A NEW METHOD TO OPERATE RURAL PUMPS USING MICROCONTROLLER AND SOLAR ENERGY

Pallavi M. Bhure, Prof. Pratik Ghutke, Dr. Hari Kumar Naidu

M-Tech scholar, Assistant Professor, HOD, Electrical Engineering

TGPCET Mohgaon, Nagpur

Abstract: In modern world, the Power Converter is one of the significant elements widely utilized for the effective use of Renewable power sources. In this paper of a Boost Converter for control of Photovoltaic power using Maximum Power Point Tracking (MPPT) control mechanism is presented. In such systems, when a solar PV system is deployed for practical application, the I-V characteristics keeps on changing with solar irradiation and temperature. In order to receive maximum power the load must adjust itself accordingly to track Maximum Power Point. We can see, the voltage at which PV module gives maximum power is called 'Peak Power Voltage' or 'Maximum Power Point'. The main aim will be to track the Maximum Power Point of the Photovoltaic module so that the maximum possible power can be extracted from the photovoltaic. In this way, the method by which the problem can be solved using MPPT technique, it finds the current Impp or voltage Vmpp at which a Photovoltaic module is observed to be obtain the maximum power but Pmax under a given temperature & solar irradiation. The algorithm utilized for MPPT are written in MATLAB and utilized in simulation. The effectiveness of system is studied with simulation results.

Keywords: MATLAB/SIMULIK, Maximum Power Point Tracking (MPPT), photovoltaic system, solar energy, Battery, Inverter.

I. INTRODUCTION

Solar water pumping systems are new but pumping water in various locations where power grid is not available or reliable. Photovoltaic (PV) generation is becoming tremendously increasing day by day as a renewable source since it offers many advantages such as incurring no fuel cost, not being polluting , requiring little maintenance and not emitting noise and harmful gaseous among others. Among a various type sources of the renewable energy, Photovoltaic (PV) sources have no supply limitations and are predicted to become the biggest contributors to electricity generation among all renewable energy. The Photovoltaic (PV) cells to convert sunlight into electricity which can be used to pumps surface water or ground water for DC pumps power. Solar panel refers to a panel designed in such that to absorb the sun rays as a source of energy for generating electricity. The solar Photovoltaic (PV) panel containing the solar array of a Photovoltaic system that generator supplies solar electricity in various commercial and residential application, each module is rated by its DC output powers under standard test condition. Due to geographical position, India has ample sunshine through the year which makes it ideal location for utilization solar energy.

PV modules have low conversion efficient therefore, controlling Maximum Power Point Tracking (MPPT) for the solar array is necessary in a PV system. Photovoltaic Power generation system supplied electric power depends on the solar radiation and temperature to designing the efficient and reliable PV system to track the maximum power operating point.

The amount of power generated by a PV depends on the operating voltage of the array. A PV Maximum Power Point (MPP) varies with solar irradiation and temperature. The V-I and V-P characteristic curves of solar cell specify a unique operating point at which maximum possible power is delivered. At the MPP, the PV operates at its highest efficiency.

The two most important factors determining energy outputs of PV are solar radiation and cell temperature. PV cell performs under standard test conditions (radiation 1000W/m2 and the temperature 25degree Celsius). On the other hand, it is necessary to know the characteristics of PV panels for different in environmental conditions since they face unusually altering conditions when they are used in real environment.

The major principle of MPPT is to extract the maximum available power from PV module by making them operate at the most efficient voltage at maximum peak Power Point. To get the efficient voltage and current, the output of PV module checks by MPPT compares it to battery voltage than fixes what is the best power that PV module can produce to charge the battery and coverts it to the best voltage to get maximum current into battery. It can also supply power to a various DC load, which is connected directly to the battery.
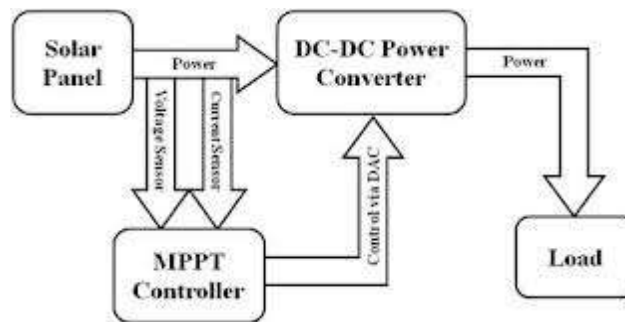
Figure 1: Block diagram for element photovoltaic system with an MPPT command

MPPT is most effectiveness under this condition-

1. Cold weather, cloudy or hazy days: Normally solar panels PV module works better at cold temperature and MPPT is utilized to extract maximum power available from them.

