Performance Analysis of Photo Voltaic System with MPPT and PWM Charge Controller

Virender* Dr. Anil Kumar Berwal**
*PHD Scholar , Department of Energy Studies , DCRUST Murthal
**Associate Professor ,Department of Energy Studies , DCRUST Murthal

Abstract

The energy demand is increasing drastically day by day in developing countries so we need to trigger up energy sources and maintain the balance between energy consumption and production. That's why it is essential to trap waste of energy. This paper will describe the comparative study of MPPT and PWM Technologies and we have described both types and their comparative study and their practical applications. Solar energy is the best source of renewable energy. Our paper will allow the best utilization of solar energy. We will calculate the efficiency of MPPT and PWM and find the methods to optimize PWM charge controller technology. This paper is organized in such a way that future researchers and engineers can select a charge controller for the stand-alone system. The effect of each configuration is analyzed using software and hardware setup.

Keyword:- Maximum power point tracking MPPT, Pulse Width Modulation PWM

1 Introduction

Solar energy is a green source of energy. The World is facing a major threat of fast exhaustion of the fossil fuel reserves. Coal, petroleum, and gas produce a huge amount of carbon emission which produces drastic change environment so this leads to research on green energy. These days solar energy is new to people and don't know how to optimize energy. There are two types of conversion of solar energy one is direct and another is indirect conversion. Direct conversion of solar radiation is that we convert it into DC power. Indirect conversion is when we convert it in the form of heat. It is a safe, silent, and non-polluting source of energy generation. Its failure rates are very low and its life span is very good near about 30 years. In stand-alone PV system charge controller plays an important role. Mostly we use two types of charge controller PWM and MPPT[1]. PWM charge controller has 10-25 % losses depending upon design[1]. Many errors come to existence when we execute a practical concept so we are going to analyze some basic type of MPPT charge controller. Eg;- TIBE (12v 15amp).

60 watt Solar Photovoltaic Panel

Maximum Power	60W
Open Circuit Voltages	22.2V
Short Circuit Current	3.56A
Maximum Power Voltage	18.2V
Maximum Power Current	3.3A

There are five types of MPPT charge controller

1. Petrub and Observe based

2. Incremental Conductance based

3. Three-point weighting based

4. Current sweep

5. Constant voltage [2].

Haidar Islam and al. el reviewed Performance Evaluation of Maximum Power Point Tracking Approaches and Photovoltaic Systems. They have described the different type of algorithms and their comparative study[8]. **Zubair Mehmood et.el has done a** Performance Analysis of MPPT Charge Controller with Single and Series/Parallel Connected PV Panels. In this, they do changes in output and find results[9]**. Manik Dautta at.el has done** Testing and Performance Analysis of Charge Controllers for Solar Home System and tell different types of charge controller used in solar home systems[10]**.** all above researched on both MPPT and PWM separately then we decide to do performance analysis of both MPPT and PWM on the same setup and find the efficiency.

2 System Design and Testing

2.1 Performance of Photovoltaic Panel

In this project, we have used the polycrystalline photovoltaic panel as the electrical source for our converter. The panel with an area of 29.5*21.6 inches has a power rating of 60W. First of all, to observe the characteristics of the experimented PV panel, the information of input and output power of the panel were collected from Terminal software which connected with an interface. The panel was measured its output for different levels of irradiation. We have used STM8S000K3 Microcontroller. It can bear very harsh conditions and can save the codes for 20 years at temp 55 c which is near solar panel life of 25 years.[3]. This microcontroller is cost-wise economical. This mppt system is for a 12-volt battery and 60-watt solar panel test setup. This test setup is used to calculate the efficiency of a small power charge controller. This is capable of operating between 10-30 volt. The system uses a two-phase interleaved buck converter to step down the panel voltage to the battery voltage. The buck converter is operated using microcontroller STM8S000K3 which calculates power point using perturb and observe method.

2.2 Pulse Width Modulation (PWM) Charge Controller:-

Pulse width modulation is the best way to achieve constant voltage battery charging. Pulse width modulation technology tappers the current of solar panels according to battery charging requirements. When a battery voltage reaches the regulation setpoint, the PWM algorithm slowly reduces the charging current to avoid heating and gassing of the battery, yet the charging continues to return the maximum amount of energy to the battery in the shortest time. The result is a higher charging efficiency, rapid recharging, and a healthy battery at full capacity

2.3 Maximum power point tracker (MPPT) charge controller:

It adjusts the PWM to allow the PV array voltage to vary from the battery voltage. By varying the array input voltage (while maintaining the battery charge voltage), the maximum output from the PV array can be achieved. The MPPT charge controller is relatively new and has many advantages over other charge regulators. In addition to getting more charge current from the PV array, some MPPT controllers allow the array to operate at a much higher voltage than the battery. This feature can be useful to reduce wire size and voltage drop from the PV array to the controller. Although the MPPT controller can increase and decrease the output from lower voltage to higher and vice versa. There are two types of process is used in MPPT charge controllers.

