MAXIMUM POWER POINT TRACKING SOLAR SYSTEM

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ABSTRACT

One of the major concerns in the power sector is the day-to-day increasing power demand but the unavailability of enough resources to meet the power demand using the conventional energy sources. Demand has increased for renewable sources of energy to be utilized along with conventional systems to meet the energy demand. Renewable sources like wind energy and solar energy are the prime energy sources which are being utilized in this regard. The continuous use of fossil fuels has caused the fossil fuel deposit to be reduced and has drastically affected the environment depleting the biosphere and cumulatively adding to global warming.

Solar energy is abundantly available that has made it possible to harvest it and utilize it properly. Solar energy can be a standalone generating unit or can be a grid connected generating unit depending on the availability of a grid nearby. Thus it can be used to power rural areas where the availability of grids is very low. Another advantage of using solar energy is the portable operation whenever wherever necessary.

In order to tackle the present energy crisis one has to develop an efficient manner in which power has to be extracted from the incoming solar radiation. The power conversion mechanisms have been greatly reduced in size in the past few years. The development in power electronics and material science has helped engineers to come up very small but powerful systems to withstand the high power demand. But the disadvantage of these systems is the increased power density. Trend has set in for the use of multi-input converter units that can effectively handle the voltage fluctuations. But due to high production cost and the low efficiency of these systems they can hardly compete in the competitive markets as a prime power generation source.

The constant increase in the development of the solar cells manufacturing technology would definitely make the use of these technologies possible on a wider basis than what the scenario are 3 presently. The use of the newest power control mechanisms called the Maximum Power Point Tracking (MPPT) algorithms has led to the increase in the efficiency of operation of the solar modules and thus is effective in the field of utilization of renewable sources of energy [3], [8].

I. OBJECTIVES OF SYSTEM

Maximum power point tracking (MPPT) is a technique used commonly with photovoltaic (PV) solar systems to maximize power extraction under all conditions.

To manufacture least cost physical and electronic tracking system with additional application such as ac through inverter.

Basic parts of projects:

- Solar panel
- Rechargeable battery
- Invertor circuit
- MPPT circuit

II. NEED OF SYSTEM

- Load shedding:

Crisis of electricity is the major problem in present era. This problem is even more critical for a densely populated developing country like India. Many of our people live here without basic facility of electricity. In many rural areas of India, electricity has not reached their home yet as well as many people face load shedding problem. While 84.9% of villages have at least an electricity line, just 46% of rural household have electricity.

Day by day crisis electricity is increasing, whereas no other solution is left for us without using the renewable source to generate electricity. Again not only we face electricity crisis but also day by day the cost of other natural resources and non-renewable resources are rising up that is going beyond the availability. Thereby such a system that can not only reduce the electricity crisis but also the crisis of other non-renewable sources is necessary.

- Limited non-renewable energy sources:

Most of the world's energy sources are derives from conventional sources fossil fuels such as coal, oil and natural gases. The primary source of the energy is a non-renewable source; however the available quantity will be 'run out' at some time in future.

One of the best solutions to overcome all these ill effects is to go for renewable energy resource such as solar energy, wind energy, Geo thermal energy etc.

III. LITERATURE SURVEY

Electricity is one of the most essential needs for human being in present. Conversion of solar energy in to electricity not only improves the electricity but also reduces pollution. The output power of solar panel depends on solar irradiance, temperature and the load impedance. A dc to dc convertor is used for improving the performance of solar panel.

History:

The timeline of solar cells begins in the 19th century when it is observed that the presence of sunlight is capable of generating usable electric energy. Solar cells have gone to be used in many applications. They have historically been used in situations where the electrical power from the grid was unavailable. [1]

Mummadi Veerachary has given a detailed report on the use of a SEPIC converter in the field of photovoltaic power control. In his report he utilized a two-input converter for accomplishing the maximum power extraction from the solar cell [3].