2. When battery is fully discharged: MPPT can extract more current and charged the battery.

II. SYSTEM OVERVIEW

1. STANDALONE WATER PUMPING SYSTEM

The main technology alternatives used for water pumping in OFF grid areas are PV, diesel and Wind powered water pumping systems. The all water pumping system have been widely used to supply water for drinking, livestock and irrigation purpose in remote OFF grid areas. A photovoltaic water pumping system (PVWP) for irrigation typically consist five main components: PV array, Power control unit, pumping system, storage unit and irrigation system. The several technical components choose are available, depending on reliability performance and economics aspects. PV module can be installed on a fixed array or a sun tracking system. Fixed PV array are cheap to installed and require no maintenance, where as the sun tracking system is expensive and requires maintenance of moving components, but allows harvesting of 30-40% more solar irradiation than the fixed system.

The Controller depends on the pump motor type, whether Direct Current (DC) or Alternate Current (AC).

1) In first case –The AC pump is connected to the PV array through DC to AC inverter that transforms the DC power produced by PV module of AC power used to drive the motor.
2) In second case- If a DC pump is chosen, then coupling is arranged with a DC-DC converter.

Most of controller available on the market also equipped with a Maximum Power Point Tracker (MPPT) that also extraction of the maximum power product by the PV array. In the case of the storage system being a battery bank, a charge controller interfaces the PV module with the battery and the power conditioning unit. A standalone photovoltaic pumping system is nothing but the system which works environment friendly and require low maintenance with no fuel cost. The application of standalone PV system is for pumping system there will be huge amount of solar irradiance and system is not connected to grid system.

2. SOLAR ENERGY

Solar energy is a Non Conventional type of energy. Solar powered electrical generation relies on photovoltaic system and heat engines. To harvest the solar energy, the most common way is to use photovoltaic panels which will require photon energy from sun and converts to electrical energy. The solar technologies are broadly classified on the basis of distributes, detain and convert solar energy into passive solar or active solar.

The active solar technique includes the use of PV panel and solar thermal collectors to trap up the energy. Solar energy has a vast area of application such as electric generation form distribution, heating water, lighting building, crop drying etc.

PV CHARACTERISTICS:

The characteristic of PV cell are a combination of current source and diode. The current source V-I characteristics are considered separately and the diode V-I characteristics are determined separately. Here these two elements that is current source and diode are in parallel connection so by adding currents the PV array characteristic are achieved. The V-I characteristic and V-P characteristic for different temperature such as 25, 50 and 75 degree Celsius are present. It is observed that as the temperature increase the open circuit voltage decrease without any considerable change in the short circuit current. As result, the maximum power from the cell is decreasing.

The comparison between different photovoltaic cell can be done on basis of their performance and characteristic curve. The characteristic and performance of PV cell with respect to standard test condition. Standard test conditions are as follows:

Temperature T = 25oC
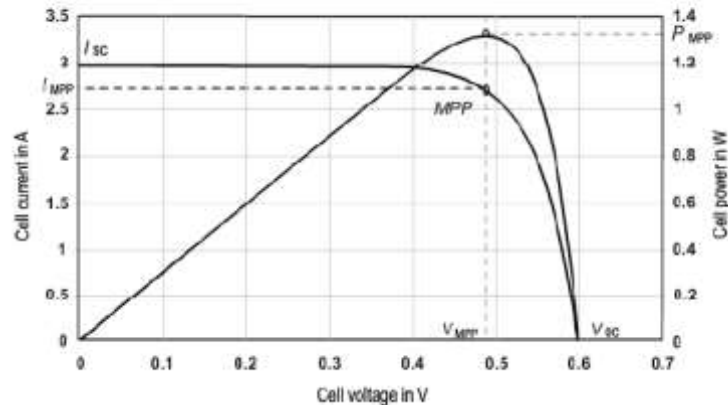Solar irradiance S = 1000 W/M2

Figure 2: P-V and I-V characteristic of solar cell.

EFFECT OF VARIATION OF SOLAR IRRADIATION

The PV and IV curves of a solar cell are highly dependent on the solar irradiation values. The solar irradiation as a result of the environmental changes keeps on fluctuating as per the load variation , but control mechanism are available that can track this change and can alter the working of the solar cell to get the proper load demands. On the basis of principle of PV cell higher is the solar irradiation, higher would be the solar input of the solar cell and hence power magnitude would increase for the same voltage value. With increase in the solar irradiation the open circuit voltage is increases. This is due to the fact that, when more sunlight incidence on to the solar cell, the electrons is supplied with higher excitation energy, thereby increasing the electron mobility and thus more power is generated.
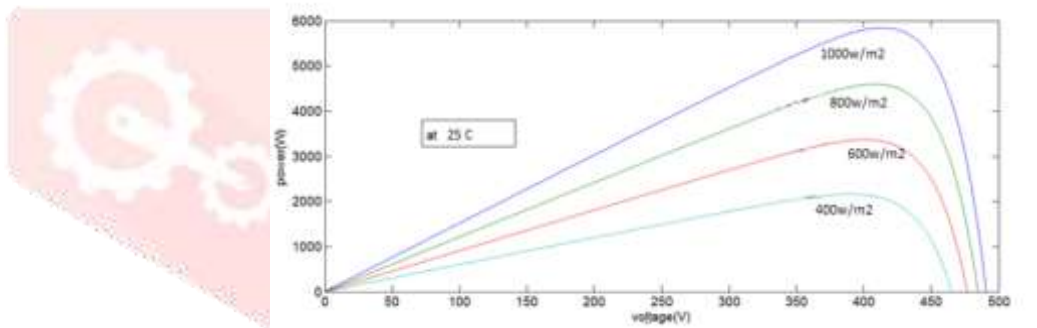