2.3.1 Buck converter
2.3.2 Boost converter

Buck Converter

Buck converters are used to lower the voltage keeping the power the same [4]. In buck converter most important is inductor and capacitor combination which leads to a decrease in voltage[6]. During the buck, process current led to an increase which led to power mostly the same. In this output voltage of the buck converter less than the input voltage. Energy is stored in the inductor as magnetic energy.

This design implements a two-phase interleaved buck converter to decrease power dissipation and increase conversion efficiency. interleaving also reduces ripple current at output and input of buck converter so power losses reduced and efficiency get boosted.

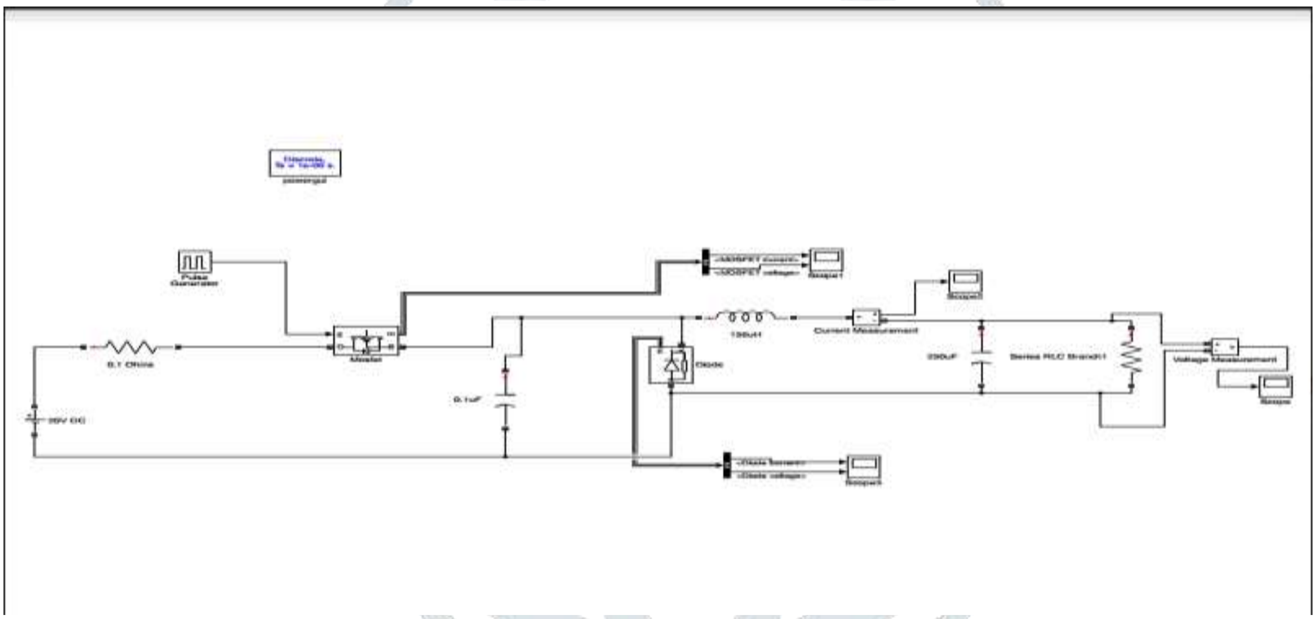


Figure 1 - Solar Panel and Buck Converter Schematic

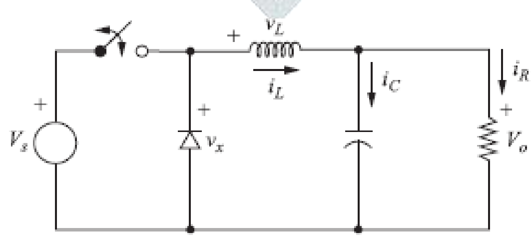


Figure 2 - Basic Schematic Buck Converter

Boost Converter

The boost converter is used to upper the voltage keeping the power the same[5]. In the boost process, we use inductor and capacitor combination. Power is always the same so current leads to decrease.

This process is used to self-regulating the power supply and battery charging system.

2.3.3 Modes of Buck-Boost Converters

2.3.3.1 Continuous Mode
2.3.3.2 Discontinuous Mode

Continuous Mode
In this mode current from end to end of the inductor come to zero so the inductor gets partially discharge before the switching cycle.
factors affecting continuous mode

- Voltage Transfer Ratio
- Inductor Ripple Current
- Input Current
- Output Current and Voltage Ripple

Capacitor Ripple Current
Voltage Transfer Ratio:

$$V_o = \frac{V_d}{(1-D)}$$

Inductor Peak to Peak Ripple Current: $\Delta I_L = \frac{V_d.D.T_s}{L}$

Input Current $I_d = I_L = \frac{I_o}{(1-D)}$

Diode Current: Peak to Peak Ripple = $I_L + \frac{\Delta I_L}{2} \approx I_L \approx \frac{I_o}{(1-D)}$