M. G. Villalva in his both reports has presented a comprehensive method to model a solar cell using Simulink or by writing a code. His results are quite similar to the nature of the solar cell output plots [1]-[2].

P. S. Revankar has even included the variation of sun's inclination to track down the maximum possible power from the incoming solar radiations. The control mechanism alters the position of the panel such that the incoming solar radiations are always perpendicular to the panels [9].

M. Berrera has compared seven different algorithms for maximum power point tracking using two different solar irradiation functions to depict the variation of the output power in both cases using the MPPT algorithms and optimized MPPT algorithms [8].

Ramos Hernanz has successfully depicted the modeling of a solar cell and the variation of the current-voltage curve and the power-voltage curve due the solar irradiation changes and the change in ambient temperature [10].

SOLAR ENERGY IN INDIA:

India, a rapidly growing economy with more than 1 billion peoples, is facing a huge energy demand. The country stands fifth in the world in the production and consumption of electricity. The electricity production has expanded over the year but we cannot deny the fact that the population of country is also expanding. The power produced in the country is mostly from coal (53%) and it is predicted that country's coal reserves won't lost beyond 2040-50. More than 72% population living in villages and half of the villages remain without electricity. It's high time that our country should concentrate more on energy efficiency, conversation and renewable energy. To meet this surging demand, solar energy is the best form of energy to fulfill the energy need of India and bridge the energy demand supply gap. [6]

Present System Available In Market:

Nowadays there are various systems are available to use solar energy to generate electricity for home appliances such as SOLAR WATER HEATER, SOLAR LAMPS etc. But there is a compromise in the maximum availability of energy the project eliminates this issue to reap maximum solar energy .This solar energy can be used to run electrical devices and can be stored and procured at the time of use.

Currently there are such systems available in market, produced nominally at a high cost. The project is a low cost, moderate efficiency device that is suitable for domestic and industrial uses.

IV. SYSTEM DEVELOPMENT

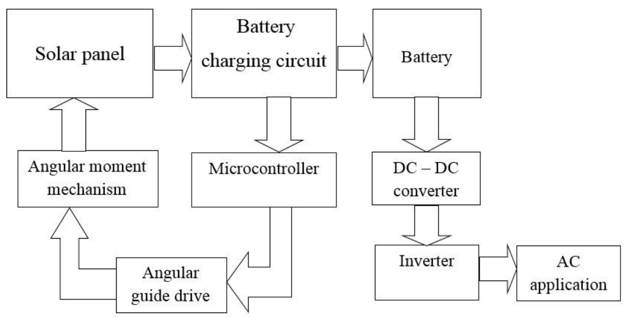


Fig: BLOCK DIAGRAM

HARDWARE SECTION

MODELLING OF SOLAR CELL

A solar cell is the building block of a solar panel. A photovoltaic module is formed by connecting many solar cells in series and parallel. Considering only a single solar cell; it can be modeled by utilizing a current source, a diode and two resistors. This model is known as a single diode model of solar cell. Two diode models are also available but only single diode model is considered here [1], [2], [4], [7], [9] and [10].

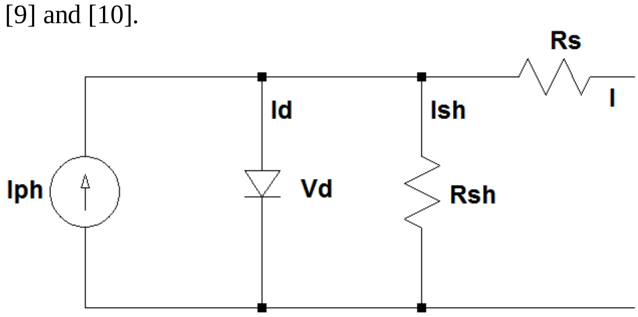


Figure 3.2.1: Single diode model of a solar cell

I-V and P-V curves for a solar cell are given in the following figure. It can be seen that the cell operates as a constant current source at low values of operating voltages and a constant voltage source at low values of operating current.