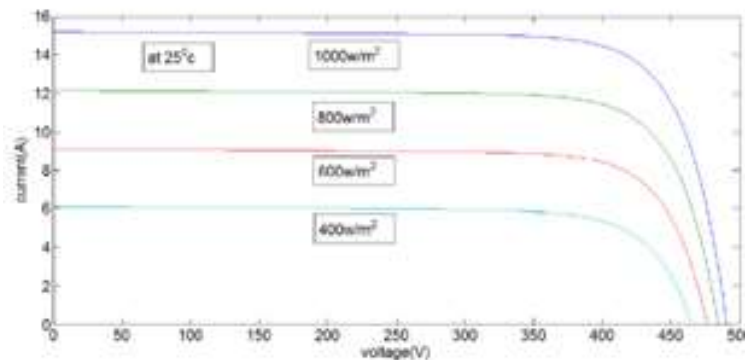Figure 3: Variation of P-V curve with solar irradiation

Figure 4: Variation If I-V curve with solar irradiation

EFFECT OF VARIATION OF TEMPERATURE

The temperature increase around the solar cell has a negative impact on the power generation capability due to that reliability and efficiency lowered. Increasing in temperature it a companied by decreasing in the open circuit voltage value. Increase in temperature causes increase in the band gap on the material and thus more energy is required to cross these barriers the efficiency of solar cell is reduced.
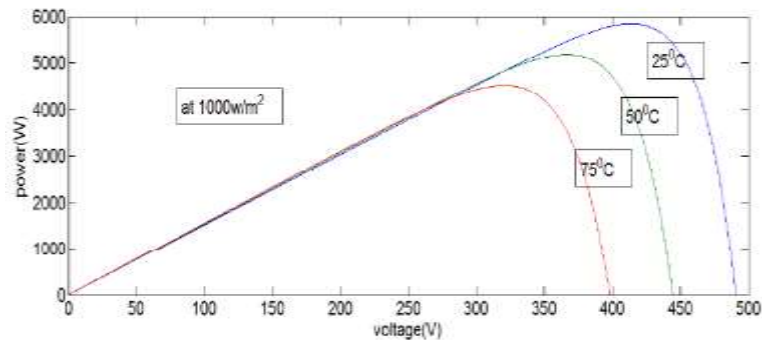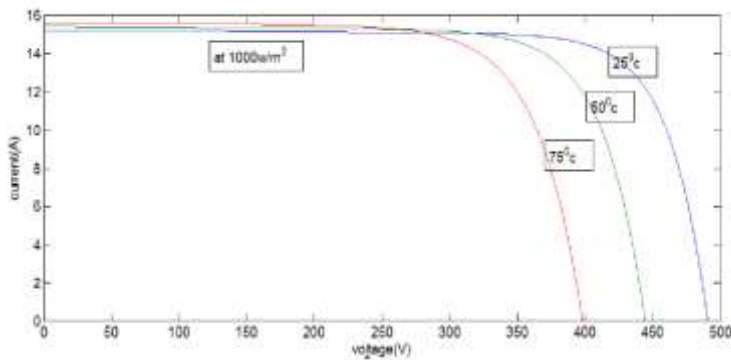

Figure 5: Variation of P-V curve with Temperature

Figure 6: Variation of I-V curve with temperature

Photovoltaic is the best method of generating electric power by using solar cells to convert energy from the sun into electricity. To produce electricity the Photovoltaic effect refers to photons of light knocking electrons into a higher state of energy. The photovoltaic effect indicates the unbiased operating condition of a photodiode in which current through the device is due to the transuded light energy by knocking photo electron on PV module to generate the current.
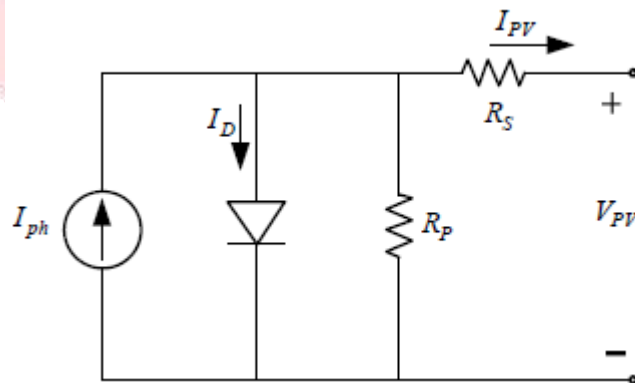

Figure 7: Equivalent circuit for solar cell

An ideal solar cell is modeled by a current source in parallel with a diode. However no solar cell is ideal and thereby in above Figure 7 shows that the shunt and series resistance are added to the model. The current source Iph represents the cell photo current. Rsh and Rs are used to represent the intrinsic series and shunt resistance of the cell. Usually Rsh is very large and Rs is small.