Peak to Peak Output Voltage Ripple (approximation) = $\frac{I_o.esr}{(1-D)}$

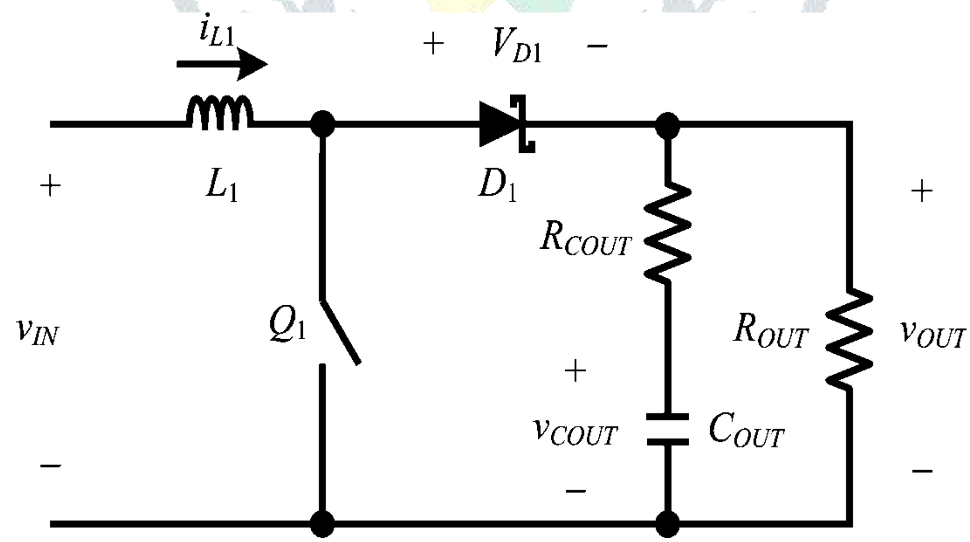


Figure 3 An Open Loop Boost Converter

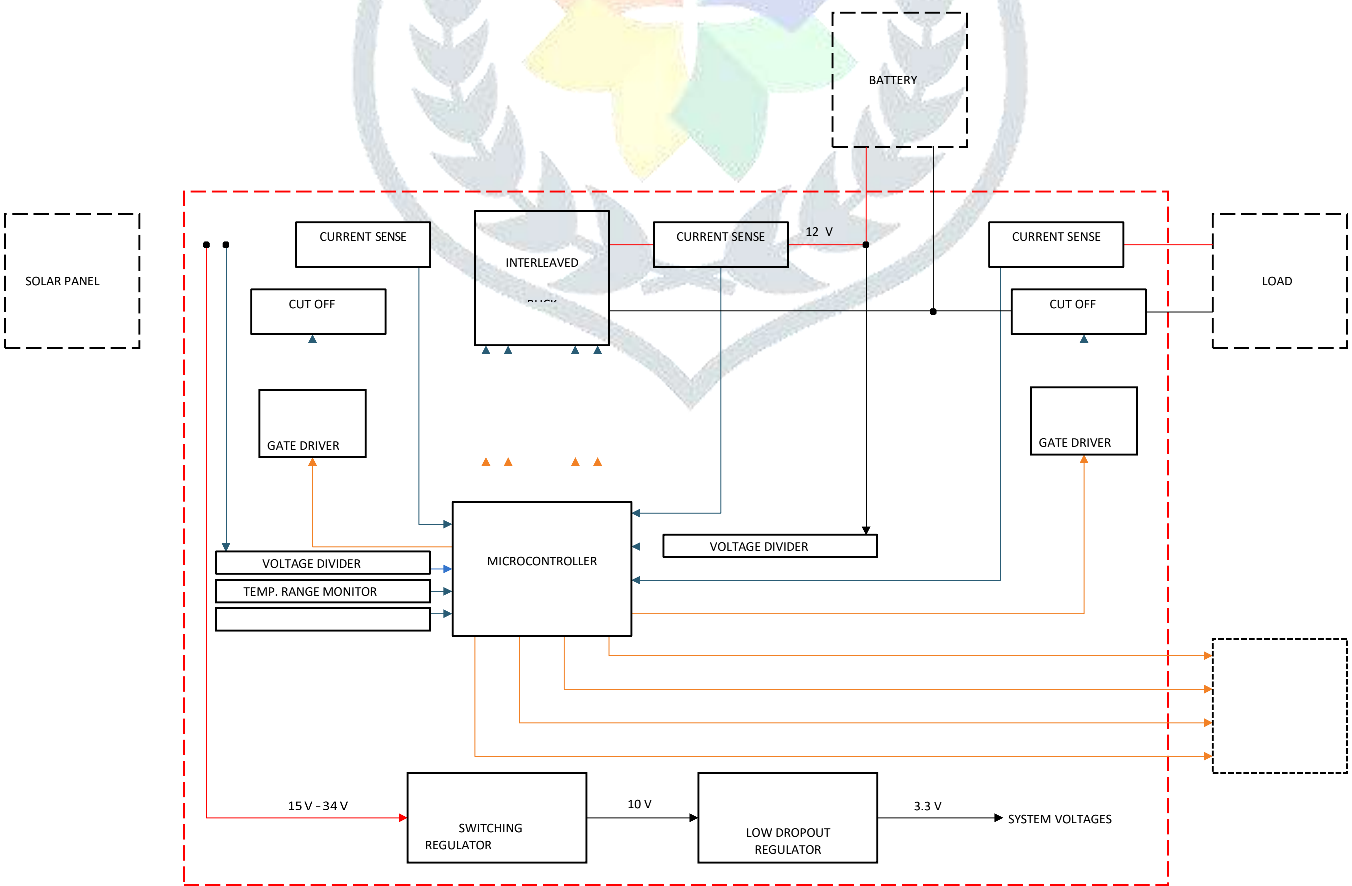
Discontinuous mode

In this mode, the current becomes zero and the inductor got fully discharge. Just as in the Boost case the boundary condition for discontinuous mode occurs when the average inductor current IL is half of the inductor peak-to-peak ripple ⊿IL

