicity, less time and parameters requirement. The algorithm starts with setting the reference voltage and power of the module. The flowchart for P & O algorithm is discussed in the figure 3.
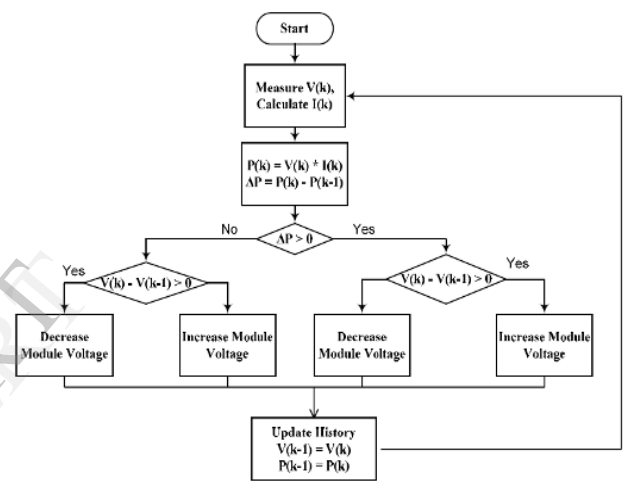

Fig.3. P & O algorithm

With P & O algorithm the PV array voltage are perturbed in each cycle of operation. It also compares the PV output power with previous cycle[5]. The maximum power point tracking can be explained with a graph shown in figure 4.
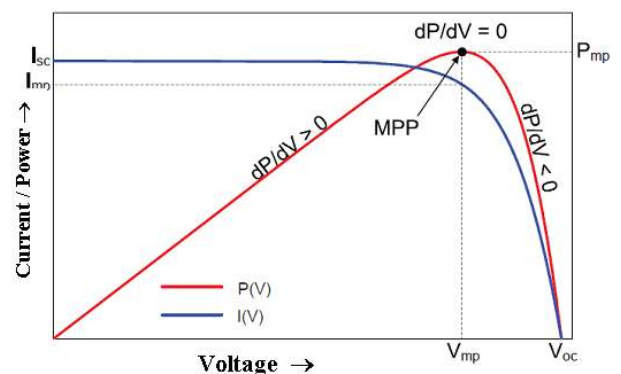

Fig.4. MPPT

- If the power and voltage are increased comparing to the previous cycle, then increase the voltage inorder to track maximum power from left of the curve.

- If the change in power is increased and change in voltage is decreased, then decrease the voltage to track MPP from right of the curve.
- If the change in power is decreased and change in voltage is increased, then also decrease the voltage to track the operating point back to MPP, which is moving away from maximum point.

When a steady state is reached the oscillation occurs around the maximum point. The step size can be reduced for the perturbation.

IV. BOOST CONVERTER INTEGRATION WITH VOLTAGE MULTIPLIER

The pulses are obtained from the MPPT algorithm are given to the switches as switching pulses. The output from the PV panel are in the range of 30-35V. The boost converter on combining with voltage multiplier to get high gain output at the load. This topology reduces the conduction losses, improves the efficiency and gain of the converter for connecting it to an inverter for connecting ac loads[1].

The advantages of integration of voltage multiplier with high step up converter for increasing voltage conversion ratio and gain. The voltage multipliers are provided with capacitors and diodes in the circuit for converting the input voltage to high level output. The converter with the voltage multiplier determines the efficiency and performance of the photovoltaic system connected to the system. The voltage multiplier aids in increasing the voltage of the boost converter. It consists of diodes and capacitor for charging and discharging of the current to the converter. The circuit diagram is shown in figure
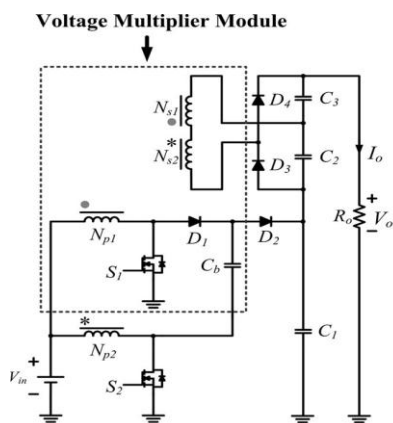

Fig.5. Boost converter integration with voltage multiplier

A. Design of coupled inductors

The coupled inductors are like smoothening transformer for filtering the ripples content. The primary and secondary windings of a coupled inductor can be obtained with

The mutual inductance is given by

$$L_m = \frac{D(1-D)^2 R_o}{2(n+1)(2n+2)f_s} \quad (5)$$

The turns ratio are set to be 1:1. The secondary's of the two coupled inductors are connected in series for high gain output.