3. SIMULATION OF PV SYSTEM

The solar panel array should supply a minimum power for charging the battery for pumping operation. In this paper solar panel have Open Circuit Voltage (Voc) and Short Circuit Current (Isc) are connected into module with cell in series. The output power of solar panel with maximum voltage (Vmpp) and maximum current (Impp) are given in the terms of sun irradiance of 1000 W/m2 and the temperature of 25degree Celsius, so that solar panel array was model using MATLAB/SIMULINK the I-V and P-V characteristic of solar panel obtain for a solar irradiation of 1000 W/ m2 at 25degree Celsius. The simple equivalent circuit consist complex parameters including the effect of temperature in the device which is very important for behavior of this type of system.
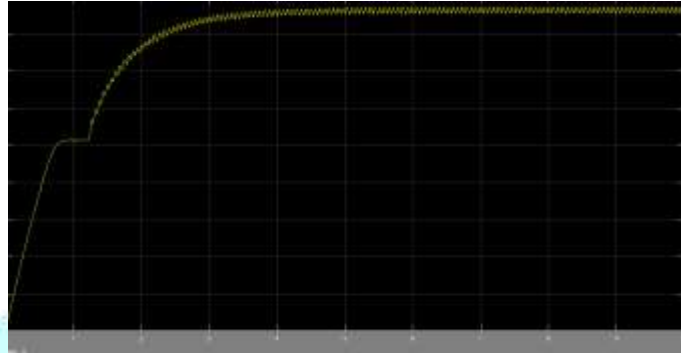

Figure 8: Simulation output of PV without inverter

4. SIMULATION OF MAXIMUM POWER POINT TRACKING

Maximum Power Point plays an important role in photovoltaic system because they maximize the power output from a PV system for a given set conditions, and therefore maximize the array efficiency. The efficiency of solar cell is very low. In order to increase the efficiency, one such method is the Maximum Power Point Tracking (MPPT). This is a technique used to obtain the maximum possible power from a varying source. In photovoltaic system the I-V curve is non linear, thereby duty cycle is varied by using a MPPT algorithm. A boost converter is used on the load side and a solar panel is used to power this converter. The incremental conductance algorithm has successfully tracked the MPOP (maximum power operating point) even when atmospheric condition changes rapidly. The work was carried out by both simulation and graphs. The Electronic system varies the electrical operating point of the modules so that the modules are capable to produce all power and deliver maximum available power.
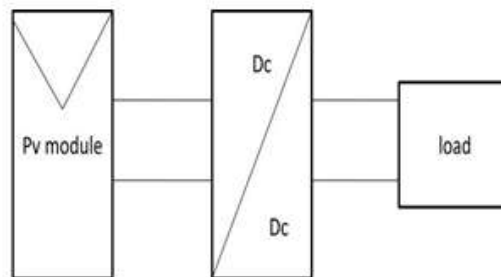