Research setup

Fig: 4 Test set-up

Basic Flow diagram



3 Result and discussion

3.1 Output of MPPT and PWM

In this system, we find the efficiency of PWM and MPPT on the test set-up. we find the efficiency of the PWM system then we find the efficiency of MPPT. The efficiency of PWM is near 70% at stand panel voltage and MPPT touched 90 %. To overcome this gap we used a power supply as a panel voltage input source then we decided to vary panel voltage from 17 to 24 volt.
Different outputs as following

3.2 Efficiency of MPPT:-

In this graph, we calculated the efficiency of output given by the MPPT Charge Controller.
The formula used:-
The maximum efficiency of a solar photovoltaic cell is given by the following equation:

Maximum efficiency =

$$\frac{\text{(maximum power output)}}{\text{(incident radiation \_lux) *(area of collector)}}$$

Efficiency at the 17 volt:-
we have set the input voltage in the test set-up as 17 volts in the power supply to find accurate efficiency. all calculation is done using a formula and finds the graph

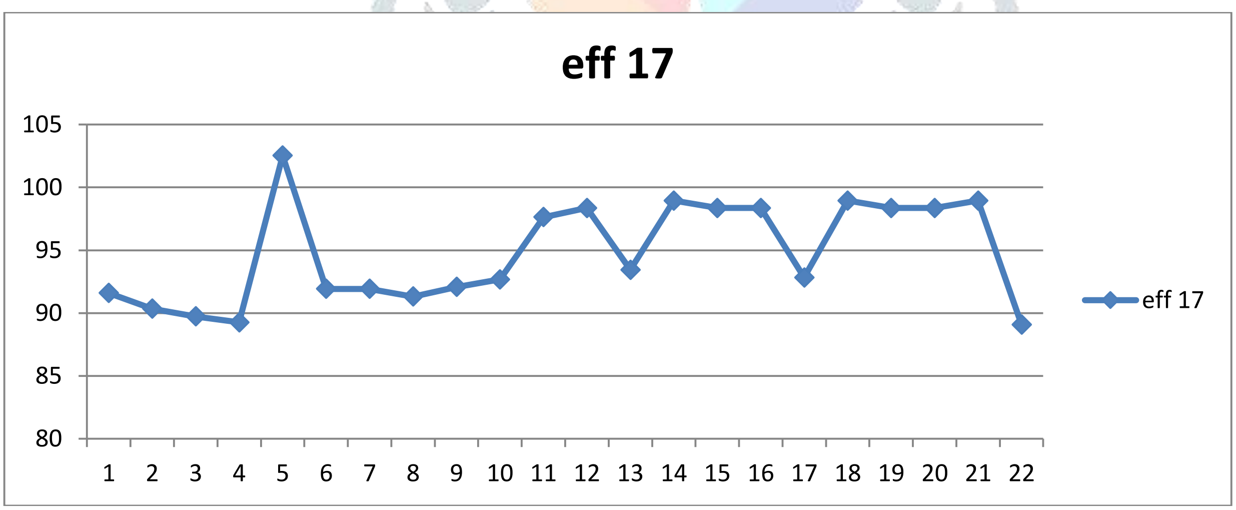


Fig 5 Efficiency at 17 Volts

Efficiency at the 18 volts:-
we have set the input voltage in the test set-up as 18 volts in the power supply to find accurate efficiency. all calculations are done using a formula and plot the graph.

