Solar Energy Harvesting Using MPPT

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***Abstract*—Solar energy is one of the most reliable sources of renewable energy. PV (Photovoltaic)modules are one's who convert solar energy into electrical energy. To increase overall system efficiency, Maximum Power Point Tracking (MPPT) technique is used. There are many MPPT techniques present, here we are using Perturb and Observation(P&O) method which has high accuracy, low in cost, and high in efficiency. This paper focuses on controlling Solar Panel, Battery and Load simultaneously using P&O algorithm. The system gives efficiency approx 25-30% without using MPPT charge controller, but by using MPPT charge controller the overall system gives efficiency upto 70%.**

Keywords—MPPT (Maximum power point tracking), PV(Photovoltaic), P&O (Perturb & observe), LVD(Low voltage disconnect)

I. INTRODUCTION (*HEADING 1*)

Due to an ever-increasing human population and energy consumption, global capacities of conventional fossil energy resources have been decreasing for more than 2 decades [1]. Even today when global warming is an important issue of discussion not only among environmentalists,but also, among commoners and industrialists alike, we still rely on fossil fuels for much of our energy needs [2]. Renewable energy is an ultimate energy source to reach high energy demand and to alleviate the greenhouse effect and energy crisis [3]. Renewable energy is generally defined as energy that comes from resources which are naturally replenished on a human timescale such as sunlight, wind, rain, tides, waves and geothermal heat [4]. The development of renewable energy has been an increasingly critical topic in the 21st century with the growing problem of global warming and other environmental issues. With greater research, alternative renewable sources such as wind, water, geothermal and solar energy have become increasingly important for electric power generation. Although photovoltaic cells are certainly nothing new, their use has become more common, practical, and useful for people worldwide. The most important aspect of a solar cell is that it generates solar energy directly to electrical energy through the solar photovoltaic module, made up of silicon cells.

Photovoltaic (PV) power is an established technology and has recently experienced rapid growth over the last twenty years [5]. PV system is one of the important renewable energy sources because it is available in most area around the world [6].

PV energy is one of the leading sources of renewable energy, which gets more preference in comparison to other forms of alternate energy due to its availability, simplicity, lower maintenance, environmental friendliness, reliability and many other benefit's [7]. This system occupies an important position in renewable energy for its flexible configuration, easy installation and no pollution [8]. It is a popular source of renewable energy especially in tropic areas [9]. This technology gained more attention due to the advantages of unlimited power resources and environment friendly ecosystem [10]. A photovoltaic module is used efficiently only when it operates at its optimum operating point. The sun is an incredible and renewable resource that has the power to fuel life on earth and provide clean, sustainable energy to all of its inhabitants. In fact, more energy from the sun reaches our planet in one hour than is used by the entire population of the world in one year. The sun's energy can be converted into electricity through solar PV modules. The dynamic nature of solar radiation results in unstable power generation throughout the day [1]. Solar cells have variable current and voltage characteristics [4]. Solar cell panels are exposed to sunlight at different angles and with variable intensity, therefore the resulting output power varies depending on the illumination angle as well as the light intensity of each panel [11].These Solar cells are connected in series and parallel to form the PV panel [5].

The maximum power point tracking (MPPT) is the automatic control algorithm to adjust the power interfaces and achieve the greatest possible power harvest, during moment-to-moment variations of light level, shading, temperature, and photovoltaic module characteristics [4]. The MPPT is responsible for extracting the maximum possible power from the photovoltaic and feed it to the load via the buck-boost converter which steps up the voltage to required magnitude [2].

The voltage at which PV module can produce maximum power is called maximum power point. Maximum power varies with solar radiation, ambient temperature and solar cell temperature. The major principle of MPPT is to extract the maximum available power from PV module by making them operate at the most efficient voltage. There are many MPPT algorithms by which we can track maximum power, in this project , we are using P&O algorithm. There is a still a scope to increase the efficiency of overall system .

By using P&O algorithm the charge controller compares present and previous instant voltages of PV module and according to that maximum power from solar panel is extracted. But when we connect battery and load at output side of this system then there is also a need to control battery and load according PV module voltage That is to say: our charge controller checks output of PV module, compares it to battery voltage then fixes what is the best power that PV module can produce to charge the battery and converts it to the best voltage to get maximum current into battery. It can also supply power to a DC load, which is connected directly to the battery.