Figure 9: Block diagram of typical MPPT system

To continuously deliver the maximum possible power to the load when variation in the solar isolation and temperature then MPPT technique are used. Photovoltaic (PV) generation is day by day important as a renewable source since it offers many advantages such as no fuel costs, not polluting, requiring little maintenance, and emitting no noise. PV modules still have relatively low conversion efficiency; therefore controlling Maximum Power Point Tracking (MPPT) for the solar array is essential in a PV system to improve efficiency.
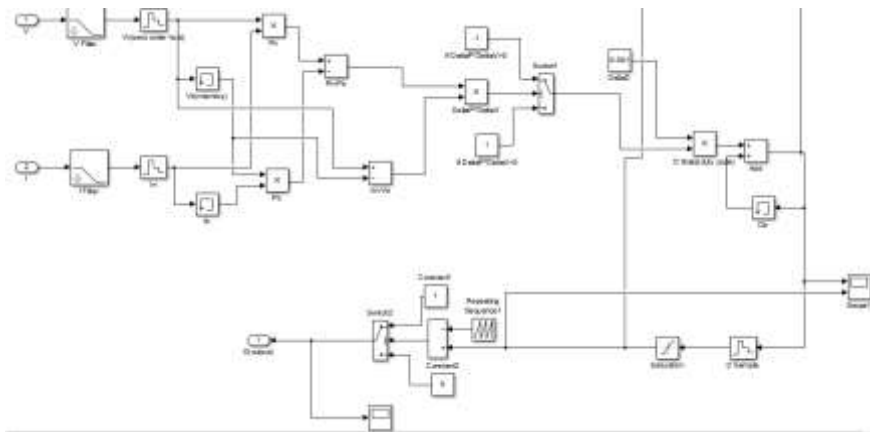
Figure 10: Simulation of Maximum Power Point Tracker
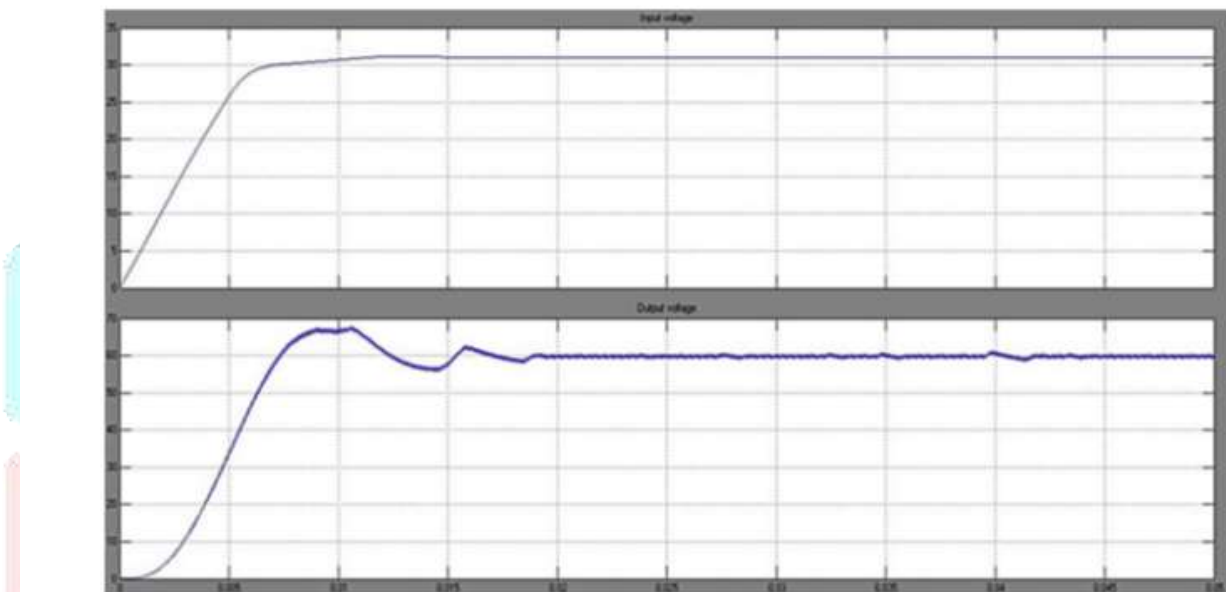
Figure 11: Voltage versus Time curve without MPPT technique with temperature and solar irradiance
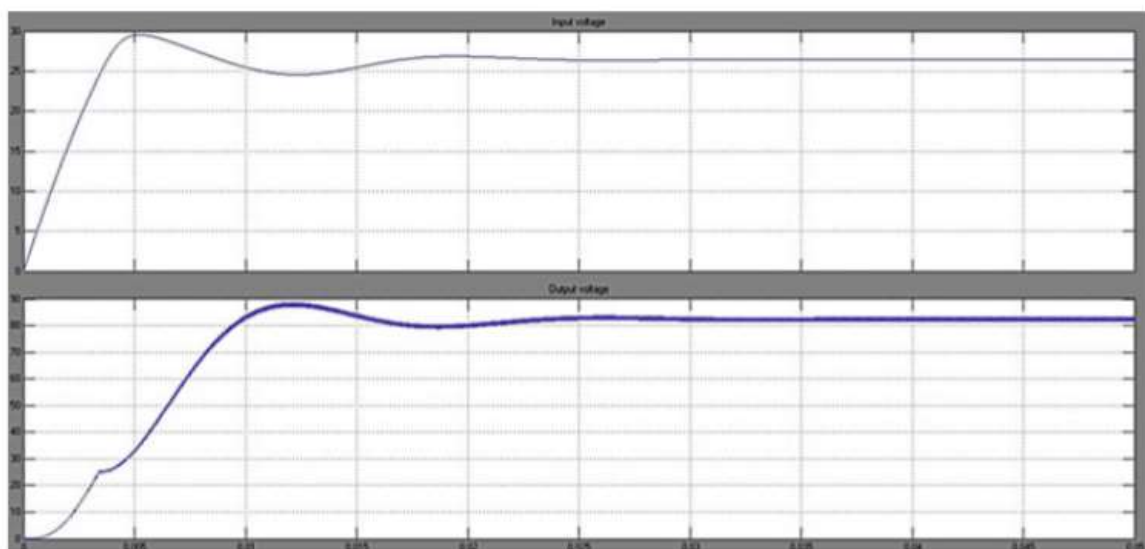
Figure 12: Voltage verses Time curve with Incremental Conductance MPPT technique with temperature and solar irradiance