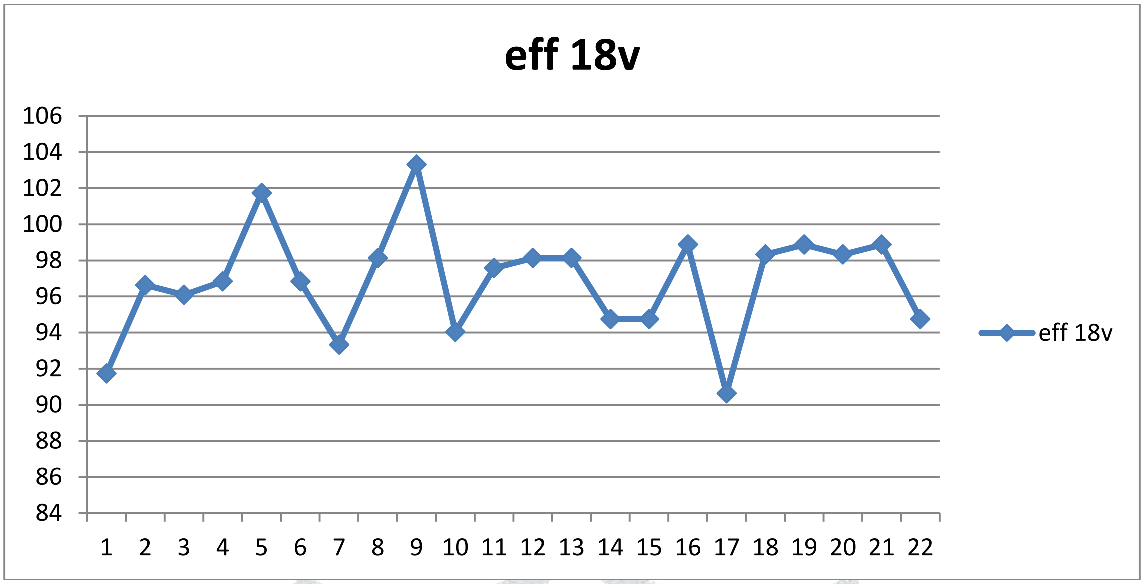


Fig 6 Efficiency at 18 Volts

Efficiency at the 19 volts:-

we have set the input voltage in the test set-up as 19 volts in the power supply to find accurate efficiency. all calculations are done using a formula and the graph is plotted as output.

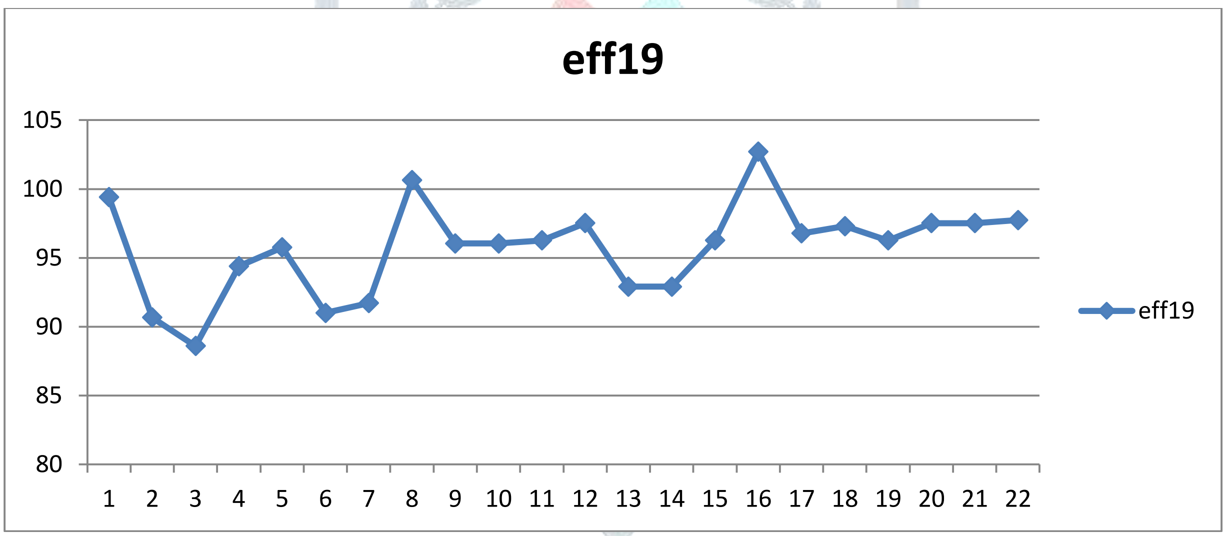


Fig 7 Efficiency at 19 Volts

Efficiency at the 20 volts:-

we have set the input voltage in the test set-up as 20 volts in the power supply to find accurate efficiency. all calculations are done using a formula and the graph is plotted as output with different values.

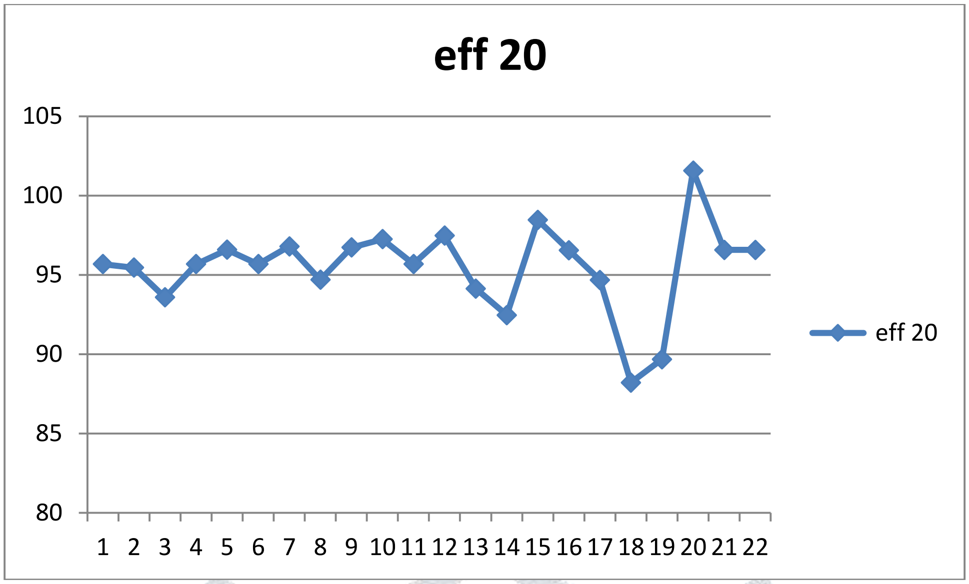


Fig 8 Efficiency at 20 Volts

Efficiency at the 21 volts:-
we have set the input voltage in the test set-up as 21 volts in the power supply to find accurate efficiency. all calculations are done using a formula and the graph is plotted as output.