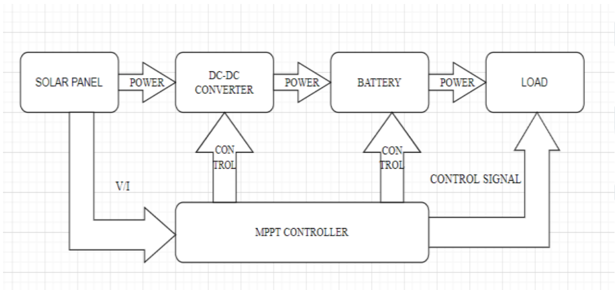

Fig.1. System Block Diagram

During morning The MPPT controller constantly checking the solar panel, battery voltage and current and accordingly generates the duty cycle for converter to safely charge the battery (means to prevent battery from overcharge and over discharge). And at evening battery is fully charged that's why connection from solar panel is cutoff and drive the load .

A. Hardware:

i. PV Sysytem

A solar cell converts the solar light to electricity by means of the photovoltaic effect. It is a p-n junction made with semiconductor material. The equivalent circuit model of the solar cell consists of electronic devices such as a current source, a diode and two resistors, one in series and one in parallel as shown in fig.2.

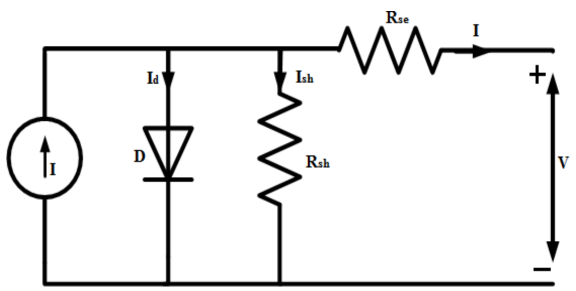

Fig.2. Equivalent circuit of pv module [2]

The equation that describes the V-I characteristic curve of a solar cell is:

$$I = I_{ph} - I_o \left[\mathrm{Exp}\left(\frac{V + I R_S}{V_T}\right) - 1\right] - \left[\frac{V + I R_s}{R_p}\right] \ldots [2]$$

Where, Iph = The PV module saturation current

I = Output Current of a PV modules

I0 = Reverse Saturation Current

V = Output Voltage of a PV modules Rs = Series Resistance of PV modules, Rp = Parallel Resistance

Vt = Thermal Voltage

The voltage generated by a solar cell is about 1 V and it is essential to connect cells in series and in parallel to create PV modules in order to supply the desired power.

ii. DC/DC Buck-Boost Converter :

A topology of the DC-DC buck-boost converter is shown in fig.3. It is modelled in two modes of operation, which are given by the operation state of the switch.

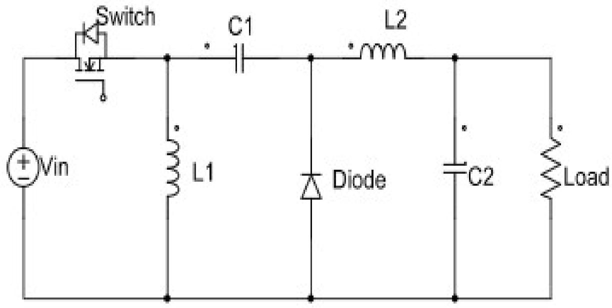

Fig.3. DC-DC Buck –Boost converter[8]

When the switch is on (closed), the input voltage source Vin is directly connected to the inductor (L1). This results in accumulating energy in L1. In this stage, the capacitor C2 supplies energy to the output load as shown in fig.4.

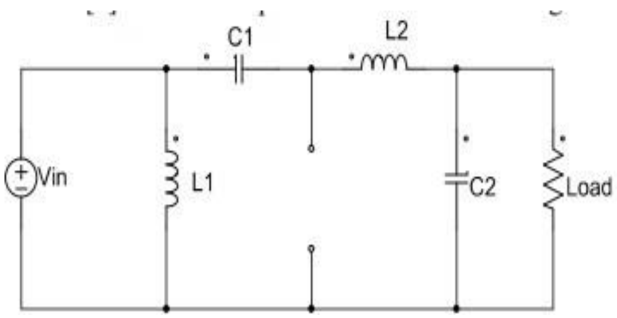

Fig.4.Buck-Boost Converter with closed switch (switch on)[8]

When the switch is off (open), the inductor L2 is connected to the output load and capacitor C2, so energy is transferred from L2 to C2 and R(Load) as shown in fig.5.