B. Design of capacitors

The capacitance values are designed for the voltage multiplier is given by

$$C_2 = C_3 = \frac{P_o}{2f_s V_{out} \Delta V_c} \quad (6)$$

where,
f_s is the switching frequency of the converter.
V_{out} is the output voltage.
P_{out} is the output power of the proposed converter
V_c is the output ripple voltage.

The capacitance value for the boost converter can be designed with

$$C_b = \frac{I_o}{f_s \Delta V_{cb}} \quad (7)$$

where, V_{out} is the output voltage across the converter.
V_{in} is the input supply voltage.
f_s is the switching frequency.
V_{ripple} is the ripple voltage across the output.
The switching frequency is given for 40kHz and provided with a load of 200Ω.

V. THYRISTOR CLAMPED H BRIDGE INVERTER

The multilevel inverter uses sinusoidal pulse width modulation technique with phase disposition principle[2]. Here we use single phase 9-level hybridised cascaded multilevel inverter for connecting it to the output of high step up converter. The MLI is shown in figure 6.
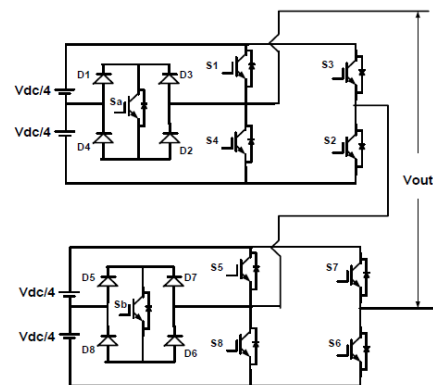

Fig.6. Multilevel inverter

The modulation index are controlled for getting the desired number of levels of the inverter's output voltage.The modulation index is changed by adjusting the magnitude of sine wave.

The output voltage when the switches ON and OFF. Proper switching of the inverter can produce nine output-voltage levels: Vs, 2Vs,3Vs, 4Vs, 0, −Vs, −2Vs, −3Vs, −4Vs. The maximum number of voltage levels obtainable by cascading n number of 5-level inverter is 4n + 1.

IV.   SIMULATION RESULTS

The simulation is done on MATLAB simulink. The simulation diagram consists of PV modeling, boost with voltage multiplier and cascaded H bridge inverter. The simulation diagram of the system is shown in the figure 8.
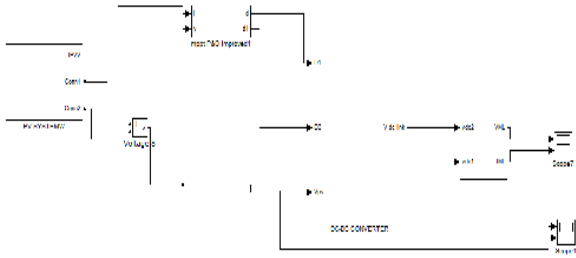

Fig.8. Simulation diagram

A.   *Simulation of PV Panel*

The PV panel modeling is done based on the equation stated above in section II. The MPPT algorithm generates the gate signals for the converter. The solar radiation for the system is given by step increment in radiation.
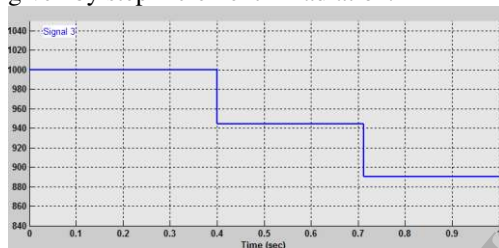
Fig.9. Change in irradiance

