Hardware Testing of New MPPT Method under Various Environmental Conditions

Arjyadhara Pradhan, Babita Panda, Srikanta Mohapatra, Lipika Nanda, Chitralekha jena

Abstract*: *There are different MPPT techniques to track the maximum power point. When a PV system is directly connected to the load the operating point seldom lies in the maximum power point, whereas it lies at some other point. Thus the effective utilization of PV cannot be done. But using MPPT techniques the system is always made to operate at peak point irrespective of any changes in atmospheric condition. The Proposed method gives better result in terms of output power and hence efficiency of the converter. This method is a trade-off between steady state accuracy and dynamic tracking by using variable step size instead of fixed step size as like P and O method. The system gives very poor performance when connected directly without mppt. An experimental analysis was conducted to validate the effectiveness of the proposed MPPT method. The proposed method was compared with the conventional Perturb and Observance method and was found that for every environmental conditions like, change in irradiance, angle of tilt, shading, soiling, colour filter, mounting the proposed method gives better power output and efficiency than P and O method. Hardware testing is done to analyze the method.

Keywords* : *Photovoltaic,sensor,microcontroller, battery

I. INTRODUCTION

The hardware implementation of the proposed MPPT method is done to validate the proposed MPPT method. The hardware is tested by using Proteus software. In a development environment, the execution of the code is tested on a debugger. Several researchers have implemented various MPPT methods in hardware using DSP or microcontrollers[3]. They have considered different types of converters like buck, boost, or buck-boost or cuk etc. Even some of the researchers have taken one solar panel or two solar panel for online monitoring of the PV voltage and current. In this chapter the proposed MPPT method is tested for different external factors and compared with that of conventional Perturb and Observance method. The Photovoltaic module voltage and current are sensed by voltage and current sensor and are given to the microcontroller where the MPPT programme is running. Similarly using same current and voltage sensor PV module voltage and current are given to the boost converter with resistive load. The output of the Boost converter is measured in terms of power by using another set of voltage and current sensor which is displayed in the LCD unit.

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Thus input power and output power is calculated by using both the MPPT Process i.e. perturb and observance method and proposed method.

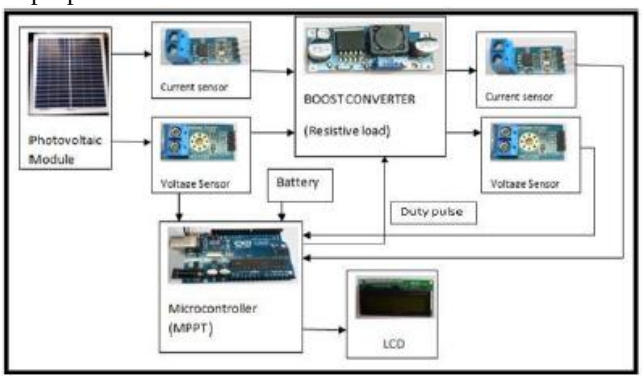

Fig 1 ***Block diagram representation of PV module connected with Boost converter***

The hardware setup as shown in figure 1 consists of two number of voltage sensor, two current sensor, boost converter, microcontroller , LCD, and a supply system to supply power to the controller. Here a 12 volt battery is used

II. DETAILS OF COMPONENTS/DEVICES

A. Photovoltaic module

Photovoltaic module is the basic source of supply for the experimental setup. The fundamental component of PV module is solar cell. 32 to 36 number of crystalline silicon solar cells are connected in series to form a PV module. Further several modules are connected in series or parallel to form panel [1]. Thus multiple panels are connected to form array. When a module is directly connected to the load the operating point is not always at the MPP point rather at some other point[2]. Hence for effective utilization of the PV system the system must operate at MPP point

B. Resistor

Resistors are electrical components having two terminals and are mostly designed to oppose the flow of current . The opposition is created by the voltage drop produced between its terminals which is proportional to the current. Thus as per Ohm's law Voltage is directly proportional to Current

C. Capacitor

Another passive element used in the electrical and electronic circuit is the capacitor. It is represented mostly as a pair of conductors separated by dielectric. With the potential difference between the conductors an electric field is created in the dielectric. Hence energy is stored in the electric field and a mechanical force is developed within the plates.