Figure 11 show the voltage versus time curve without the MPPT technique at temperature 25oC with irradiation levels 1,000 W/m2. It is inferred that the output voltage obtained without MPPT technique had perturbations before obtaining the required

output and the output voltage was not of the desired value. The P&O method was applied it is inferred that using the perturb and observe technique, when the irradiation is constant, it oscillates around the MPP value. The amplitude of the oscillations depends directly on the size of increment in the reference voltage, ΔVref. Also, when the irradiation is constant, the corresponding MPP voltage is reached after a delay, which depends on the size of change in voltage. The P&O block was replaced using the Incremental Conductance technique and the output was observed as shown in Figure 12. The results are almost practically the same. Fig.12 shows the Voltage versus Time curve with Incremental Conductance MPPT technique. In this case the tracking is adequate, which demonstrates that irradiation step changes do not pose a challenge to the hill-climbing algorithms and are not suitable for testing MPPT. As expected, the convergence speed, i.e. how fast the steady state is reached, and the amplitude of the oscillations are a trade off, as both cannot be improved at the same time: if one is reduced the other increases, because both depend directly on the size of the voltage increment

5. SIMULATION OF BOOST CONVERTER

The advantages comparing with the conventional series connected boost converter where reported. Simulation and experimental results of a laboratory prototype were presentable. The ripples are added to each converter then current ripple at the load side increases, which also reduce the lifetime of the battery storage. When the switching frequency is increasing due to that ripple are reduce; the extra switching losses must be taken into account. The switching technique are based on parallel input source including boost converters since the current ripple of the battery charging current can be minimized without the restriction of source voltages, current and duty cycle.

It consist of input inductor and output inductor capacitor is used to absorb the AC current repel of the battery and an output capacitor. To run the pumping different modes of integrated boost convertor with single switch is used. The input inductance and output inductance are operated in continuous conduction mode (CCM). The input inductance charged up by the slope of photovoltaic source. The PWM incurring no fuel costs, not being polluting, requiring little maintenance, and emitting no noise, PV modules still have relatively low conversion efficiency; therefore controlling Maximum Power Point Tracking (MPPT) for the solar array is essential in a PV system to improve efficiency. A MPPT solar charge controller is the charge controller embedded with MPPT algorithm to maximize the amount of current going into the battery from PV module when no available of power.
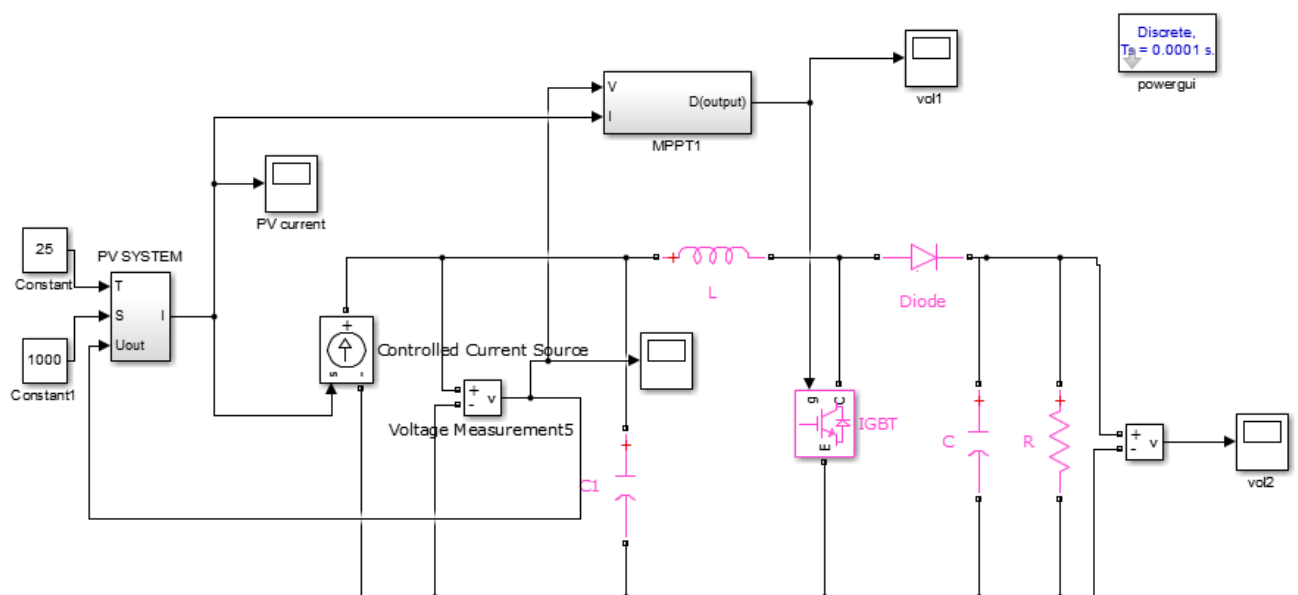
Figure 13: SIMULINK model of PV system with Boost converter