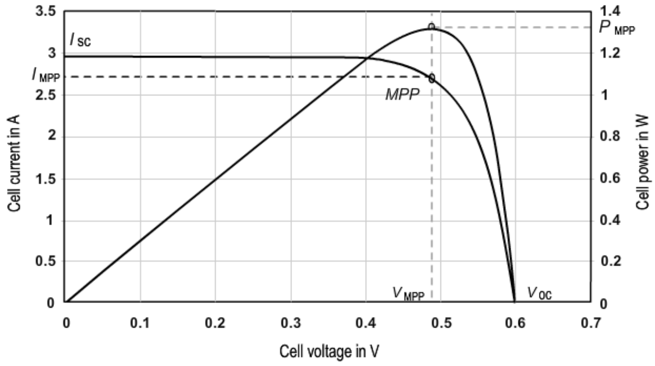


Figure 3.2.2: P-V I-V curve of a solar cell at given temperature and solar irradiation

EFFECT OF VARIATION OF SOLAR IRRADIATION

The P-V and I-V 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, but control mechanisms are available that can track this change and can alter the working of the solar cell to meet the required load demands. Higher is the solar irradiation, higher would be the solar input to the solar cell and hence power magnitude would increase for the same voltage value. With increase in the solar irradiation the open circuit voltage increases. This is due to the fact that, when more sunlight incidents on to the solar cell, the electrons are supplied with higher excitation energy, thereby increasing the electron mobility and thus more power is generated [7] and [10].

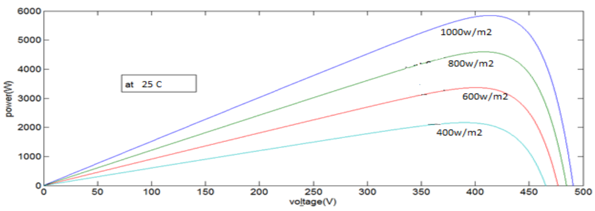


Figure 3.2.3: Variation of P-V curve with solar irradiation

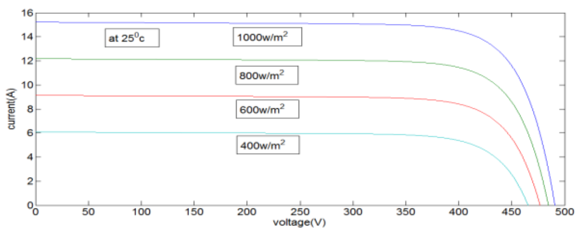


Figure 3.2.4: Variation of I-V curve with solar irradiation

EFFECT OF VARIATION OF TEMPERATURE

On the contrary the temperature increase around the solar cell has a negative impact on the power generation capability. Increase in temperature is accompanied by a decrease in the open circuit voltage value. Increase in temperature causes increase in the band gap of the material and thus more energy is required to cross this barrier. Thus the efficiency of the solar cell is reduced [7] and [10].