The solar PV modeling with the modeling equation are shown in figure 10.
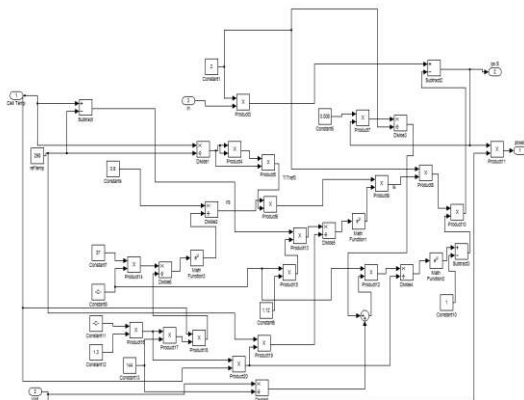
Fig.10. Modeling of PV cell

The figures 11 and 12 shows the PV characteristics obtained for the photovoltaic system. The PV characteristics of the system are non-linear in nature.
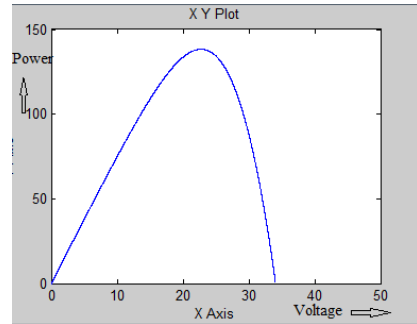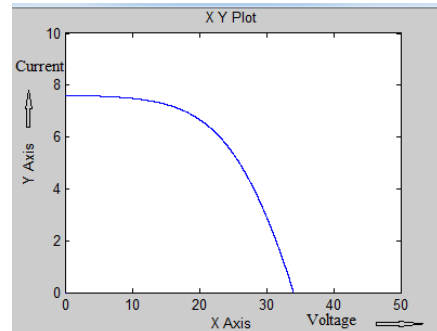

Fig.11. P-V Characteristics

Fig.12. I-V Characteristics

B.   *Simulation of Boost with voltage multiplier converter*

The pulses for the converter provided by P & O algorithm are based on transport delay. The converter works in continuous mode of operation, with a phase shift of 180° and duty cycle greater than 0.5. The output voltage across the converter for an input of 30V from PV system is 300V. So the gain is 10 for a turns ratio of 1. The output of the converter is shown in figure 13.
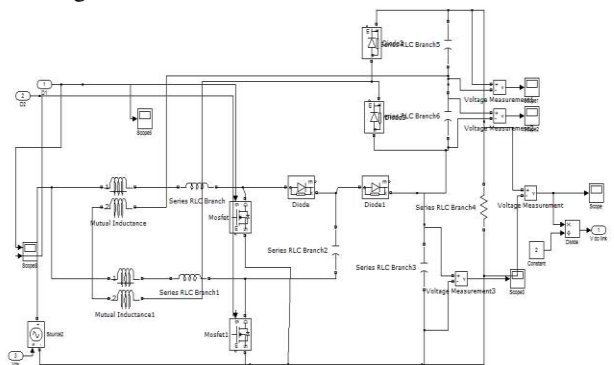

Fig.13. Simulation diagram of boost converter

The output voltage obtained across the load is the sum of the voltages developed across the capacitors. The voltage stress across the switch can be minimized. Also improves the gain and efficiency of the converter.
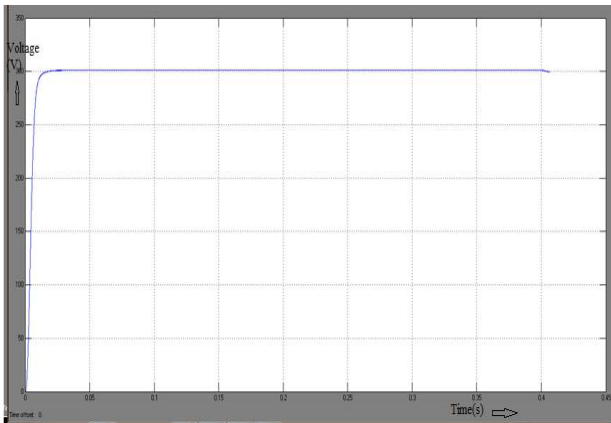
Fig.14. Output voltage of boost converter across the load
The converters are provided with capacitances of values C1=470µF,
C2=C3=Cb=220µF and load resistance R= 200Ω respectively.