6. BATTERY

Selecting the suitable battery for a PV application depends on many factors. For off grid and critical applications, storage systems are required, the most common medium of storage are the lead acid batteries. Presently researches are going on in the field of lithium ion batteries and to implement the concept of fuel cells in solar PV systems. One of the most expensive components in the PV systems is the battery. Under sizing the batteries will become more costly as the battery life cycle is significantly reduced at higher Depth of Discharge (DOD %). At a higher depth of discharge, expected average number of charge-discharge cycles of batteries. Further a higher current discharge than the rating will dramatically reduce the battery life. This can be avoiding by carefully sizing of battery according to the 'C-rating' during the system design. It signifies the

maximum amount of current that can be safely withdrawn from the battery to provide adequate backup and without causing any damage. Selecting the suitable battery for a PV application depend on many factor. Battery selection depends on physical properties. Consideration in battery subsystem include the number of batteries are connected in series and parallel toget the higher voltage and current values, over current disconnect requirement and selection of proper wire sizes and types. In cloudy days, the energy output from the solar PV system is generally stored in battery or in a battery bank depending on the requirements of the system. Batteries are use as backup system in grid connected system. The primary function of battery in PV system are-

   1. Energy storage capability and autonomy: To store electrical energy when it is produced by the PV array and to supply energy to electrical loads as needed or when on demand.

   2. Voltage and current stabilization: At stable voltage and current values, supply the power to electrical load by suppressing or smoothing out transients that may occur in PV system.

   3. Supply surge current: To supply surge or high peak operating currents to electrical loads or appliances to gain the power for output.

7. PULSEWIDTH MODULATION (PWM)

In the Pulse Width Modulation method uses solid states switch to apply pulses of current at reasonably high frequency but with a varying duty cycle, such that battery receives a constant voltage charge from the array. This type of controller shows in series configuration. The power dissipation is reduced with PWM technology.

8. INVERTER

Inverters are used to convert DC current into AC current in PV system. The user must match the power quality required by load with the power quality produced by the inverter. The energy conversion system includes a DC- DC Converters between the PV array and the inverter. They are connected to the various electric grid with the PV system operation at the cost of slightly decreasing the global efficiency of the combined system because of the connection of two cascaded stages. The intermediate DC-DC converter is build with as insulated gate bipolar transistor (IGBT) as main power switch in a standard unidirectional boost topology that employs an energy storage reactor, a rectifier diode and a voltage smoothing capacitor C. The converter is linked to the PV system with a filter capacitor for reducing the high frequency ripple generated by the transistor switching. One is to ensuring that the PV module is operated at the maximum power point (MPP). The other is to inject sinusoidal current into the grid. The development of single phase sinusoidal pulse Width Modulation (SPWM) microcontroller based inverter. In this configuration use of Microcontroller to generate sinusoidal Pulse Width Modulation (SPWM) pulses. It consist of DC voltage source or photovoltaic module, for switching elements (IGBT) , LC Filter, Transformer and Load, and that it must be capable of delivering high current at low voltage.

   To reduce complexity, cost and number of power conversion, which results in higher efficient a single stage controlled current voltage source inverter is used compensate at the reactive power demanded by non linear or variation in loads

   For a solar PV output of 2.7V DC, we design a boost converter with output voltage 2V, supply current 0.25A. Switching frequency 6.25KHZ such that the variation in inductors is not more than 40% of average inductor current for all operating conditions. The output ripple should be not more than 2%. The Boost Converter was designed for a 2.7V input from solar PV Panel with L 0.05 MH and (18.15microfarad).

   A single phase full bridge inverter (PWM) circuit was used to convert the boost DC voltage to alternating voltage. The above model can be conviently used for integrating the solar PV system to grid system. The inverter system model with MATLAB/SIMULINK was achieved using the power system and standard SIMULINK block sets. The system was analyzed by sending the required signal to scope and the work space, which allows analyzing and designing of the inverter model.
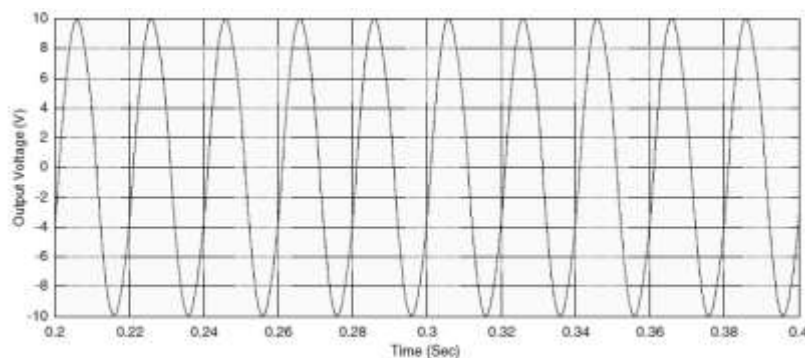