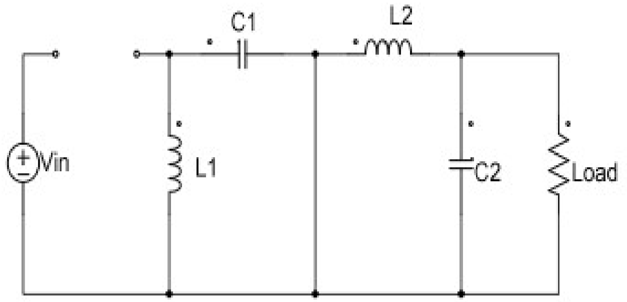

Fig.5.Buck-Boost Converter with open switch (switch off)[8]

B. Software :

i. P & O algorithm-

The Perturb and Observe (P&O) method is one of the most commonly used methods in practice. The advantage of this method is that it is simple and easy to implement and it is the most used algorithm. The P&O is based on the variation of the PV module output voltage, controlling the duty cycle of the DC/DC converter, and comparing the power supplied by the solar cells in the current instant of time with the power obtained in the previous instant of time.

If the power of the current cycle is greater than the previous one, the voltage must be modified in the same way, increasing or decreasing it, whereas if the power is lower than the previous power, then the voltage must be varied in the opposite way, increasing or decreasing it as well. When the MPP is reached, the control algorithm oscillates around the maximum power. The flowchart of the P&O is shown in Fig.6.

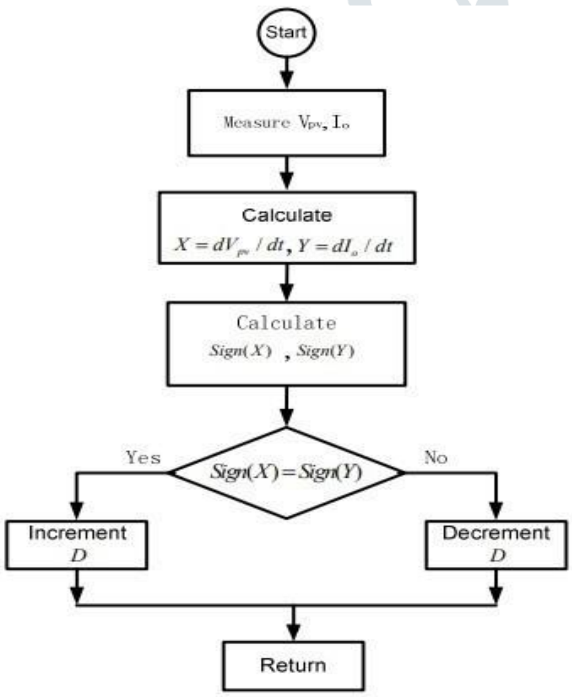

Fig.6. Flow chart of P&O algorithm [3]

The P&O algorithms operate by periodically perturbing, i.e. incrementing or decrementing, the array terminal voltage and comparing the PV output power with that of the previous perturbation cycle. If the PV array operating voltage changes and power increases, the control system moves the PV array operating point in that direction. Otherwise, the operating point is moved in the opposite direction as shown in Fig.7.

Firstly, The DC-DC converter adjusts slightly the voltage from the PV array and measures power, then it varies the terminal voltage of the PV and takes a second measurement of the power. If MPP increases, further adjustments in that direction are tried until maximum power is reached as shown in Fig.7.

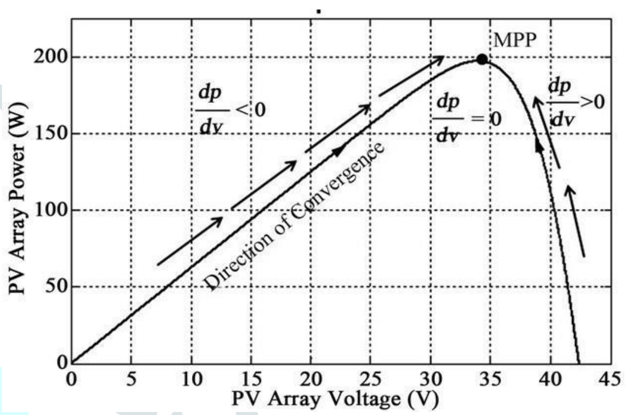

Fig.7. P-V Curve of solar panel

ii. Charging algorithm for battery :

When the controller is connected to the battery, the program will start the operation. Initially, it checks if the panel voltage is sufficient for charging the battery. If yes, then it will enter into the charge cycle. The Charge Cycle consists of 3 stages.