C. Simulation of Multilevel inverter

The output of converter is given to a multilevel inverter for inverting the dc voltage to ac voltage. The inverter is a hybrid combination of cascaded H bridge inverter with phase disposition principle. The output of which is shown in figure 16.

The reference sine wave of fundamental frequency is compared with four carrier triangular waves for generating basic pulses for the inverter. The triangular pulses are selected for a frequency of 25kHz.

This topology can be used for power factor correction, the figure shows the current and voltages are in phase. The figure 15 shows the gating pulses for the inverter to operate.
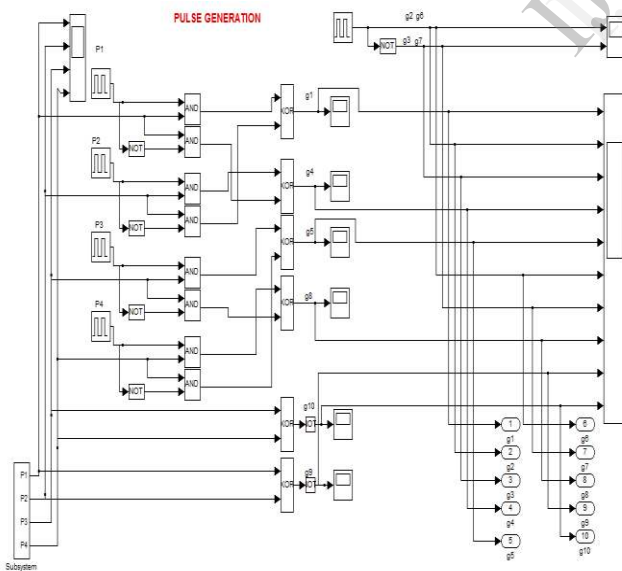

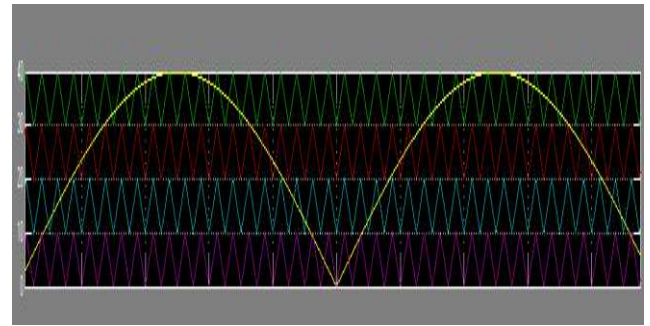Fig.15. Pulse generation for Multilevel inverter

Fig.16. Phase disposition
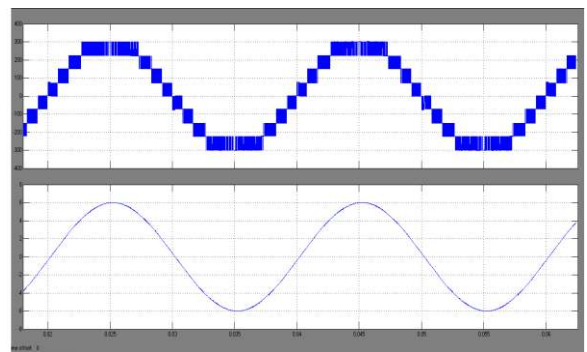The multilevel inverter use phase disposition technique.