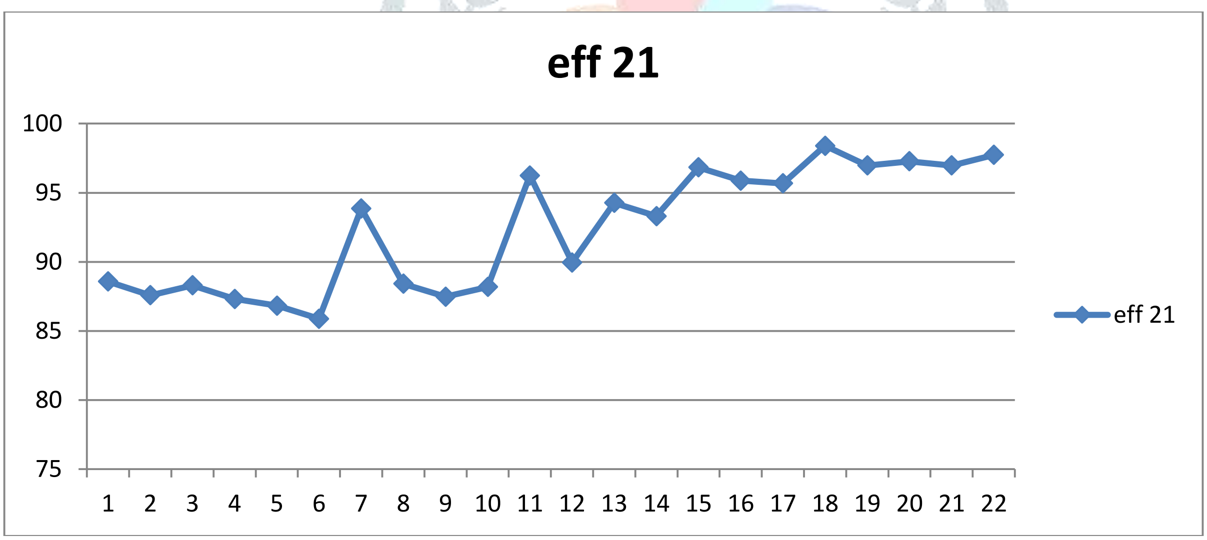


Fig 9 Efficiency at 21 Volts

Efficiency at the 22 volts:-
we have set the input voltage in the test set-up as 22 volts in the power supply to find accurate efficiency. all calculations are done using a formula and plot the graph.

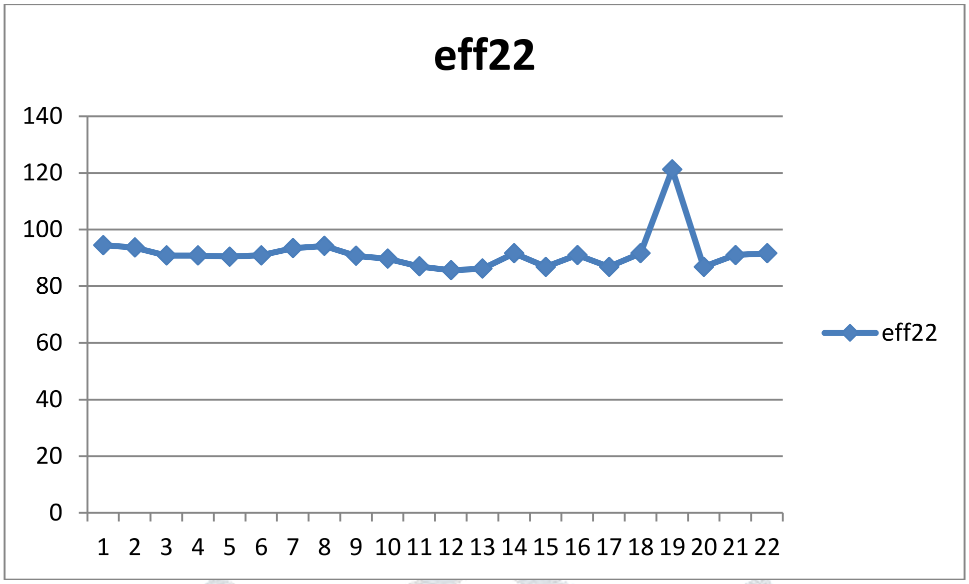


Fig 10 Efficiency at 22 Volts

Efficiency at the 23 volts:-
we have set the input voltage in the test set-up as 23 volts in the power supply to find accurate efficiency. all calculation is done using a formula and find the graph