D. Inductor

It is also called choke or reactor which is a passive linear circuit element. When current flows through the coil a magnetic flux is produced which is directly proportional to the electrical current. As the current flowing through the inductor changes a voltage is induced as per Faraday's law of electromagnetic induction.

E. Voltage sensor

Voltage sensors are used to measure the voltage supply and further the measurements are converted to signals which go into specialized electronic devices for recording. Arduino voltage sensor is based on resistance points pressure principle [87].

Here the input voltage can be reduced five times the original value of voltage. Generally the arduino analog input voltage is 5 volt hence the module input voltage must be within 25 volt.

F. Current sensor

A Current sensor is a device used for detecting electric current in a wire and hence generates a signal proportional to current. The signal can be analog or digital. The generated signal can be used in various ways like displaying the current measured in case of ammeter or can be store in data aqusition system for further analysis [88].The current sensor used for Arduino uno is ACS712.

G. Boost converter

Boost converter is used to step up voltage[4]. The circuit consists of two input capacitor of rating 100 microfarad , 25 volt. N channel mosfet IRF 540N and 3 inductors of 10 micro henry in series. Diode IN4007 is used. Output capacitor of 470 microfarad is used. Further the converted is connected with a resistive load of 1kohm[14].

H. Controller

The Microcontroller used here is Arduino Uno which is based on ATmega328. Two methods are used to show the output.

Perturb and Observance method is most traditional method and is the most simplest among all MPPT algorithms. It is based on the concept that at MPP point change in power is zero [5]. Towards the right of the MPP point change in power is negative and hence the voltage is decremented in order to reach the MPP point[6] . But to the left of this point delta p is positive and hence the voltage is incremented to reach MPP. MPP or knee point is the point where the system operates at highest efficiency[7]. Hence P and O method works by pertubating the PV voltage. But during rapidly changing weather condition the P and O method will oscillate around the MPP point and cause loss in power [8] . Hence the P and O algorithm is controlled by two ways one is by directly controlling the duty ratio and other by controlling the reference voltage using a PI controller[9]

In the proposed method a new algorithm for MPPT has been described with the help of a flowchart. The new technique used basically is a modified version of P and O technique giving better results in comparison to other methods. Maximum power point tracking is based on the concept of operating the PV system at maximum power point irrespective of any weather and load conditions. Thus in the proposed technique the Maximum power are taken as fishes

(function of PV voltage and current) and the main objective is to find out the prey i.e. the knee point. The fixed step size significantly affects the overall system reducing the system performance and efficiency. Instead of using fixed step size as in traditional P and O method here we use six sets of values for duty cycle (fitness value). Initially the fishes are set with a fixed fitness value. Then the present value of power and previous power are evaluated and checked for the best power (prey).The iterations proceeds for six cycles and hence the prey (maximum power) with best fitness value (duty cycle) is fixed. Hence this duty cycle is given to the gate signal of converter switch to operate at maximum power point.

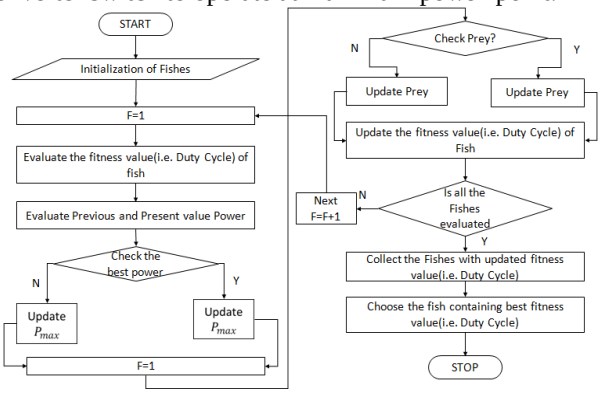

Fig 2 *Flow chart of proposed technique*

Figure 2 describes the algorithm of the proposed technique. The algorithm begins with initialization of maximum power. Then the fitness value of fishes i.e. the duty cycle is evaluated. For 1st iteration current power is calculated which is the product of present value of PV voltage and PV current. Similarly past PV power is also calculated. Then best power is checked i.e. if the present power is more than the past power , maximum power is set as current power else past power. Next the algorithm checks for the prey i.e. the maximum power of the PV module selected and updates the Prey. Then the fitness value (duty cycle) is updated along with one fixed value. Further the process continues till all the fishes are evaluated and hence the iterations proceeds six times as six set of duty cycles are taken into consideration. Finally the fish i.e. maximum power containing the best duty cycle is selected

I. Mosfet

Metal oxide semiconductor field effect transistor are devices basically used for integrated circuits as a large number of mosfet can be packed on a single integrated chip. Its wide range of application include random access memory, flash memory, Processors [10]. It is a voltage controlled current source.