Fig.17. Output voltage and current of multilevel inverter

VI. EXPERIMENTAL SETUP

The experimental set up includes the practical setup of boost with voltage multiplier. The modeling is based on the pulse from PIC microcontroller and driver circuit. The modeling of driver circuit is explained in the figure shown below.
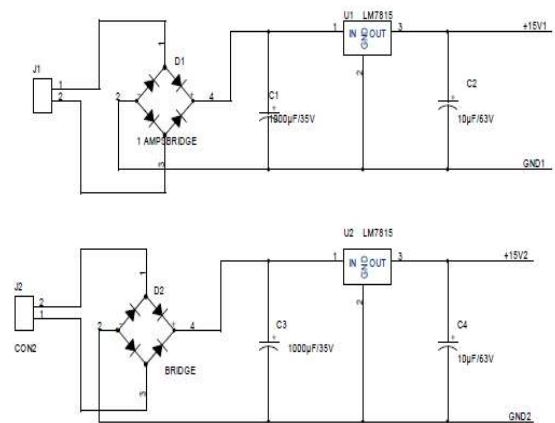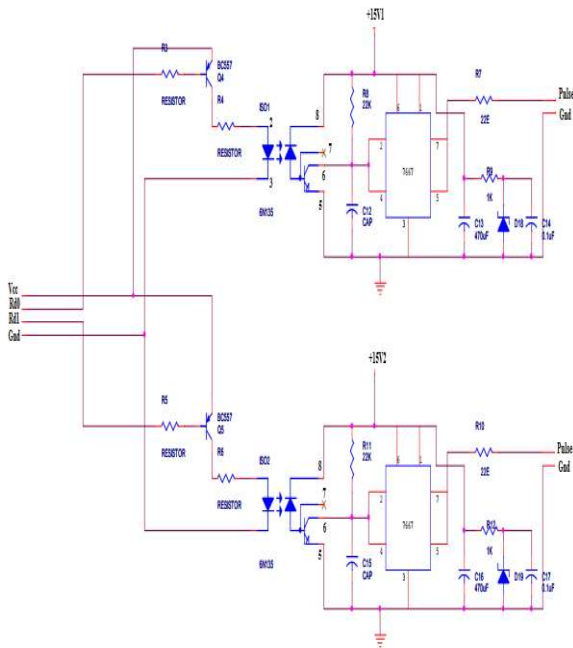

Fig.18. Driver circuit power supply

Fig.19. Driver circuit with optocoupler

The output obtained for the converter for an input of 12V is 93.5V with a switching frequency of 50kHz and designed new duty cycle of 0.2.
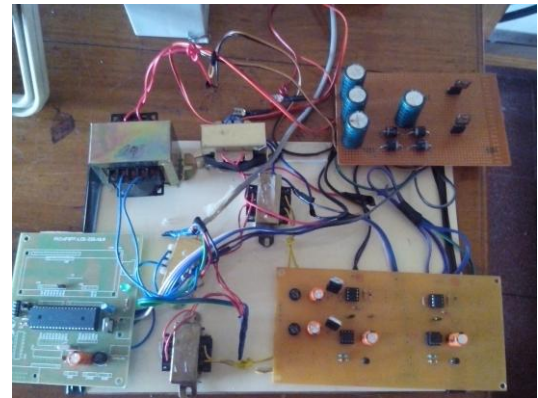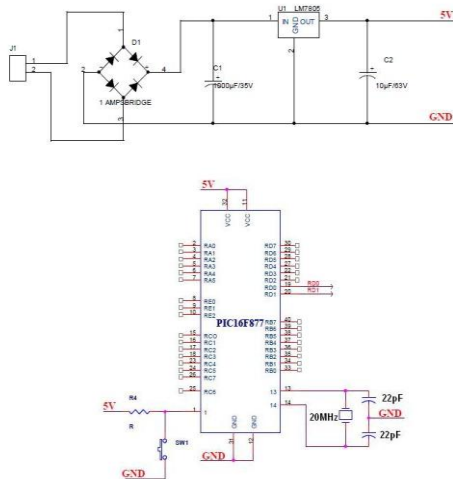

Fig.21. PIC controller setup

Fig.20. Experimental setup

VII. CONCLUSION

The boost converter and inverter integration with photovoltaic system is discussed. The gain and efficiency of the converter depends on the design, components used in the topology. The maximum power can be tracked with MPPT technique in the photovoltaic system for better performance. The design of the converter determines the performance of the system. The smaller value of duty cycle increases the robust working of the photovoltaic system. This system are advantages for various application such as reduction in conduction losses, voltage stress across the switch, leakage energy recycling, better efficiency and gain. The dc-dc converter discussed is integrated with thyristor clamped cascaded H bridge for connecting the R-L load.

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