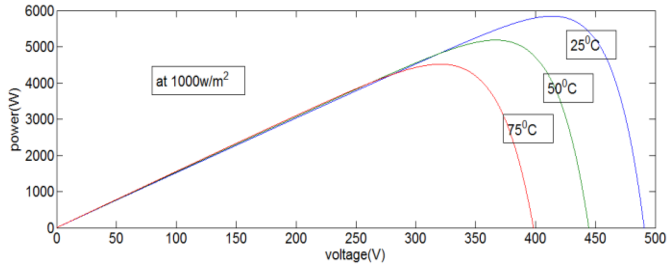


Figure 3.2.5: Variation of P-V curve with temperature

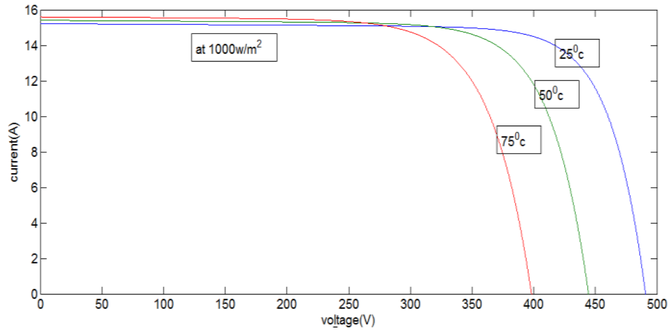


Figure 3.2.6: Variation of I-V with temperature

BOOST CONVERTER

Boost converter steps up the input voltage magnitude to a required output voltage magnitude without the use of a transformer. The main components of a boost converter are an inductor, a diode and a high frequency switch. These in a co-ordinated manner supply power to the load at a voltage greater than the input voltage magnitude. The control strategy lies in the manipulation of the duty cycle of the switch which causes the voltage change [11] and [12].

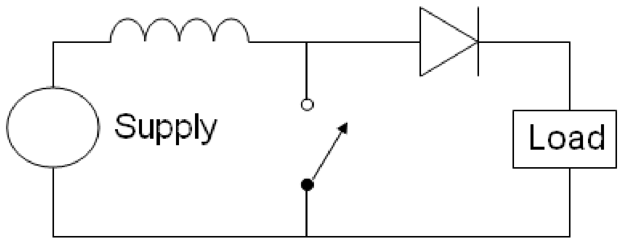


Figure 3.2.7: A boost converter

MODES OF OPERATION

There are two modes of operation of a boost converter. Those are based on the closing and opening of the switch. The first mode is when the switch is closed; this is known as the charging mode of operation. The second mode is when the switch is open; this is known as the discharging mode of operation [12].

Charging Mode

In this mode of operation; the switch is closed and the inductor is charged by the source through the switch. The charging current is exponential in nature but for simplicity is assumed to be linearly varying [11]. The diode restricts the flow of current from the source to the load and the demand of the load is met by the discharging of the capacitor.

Discharging Mode

In this mode of operation; the switch is open and the diode is forward biased [11]. The inductor now discharges and together with the source charges the capacitor and meets the load demands. The load current variation is very small and in many cases is assumed constant throughout the operation.

WAVEFORMS

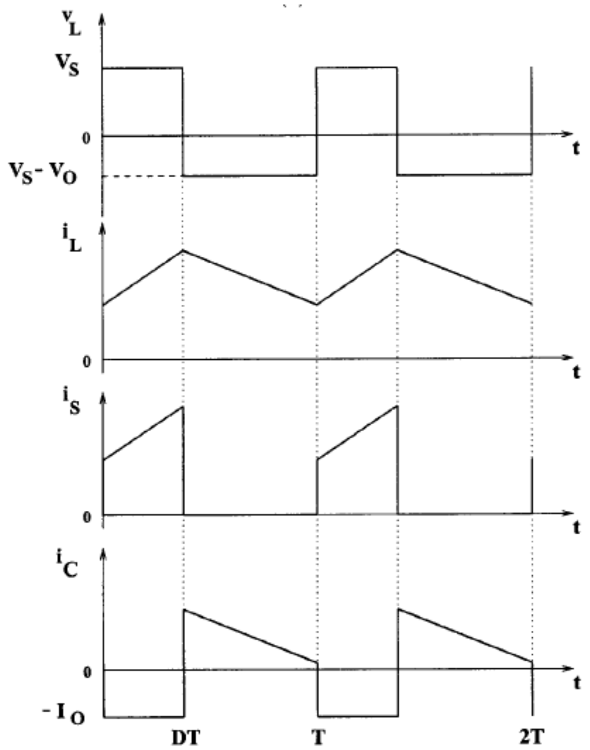


Figure 3.2.8: Waveforms of boost converter

MAXIMUM POWER POINT TRACKING (MPPT):