J. Diode

Diode conducts electric current in one direction and blocks current in the reverse direction. It is mostly a two terminal electronic component[11]. In one side it has low resistance and high resistance in the other side. Diodes are used as rectifiers for converting ac to dc current and extracting radio signals modulations in radio receivers. In this experiment Diode IN4007 is used.

DC blocking voltage is 1000 volt and the RMS reverse voltage is 700volt. Peak forward surge current is 30 ampere and forward voltage is 1 volt.

K. LED

Light emitting diodes are semiconductor devices which are made of silicon. It is a two lead semiconductor which emits light when activated. When current passes through it photons are emitted as by product. The working of the LED is based on Electroluminescence effect. In ordinary light bulbs the metal filament are heated till white hot to produce light but LEDs produce photon without being heated.

L. LCD

LCD stands for Liquid crystal display which is a combination of both liquid and crystal properties. Within a certain temperature range the molecules are mobile like the case of liquid but are grouped together to form crystal.

M. Battery

The power supply unit for the microcontroller is replaced by battery source. Three number of 4 volt, 1 ampere battery are connected in series to supply 12 volt , 1AH to the microcontroller

III. EXPERIMENTAL SETUP

The Experiment is conducted on a real time study basis considering a 20 Watt PV module of make FRONTECH. The module is connected to the current and voltage sensor which takes PV voltage and current as input to the Boost converter and MPPT controller. Both Perturb and Observance method and Proposed method are used in the microcontroller ARDUINO UNO. With the help of the selector switch either of the MPPT method can be tested for the output. A 12 volt battery is used for supplying power to the microcontroller. The experiment is conducted on the terrace of School of electrical engineering, KIIT deemed to be University from morning 10 am to 4pm. Various environmental factors are taken into consideration like Change in Irradiance, Angle of tilt, Shading, Dust, Colour spectrum, mounting.

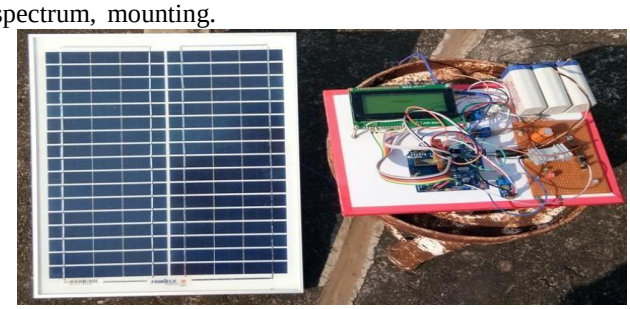

Fig 3 ***Experimental set up for the real time test conducted.***

Figure 3 shows the experimental setup considering the PV module along with the Arduino UNO controller and Boost converter.

A. Irradiance

As already mentioned and studied in chapter two the various factors affecting PV module performance, solar irradiance is considered as one of the major factor which must be taken into account considering the power output and efficiency of the system using any MPPT method. Irradiance increases from morning 10:00 am , reaches maximum value

i.e. 930 watt/m^2 at around 1:00 pm and then slowly decreases to 440 watt/m^2 at 4:00 pm. Both the MPPT method i.e. traditional perturb and observance method and proposed method are tested for different values of irradiance throughout the day using the above experimental setup.