- Stage 1(Bulk charge):

In this stage, Arduino will regulate the charging current by maintaining the voltage level at intermediate voltage for one hour. The voltage is kept constant by adjusting the duty cycle.

- Stage 2 (Absorption charge):

In this stage, Arduino will regulate the charging current by maintaining the voltage level at intermediate voltage for one hour. The voltage is kept constant by adjusting the duty cycle.

- Stage 3 (Float charge):

The controller generates the trickle charge to maintain the voltage level at just lesser than intermediate voltage. This stage keeps the battery to be fully charged and protect it from overcharge. If the battery voltage drops more than the limit, charge cycle will be repeated.

iii . Load Control :

To automatically connect and disconnect the load by monitoring dusk/dawn and battery voltage, load control is used. The primary purpose of load control is to disconnect the load from the battery to protect it from deep discharging. Deep discharging could damage the battery. The PV panel itself is used as the light sensor. Assuming solar panel Voltage >5V means dawn and when < 5V means dusk.

ON Condition: In the evening, when the PV voltage level falls below 5V and the battery voltage is higher than the LVD setting, the controller will turn on the load.

OFF Condition: The load will cut off in the following two conditions-

In the morning when the PV voltage is larger than 5v.

When the battery voltage is lower than the LVD.

II. *Results & Discussions:*

For every instant of time current and voltage across PV system is changing according to change in irradiance and temperature. Voltage and current sensors track this change for every instant and given this signal to converter as well as to Mppt controller, then Mppt controller with the help of p&o algorithm generates a signal which works as a duty cycle for converter. with help of this duty cycle, converter is either works as a Buck or Boost converter. The behavior of converter to work as a buck or boost is totally dependent upon values of current and voltage for present(k) and previous(k-1) instant of time.

For converter to work as a Buck converter-

dP = differential power , dV = differential voltage

dP= P(k) - P(k-1) and dV=V(k) - V(k-1)

Case (1)- if dP > 0 , dV < 0

then Duty cycle= D(k)= D(k-1)+dD

And if dV > 0,

then Duty cycle=D(k)=D(k-1)-dD

Case (2)- if dP< 0And if dv < 0

then Duty cycle= D(k)= D(k-1)-dD

And if dv > 0,

then Duty cycle= D(k)= D(k-1)+dD

Where dD = is differential duty cycle which we have adjust according to the values of current and voltage across pv system for present and previous instant of time.

For converter to work as a Buck converter-

Keep our system leakage proof (Which happens when battery is fully charge), Buck converter is used. By keeping value of duty cycle less than 0.5 this converter will work as a Buck converter which keeps system leakage proof.

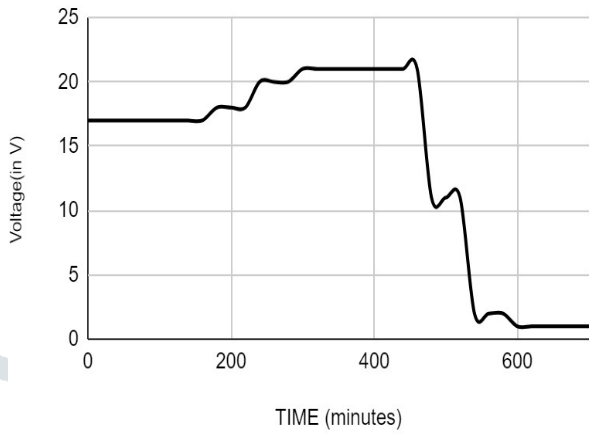

Fig.8. Voltage vs Time graph of solar panel(8am to 4pm)

Above graph is of controlled voltage from solar panel vs time to safely charge the battery