When a solar Photovoltaic module is used in a system, its operating point is decided by the load to which it is connected. Also, since solar radiation falling on a Photovoltaic module varies throughout the day, the operating points of module also change throughout the day. As an example, the operating point of a PV module and a resistive load for 12 noon, 10am and 8 am is schematically shown in fig. below denoted by a, b and c. Ideally, under all operating condition, we would like to transfer maximum power from a Photovoltaic module to the load. In fig the trajectory of a point at which the solar PV module will give maximum power is also shown. Thus, for maximum power transfer, instead of operating at point a, b and c the module should be operating at point a', b' and c'. In order to ensure the operation of PV modules for maximum power transfer, a special method is called as Maximum Power Point Tracking is employed in Photovoltaic systems. MPPT is electronic systems that operate the PV modules in a manner that allows the modules to produce all the capable power. Maximum Power Point Tracking is not a mechanical tracking system that physically moves the panel to make them point more directly toward the sun. Maximum Power Point Tracking is a fully depend on electronic system that varies the electrical working point of the modules so that the modules are able to give maximum available power. Additional power harvested from the module is then made available to increase the battery charge current. MPPT can be used in combination with a mechanical tracking system, but the two systems are totally different.

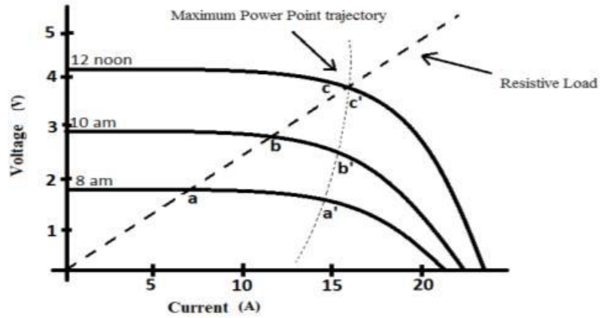


Fig. 3.2.9: CURRENT VS. VOLTAGE MPPT GRAPH

The maximum power tracking method makes use of an algorithm and an electronic circuitry. The method is based on the rule of impedance matching between load and PV module, which is compulsory for maximum power transfer. This impedance matching is done by using a DC to DC converter. Using chopper, by changing the Duty cycle (D) of the switch the impedance is matched. Block diagram of MPPT is shown below.

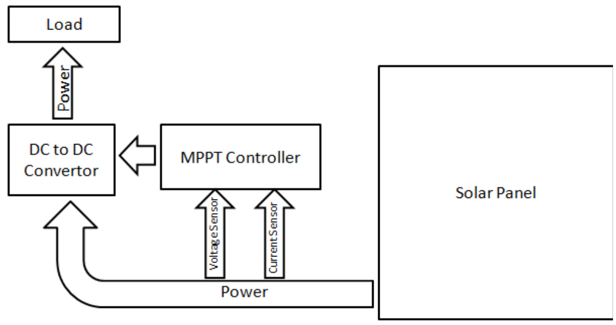


Fig. 3.2.10: BLOCK DIAGRAM OF MPPT

The power from the solar module is designed by measuring the voltage and current. The duty cycle is adjusts by this voltage and current which is an input to the algorithm, resultant in the adjustment of the load impedance accordingly to the power output of PV module. For instance, the related between the input voltage and the output voltage and impedance of load reflected at the input side of a buck type DC to DC converter can be given as

$Vo = Vi \times D$

$Rin = RL/D$

Here D is the duty cycle, Rin is the reflected at the input side, Vo is output voltage, Vi is input voltage.

PHYSICAL TRACKING

Dual Axis Tracking:

In dual-axis tracking system the sun radiations are captured to the maximum by tracking the movement of the sun in four dissimilar directions. The dual-axis sun tracker follows the angular height position of the sun in the sky in addition to follow the sun east-west movement. The dual-axis works in the same way as the single-axis but measures the vertical as well as the horizontal axis.