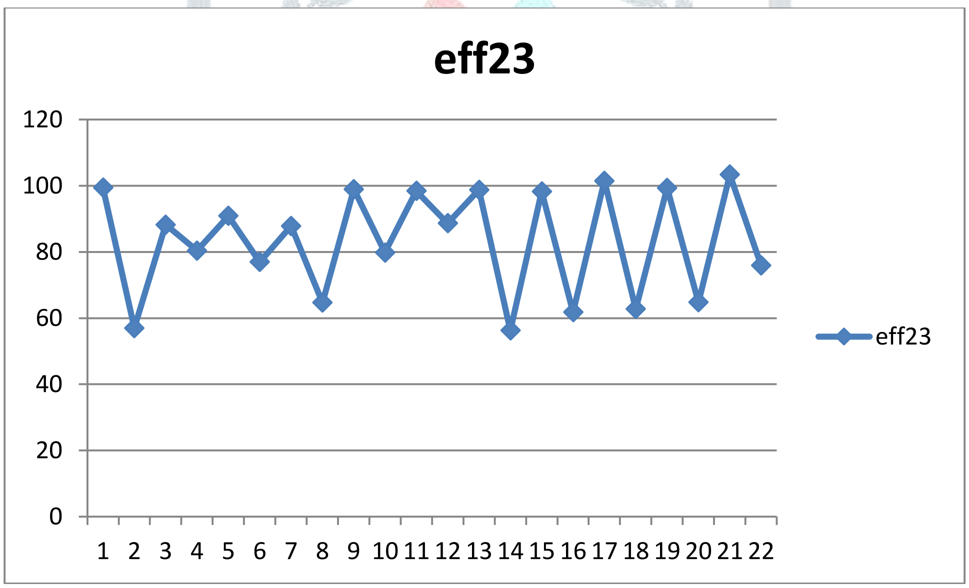


Fig 11 Efficiency at 23 Volts

Efficiency at the 24 volts:-
we have set the input voltage in the test set-up as 24 volts in the power supply to find accurate efficiency. As we feed 24 volts from the power supply set-up is generating little variation. all calculations are done using a formula and find the graph.

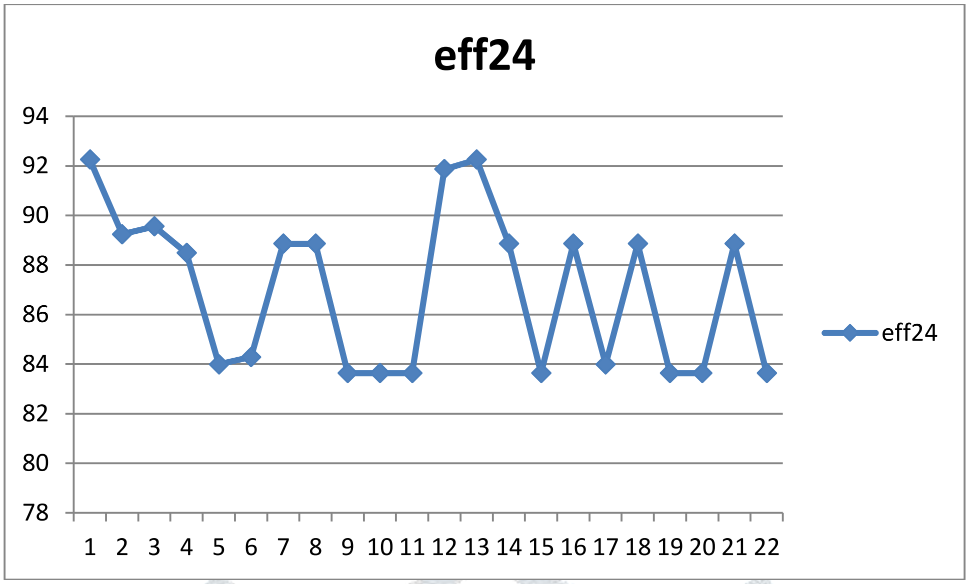


Fig 12 Efficiency at 24 Volts

Comparison of all the outputs:-
we compared all the output in a single graph.