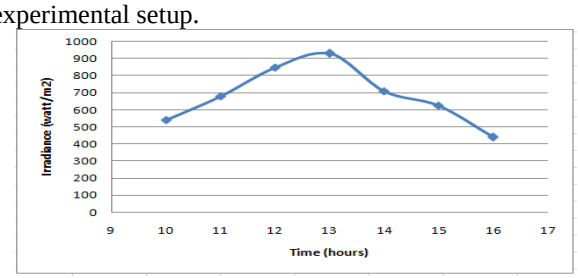

Fig 4 ***Change in irradiance versus time from morning 10 am to 4 pm.***

With the position of the sun solar irradiance as well as module temperature also changes throughout the day. With the increase in irradiance module temperature also increases as all the radiations are not converter to useful energy rather a part of it is converted and rest are responsible for raising the module temperature. The system is greatly affected with rise in temperature.

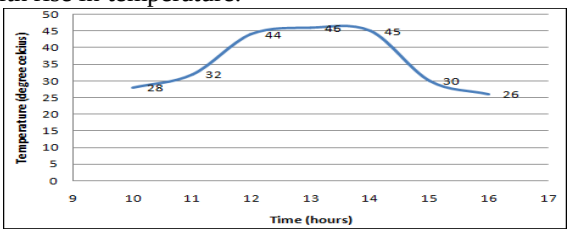

Fig 5 ***Variation of temperature from morning 10 am to 4pm.***

Figure 5 shows the values of temperature considered for the given time period. The temperature is maximum at around 1:00pm i.e. 46^{0}C. At this condition sun's position is overhead and the module receives the maximum energy hence the temperature also rises. During the starting of the experiment at around 10:00am the module temperature is 28^{0}C and at the end of the experiment at 4:00pm it is 26^{0}C .

B. Angle of Tilt

Photovoltaic module tilt angle and panel orientation are another factor which affects the output of the PV system. Both these factors depends on the latitude , longitude of a particular geographical location along with the time of the year i.e. the sun's position. To validate the effectiveness of the proposed MPPT method the experiment is conducted at three different tilt angle and the readings of the proposed method is compared with the conventional P and O method. The converter efficiency is calculated with the help of the input and output data.

C. Shading

Shading is another important factor which is considered which evaluating the effectiveness of PV system.

Hard shading blocks the sunlight from reaching the PV module where as soft shading decreases the intensity of radiation received by the module. Many natural factors like trees, building, tower, hoarding, tall structures creates full or partial shading depending on the PV panel mounting. Partial shading causes circulating current to flow in the circuit and hence causes hotspot formation i.e. high temperature at a particular place.

D. Colour filter

Photovoltaic module tested for different colour filter shows the dependency on the wavelength of light. The response of PV module is different for different colour. Studies show that the energy available on the PV surface lies between the wavelengths of orange and red colors whereas the energy of the system lies between yellow and green colors of light. In this experimental setup three different colour filter are considered i.e. red, green, violet. All these colour filters are tested by using both the MPPT methods and the output of the boost converter is noted down .Hence power and efficiency are further calculated .

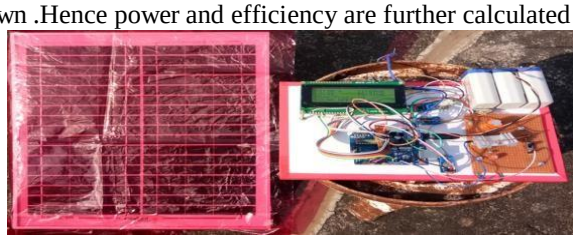

Fig 6 *Red colour filter*

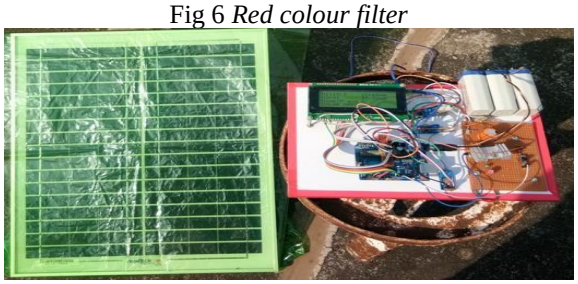

Fig 7 *Green colour filter*

Fig 8 ***Violet colour filter***

E. Dust

Dust is always a hindrance for the solar radiation entering inside the PV module. Studies show that dusty panels gives less output where as clean panel gives more output. The proposed MPPT method is compared with the conventional P and O method by taking dust factor into account. In this experimental setup two modules of same ratings are considered . In one module dust is sprayed uniformly by sieving process. The dust used in this work is a mixture of sand, clay, limestone, coal. The other module is considered in clean condition. The experiment was conducted for a day basis and the average values of input and output of the converter are noted down.