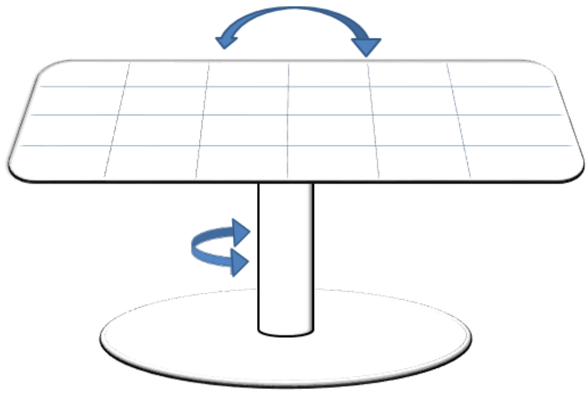


Fig. 3.2.11: DUAL AXIS TRACKER

The dual axis tracker in paper consists of two sets of phototransistor sensors, two DC motors and micro-controller. Single set of sensors and one motor is used to tilt the tracker in sun east to west direction and the other set of sensors and the second motor which is fixed at the bottom of the tracker is used to tilt the sun tracker in the sun north to south direction. When the sun moves towards the north, the tracker has to track the sun path in anti-clockwise direction along the horizontal axis (east to west). If the sun moves towards the south direction then the tracker has to track the sun in clockwise direction. The sensor senses the light from the sun and sends the signals generated by them to the micro-controller. The controller detects the stronger signal and instructions the motor to rotate in clockwise or anti-clockwise direction. To overcome the disadvantages in the single-axis sun tracking system, a dual-axis sun tracking system was introduced.

The power output for the dual-axis and fixed axis panel are tabulated for a single day. The average power values of the dual-axis panel produces more power than that of the fixed mount.

Fixed Mount:

In fixed axis mount the solar panel is mounted fix. In this panel is not moving along any axis. Panel is at its constant position so it is not able to capture irradiance as per the position of sun. Power efficiency of single axis solar tracking is more than is more than fixed mount.

Single-Axis Tracking System:

The single-axis solar tracking system analyzed in the paper consist of a PV panel rotating around a tilted shaft under the action of a DC Motor controlled according to the current sun position estimated by means of two light intensity sensors. The light sensor's consists of two LDR's which is placed on either side of the panel separated by an opaque plate. Depending on the intensity of the sun radiation one of the two LDR's will be shadowed and the other will be illuminated.

The power output for the single-axis and fixed mount panel are tabulated for a single day. The average power values prove that the fixed mount axis produce less power than that of single-axis panel.

SOFTWARE SECTION

As we have mentioned earlier the entire system was implemented using an Arduino Uno as microcontroller and it works as the heart of our project. The algorithm was both programmed and implemented in Arduino. Arduino is nowadays is an open source programming tool that is becoming more popular for its ease of application where the UI (user interface) enables the user to apply different knowledge of coding in a single platform. For this reason, we chose to implement our algorithm by Arduino and it is also easy to debug the error.

In our project we implemented incremental conductance methods to track the MPP. This incremental conductance method calculates output voltage and current and it is independent of temperature and other climatic condition.

We have already described the method of incremental method how it works in the MPPT method part. Now we will just take a brief look at the flow chart again and the coding of the incremental conductance method is added in the later part for better understanding of the implementation.