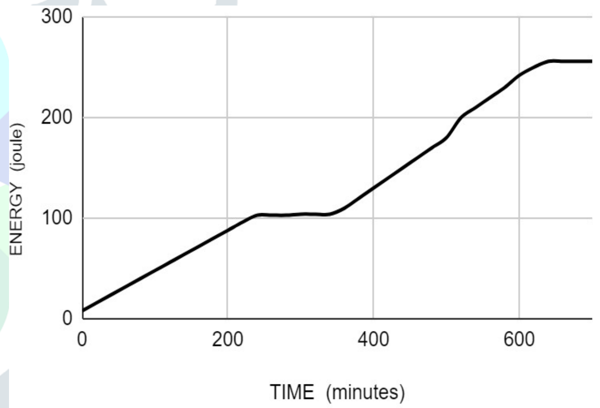

Fig.9. Charging of battery in one day(8am to 4pm)

For a 16v battery, during sunrise(8am) battery is fully discharged (12v) and start's charging cycle, first stage is of bulk charge, where current through the battery is constant and voltage is linearly increasing to intermediate voltage(14.4v).Next stage is of intermediate charge where current through the battery increases linearly and voltage across battery is constant at intermediate voltage (14.4v).after that next stage is float charge were voltage across the battery is step down from intermediate voltage to keep the battery fully charge and prevent it from overcharge .

For 16v battery, the charge stored by a battery in one day (8am to 4pm) by using MPPT charge controller is approx 6700 joules (in minutes).

IV CONCLUSION:

This paper focusses on increasing the efficiency of the overall system by connecting the battery and the load to the solar charge controller. The system gives efficiency approx 25-30% without using MPPT charge controller, but by using MPPT charge controller the overall system gives efficiency upto 70%. In this way by using MPPT with P&O algorithm we can efficiently harvest the solar energy and the harvested energy can be used for charging of small power devices.

REFERNCECS:

1. Xiao, W., Elnosh, A., Khadkikar, V., & Zeineldin, H.“Overview of maximum power point tracking technologies for photovoltaic power systems”,‘IECON 2011-37th Annual Conference ofthe IEEE Industrial Electronics Society’.
2. Gokilapriya, D., & Barvin Banu, S. “MPPT Measurement of Photovoltaic System Under PartialShading Condition Using DPSO Algorithm”,‘SPRINGER’(2014).
3. Jiang, Y., Qahouq, J. A. A., Hassan, A., Abdelkarem, E., & Orabi, M.“Load current based analog MPPT controller for PV solar systems”, ‘2012 Annual IEEE Applied Power Electronics Conference and Exposition (IEEE)’.
4. Gosumbonggot, J., Nguyen, D.-D., & Fujita, G. (2018). “Partial Shading and Global Maximum Power Point Detections Enhancing MPPT for Photovoltaic Systems Operated in Shading Condition”, ‘ 2018 53rd International Universities Power Engineering Conference (UPEC) (IEEE)’.
5. Guihua Liu, Panbao Wang, WEI Wang and QI Wang (2012)“Mppt algorithm under partial shadingConditions”, ‘SPRINGER (2012)’.
6. Taohid latif and Syed R.Hussian (2014) “design of charge Controller based on sepic and buck topolgy using modified Incremental Conductance MPPT”, ‘IEEE (2014)’.
7. Mohapatra, A., Nayak, B., & Saiprakash, C. (2019). “Adaptive Perturb & Observe MPPT for PV System with Experimental Validation”, ‘2019 IEEE International Conference on Sustainable Energy Technologies (ICSET)’.
8. Mohammad Agung Dirmawan, Suhariningsih, Renny Rakhmawat. “The Comparison Performance of MPPT Perturb and Observe, Fuzzy Logic Controller, and Flower Pollination Algorithm in Normal and Partial Shading Condition”, ‘2020 International Electronics Symposium (IES)(IEEE)’.
9. Özçelik, M. A., & Yilmaz, A. S. (2015). “Improving the performance of MPPT in PV systems by modified Perturb- and-Observe algorithm”,‘Journal of Engineering Research (SPRINGER-2015)’.
10. Ratnakar Babu Bollipo, Suresh Mikkili, Praveen Kumar Bonthagorla “Hybrid, optimization, intelligent and classical PV MPPT techniques: Review.”‘(2020) CSEE(IEEE) Journal of Power and Energy Systems’.
11. Amel Abbadi,F. Hamidia , A. Morsli, D. Boukhetala ,and L. Nezli “Fuzzy-Logic-Based Solar Power MPPT Algorithm Connected to AC Grid”,‘Springer international publishing AG 2018’.