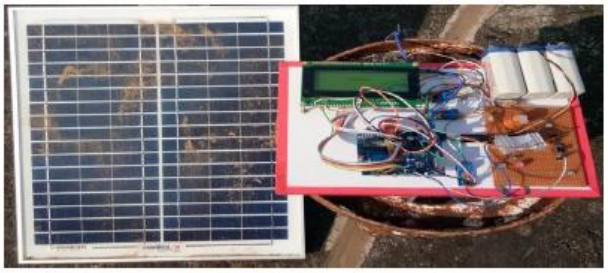

Fig 9 ***Experimental setup under dusty condition***

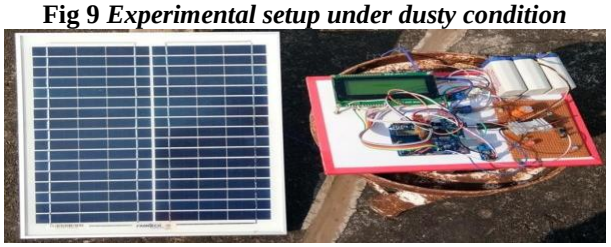

Fig 10 ***Experimental setup under clean condition***

F. Mounting

Mostly PV panels are ground mounted in case of large farms but for local residential purpose PV panels are rooftop mounted. Elevation and temperature effect is seen in case of change in mounting of the panel. In this experimental setup one set of PV module along with the controller is fixed on the rooftop and another mounted on ground. It is found that rooftop mounted modules are more heated up due to concrete structure. The modules are affected by direct solar radiation falling on the top surface as well as radiation of heat from the cemented surface. Thus module front and back surface are highly heated up as a result the energy conversion efficiency decreases. But in case of ground mounting the modules only receive the solar radiation on the top surface where as the back radiation from the ground has negligible effect.

IV.RESULT AND DISCUSSION

From the real time experiment conducted with various external factors power and efficiency are calculated for each MPPT method considering the various external factors.

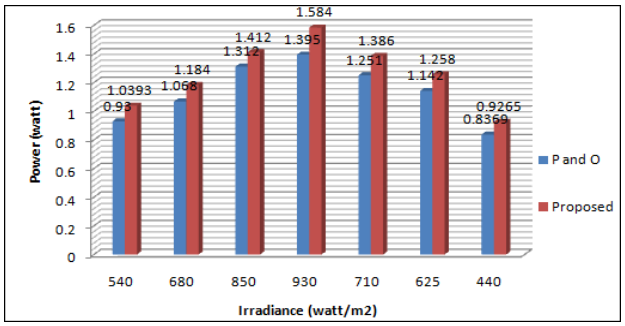

Fig 11 ***Output power considering both the methods at different irradiance***

From figure11 it is found that the maximum power is highest for Proposed method i.e. 1.584 watt at irradiance level 930 watt/m^2 where as maximum power for P and O method at same irradiance is less. From figure 12 efficiency is also more at high irradiance for proposed method i.e. 97.9% then that of P and O method.

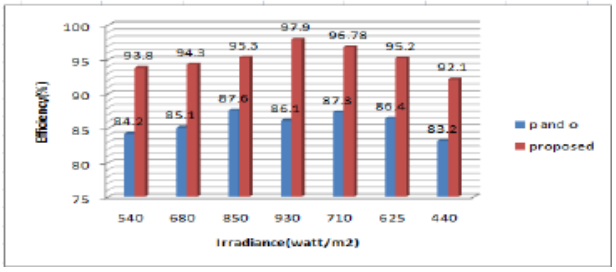

Fig 12 ***Efficiency considering both the methods at different irradiance***

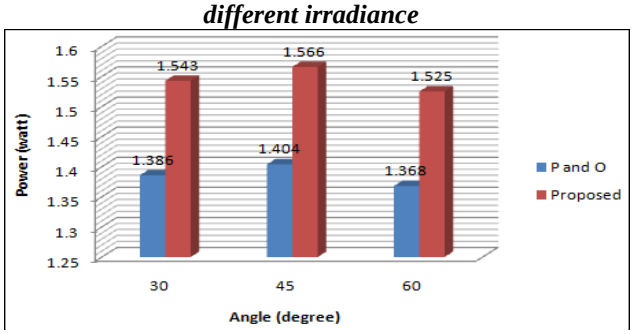

Fig 13 Output power considering both the methods at different tilt angle

Considering various tilt angle from Fig 13 and figure 14 it is clear that the efficiency maximum power output is more at 45 degree title angle as per the geographic location and time of the year and more for the proposed method then that of conventional P and O method.