Battery Charging Circuit

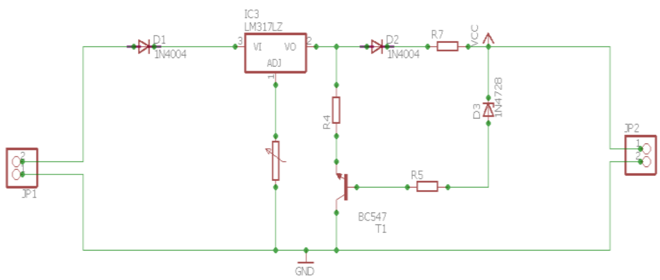


Fig. 3.3.10: SCHEMATIC OF BATTERY CHARGING CIRCUIT

Here is the solar charger circuit that is used to charge lead acid or Ni_Cd batteries using the solar energy power. The circuit harvest solar energy to charge a 6V 4.5Ah rechargeable battery for various applications. The charger has voltage and current regulation and over voltage cutoff facilities. The circuit uses 9V solar panel and voltage regulator IC LM317. The solar panel consists of solar cells each rated at 1.2V. 9V dc is available from the panel to charge the battery. Charging current passes through D1 to the voltage regulator IC LM317. We can also adjust the output voltage and current by using adjust pin as per our requirement.

VR is placed between the adjust pin and ground to provide an output voltage of 7 volt to the battery. Resistor R3 resists the charging current and diode D2 prevents discharge of current from the battery. Transistor T1 and Zener diode ZD act as cutoff switch when the battery is full. Normally T1 is off and battery gets charging current. When the terminal voltage of battery rises above 6.8V Zener conducts and provides base current to T1. It then turns on grounding the output of LM317 to stop charging.

INCREMENTAL CONDUCTANCE ALGORITHM:

The IC algorithm is based on the observation that the following equation holds at the MPP:

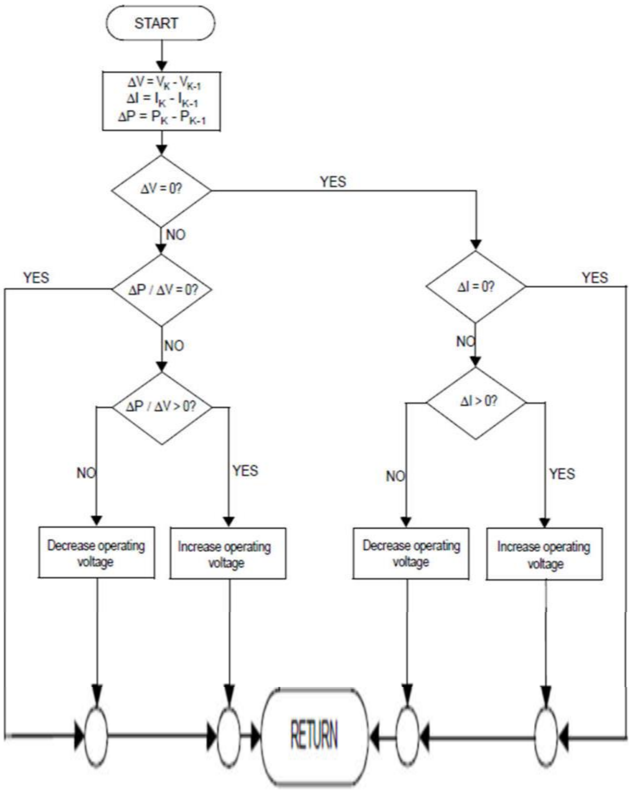
$$(dIPV/dVPV) + (IPV/VPV) = 0$$

Where IPV and VPV are the Photovoltaic array current and voltage, respectively.

When the optimal operating point in the P-V plane is to the right of the Maximum Power Point, we have (dIPV/dVPV)

+ (IPV/VPV) < 0, whereas when the optimal operating point is to the left of the Maximum Power Point, we have (dIPV/dVPV) + (IPV/VPV) > 0.
The Maximum Power Point can thus be tracked by compare the instantaneous conductance IPV/VPV to the IC (dIPV / dVPV). Therefore the sign of the quantity (dIPV/dVPV) + (IPV/VPV) indicate the correct direction of perturbation top to the MPP. Perturbation stops if there is a change in dIPV once MPP has been reached and the operation of Photovoltaic array it is maintained at this point. This is noted. For this condition the algorithm decrements or increments Vref to track the new Maximum Power Point (MPP). The increment size determines how quick the MPP is tracked.
Through the IC algorithm it is therefore in theory it is possible to know when the MPP has been reached, and thus when the perturbation can be stopped. The IC method offers good performance changing according to atmospheric conditions.