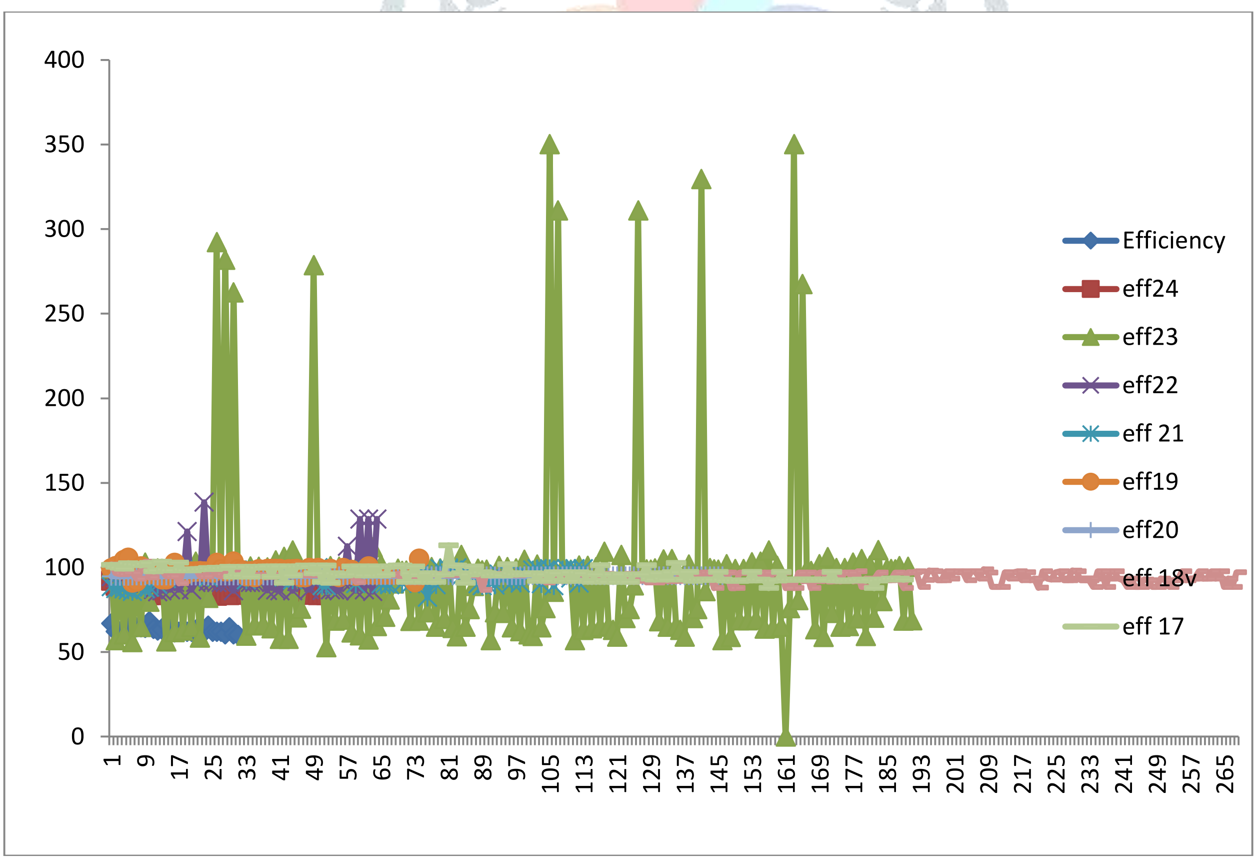


Fig 13 Output graph of PWM and MPPT charging

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$$\text{Maximum efficiency} = \frac{\text{(maximum power output)}}{\text{(incident radiation \_lux)} * \text{(area of collector)}}$$

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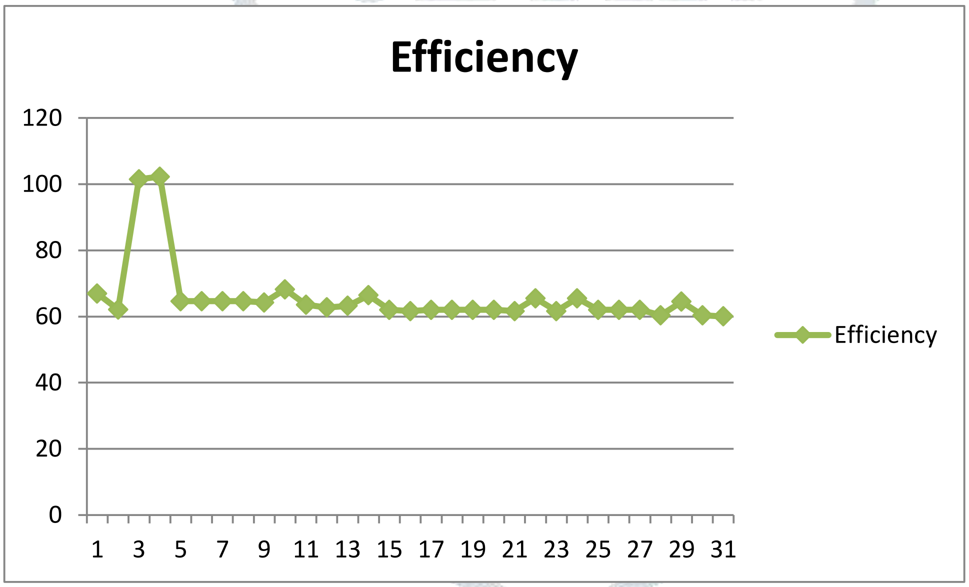

Fig 14. The efficiency of at panel PWM.

Conclusion:-
when we charge batteries with PWM charge controllers and feed the panel voltage near battery charging voltage then PWM has near to optimal output and we suggest it for small projects. Because of in case of cloudy day panel voltage start dropping. In the case of MPPT, it has DC-DC Converters which leads to a small amount of power loss but power optimization is maximum.

Future Scope
The standard software can be designed which can predict the losses. It will help the people to take the decision on which technique they should use. This research coined an exact value of the performance of both techniques. The industry of solar get good help in calculating the exact amount of installation

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