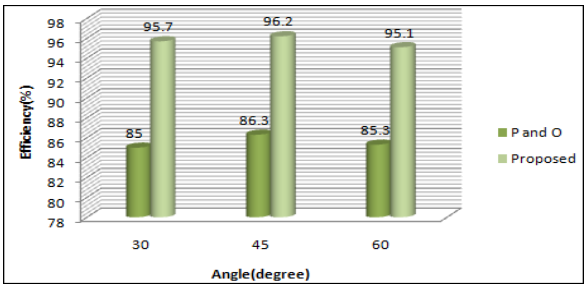

Fig 14 ***Efficiency considering both the methods at different tilt angle***

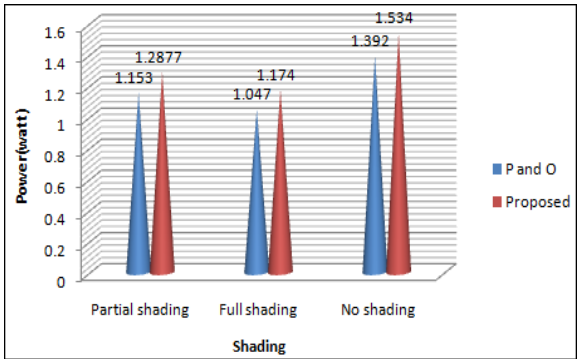

Fig 15 ***Output power considering both at different shading condition***

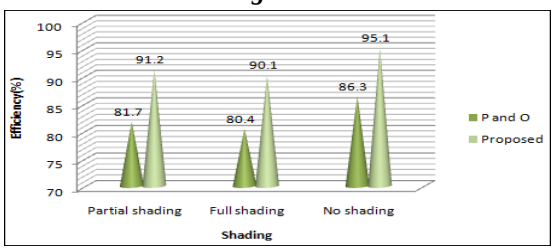

Fig 16 ***Efficiency considering both the methods at different shading condition***

Considering different shading condition as shown in Figure 15 and 16 maximum power and efficiency is more for proposed method then that of P and O method for no shading condition and it decreases with increase in shading.

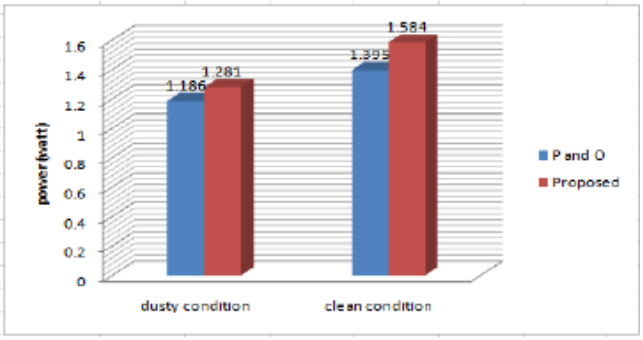

Fig 17 ***Output power considering both the methods at dusty condition***

Taking dust as another environmental factor the proposed method is tested for duty and clean condition. From figure 17, 18 it is clear that irrespective of dusty condition or clean condition the proposed method gives more maximum power and efficiency then that of the conventional Perturb and Observance method. For clean condition the efficiency of proposed method is found to be 97.9% where as for dusty condition it is 89.7 %.