Figure 14: Scope output for inverter model

9. MICROCONTROLLER

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        P 1 . 0 ⊏  1        40 ⊐ V C C
        P 1 . 1 ⊏  2        39 ⊐ P 0 . 0  ( A D 0 )
        P 1 . 2 ⊏  3        38 ⊐ P 0 . 1  ( A D 1 )
        P 1 . 3 ⊏  4        37 ⊐ P 0 . 2  ( A D 2 )
        P 1 . 4 ⊏  5        36 ⊐ P 0 . 3  ( A D 3 )
        P 1 . 5 ⊏  6        35 ⊐ P 0 . 4  ( A D 4 )
        P 1 . 6 ⊏  7        34 ⊐ P 0 . 5  ( A D 5 )
        P 1 . 7 ⊏  8        33 ⊐ P 0 . 6  ( A D 6 )
        R S T   ⊏  9        32 ⊐ P 0 . 7  ( A D 7 )
  (RXD) P 3 . 0 ⊏ 10        31 ⊐ EA/VPP
  (TXD) P 3 . 1 ⊏ 11        30 ⊐ ALE/PROG
  (INT0) P 3 . 2 ⊏ 12        29 ⊐ PSEN
  (INT1) P 3 . 3 ⊏ 13        28 ⊐ P 2 . 7  ( A 15 )
  (T0)  P 3 . 4 ⊏ 14        27 ⊐ P 2 . 6  ( A 14 )
  (T1)  P 3 . 5 ⊏ 15        26 ⊐ P 2 . 5  ( A 13 )
  (WR)  P 3 . 6 ⊏ 16        25 ⊐ P 2 . 4  ( A 12 )
  (RD)  P 3 . 7 ⊏ 17        24 ⊐ P 2 . 3  ( A 11 )
        X T A L 2 ⊏ 18      23 ⊐ P 2 . 2  ( A 10 )
        X T A L 1 ⊏ 19      22 ⊐ P 2 . 1  ( A 9 )
        G N D   ⊏ 20        21 ⊐ P 2 . 0  ( A 8 )
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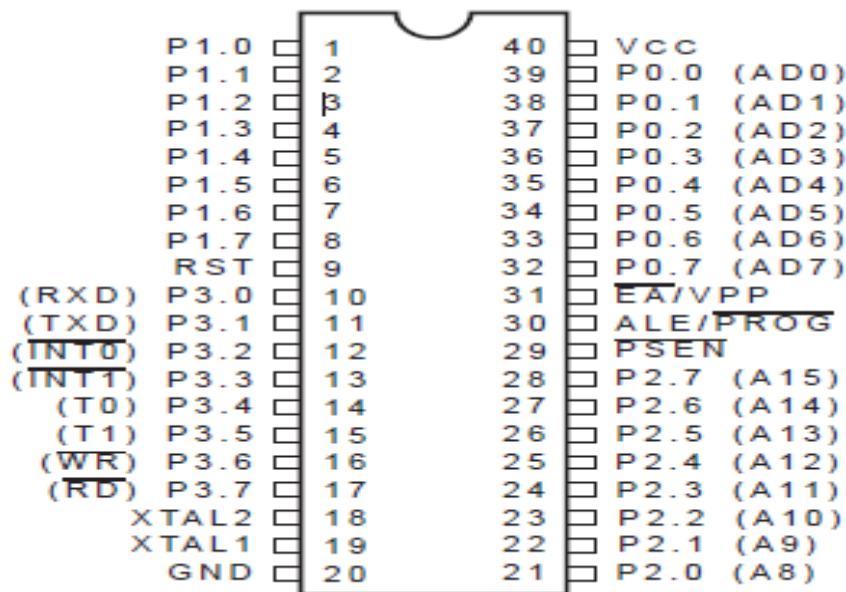
Figure 15: Pin configuration

The AT89C51 is a low-power, high-performance CMOS 8-bit microcomputer with 4Kbytes of Flash Programmable and Erasable Read Only Memory (PEROM). The device is manufactured using high density nonvolatile memory technology and is compatible with the industry standard MCS-51™ instruction set and pinout. The on chip Flash allows the program memory to be reprogrammed in-system or by a conventional nonvolatile memory programmer. By combining a versatile 8-bit CPU with Flash on a monolithic chip, the Atmel AT89C51 is a powerful microcomputer which provides a highly flexible and cost effective solution to many embedded control applications.

III. CONCLUSION

In this paper solar powered water pumping system of standalone PV system with MPPT is simulated by MATLAB/SIMULINK. A single switch converter with battery is designed for this purpose. The model has been providing efficient in different modes of operation with MPPT. To achieved the Maximum Power Point Tracking and maximization of the real power output of the PV system. The MPPT was implemented using control technique of incremental conductance method to understand and master the performance of PV system and allow optimizing the design and lowering cost, improves system reliability and efficiency. The proposed system with MPPT can be implemented practically using microcontroller with less cost.

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