Flow chart:



FLOW CHART 1: INCREMENTAL CONDUCTANCE

I-V and P-V characteristics curve:

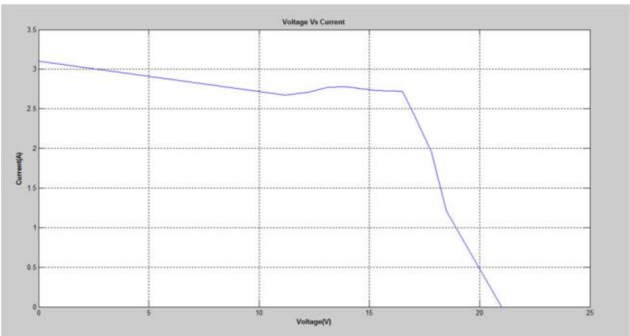


Fig. 3.4.1: I-V characteristics curves

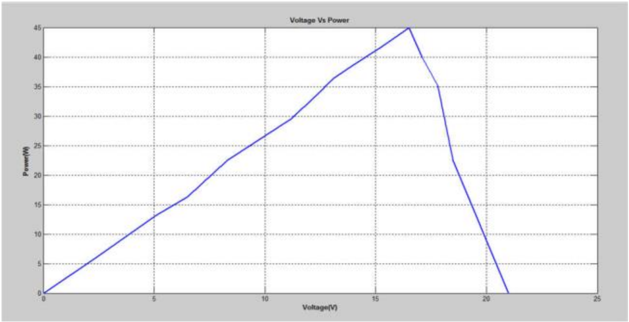


Fig. 3.4.2: P-V characteristic curves

V. APPLICATION, ADVANTAGES, DISADVANTAGES

Application:
1. It can be used as source to the Uninterrupted Power Supply (UPS) for low wattage home appliances such as bulb.
2. It can be used to charge dc appliances such as mobile phone and can be stored in dc batteries.
3. It is useful for low wattage application in electronics industrial areas.

Advantages:
1. The system uses MPPT algorithm hence the efficiency of the system is higher.
2. 16x2 LCD display have been interfaced hence battery voltage can be displayed on it. The user will be informed regarding battery status without use of LED.
3. The system is designed for large current ratings in Ampere.
4. Microcontrollers are implemented which are intelligent chips. Hence the system can be modified as per the need of application.
5. Use of microcontroller ensures reliability of the system.
6. The system is user friendly hence can be easily operated by users.
7. System is compact and handy.

Disadvantages:
1. Programming of microcontrollers is required which increases the software cost and creates complexity at the time of making prototype.
2. Computers are needed to write and burn the software in microcontrollers.

VI. CONCLUSION

In the final analysis, this thesis presents an efficient photo voltaic system with the capability of tracking the maximum power point using incremental conductance method. Each components of this system such as the solar panel, charge controller, DC-DC converter has all been discussed about. The coding in terms of flowchart and MATLAB simulations of the I-V characteristics for load and irradiations variation has been presented. Since the purpose of this thesis was to design a more efficient MPPT solar charge controller using an Arduino, so we have explained the maximum power point tracking and the procedure we have followed to achieve that point. The use of an Arduino and its advantages has been provided in this paper along with the converter used for our design of the solar charge controller.

Improvement to this project can be made by tracking the maximum power point in changing environmental conditions. Environmental change can be change in solar irradiation or change in ambient temperature or even both. This can be done by using Simulink models to carry out MPPT instead of writing it code in Embedded MATLAB functions. In the Simulink models the solar irradiation and the temperature can be given as variable inputs instead of constant values as done here.

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