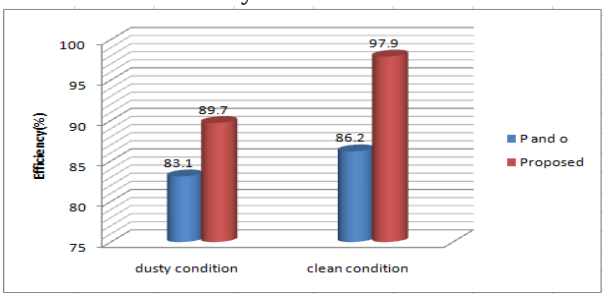

Fig 18 ***Efficiency considering both the methods at dusty condition***

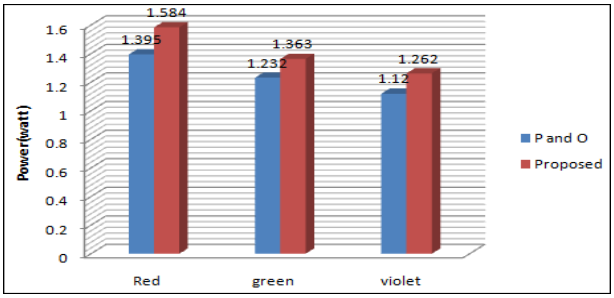

Fig 19 ***Output power considering both the methods for various colour filter***

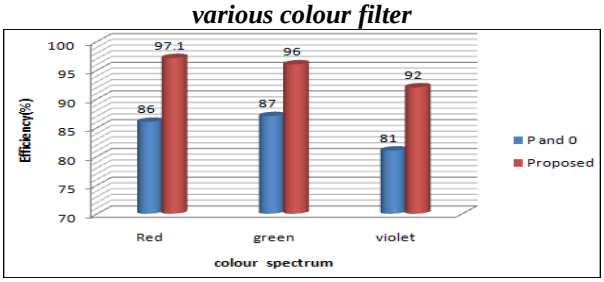

Fig 20.*Efficiency considering both the methods for various colour filter*

Figure 15 and 16 maximum power and efficiency is more for proposed method then that of P and O method for no shading condition and it decreases with increase in shading.

Using various colour films the proposed method is tested and from figure 19, 20 it is found that both the maximum power and efficiency for red colour is more using proposed method then of conventional P and O method.

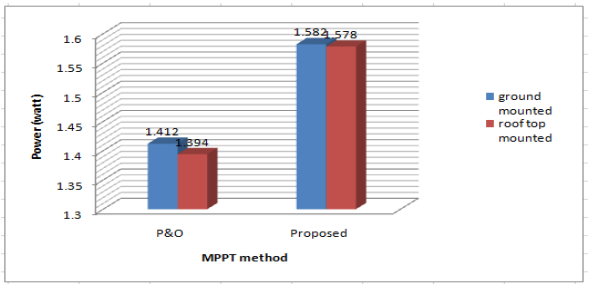

Fig. 21 ***Output power considering both the methods for mounting condition***

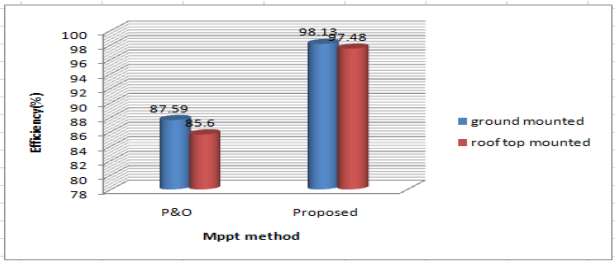

Fig 22.*Efficiency considering both the methods for mounting condition*.

The output power as well as efficiency of the converter using proposed method is more than the P and O method for both ground mounting and roof top mounting as shown in Figure 21 and figure 22. Even it is also clear that ground mounted modules perform better then the roof top mounted modules. Hence large PV farms have ground mounted panels for supplying electricity.

V. CONCLUSION

The proposed MPPT technique was implemented in hardware. Initially the design of the circuit was tested by using Proteus 8 professional software. Microcontroller ARDUINO UNO is used for writing the MPPT programme

i.e. both Perturb and Observance method and Proposed method. A boost converter along with resistive load is used for the testing purpose. The hardware tested on the real time basis for a day duration shows the variation in solar irradiance and temperature from morning 10 am to 4 pm. Considering six environmental factors like irradiance, tilt angle, dust, shading, colour spectrum, mounting it is found that the proposed technique gives more efficiency and power output in comparison to the conventional P and O method. Hence the proposed MPPT method can be used for a real application like PV water pumping load

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