The Efficiency of Solar PV System

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Abstract—the need of electrical energy is essential part of any state to stable itself as well as to promote itself. The most reliable resources of electrical energy are Renewable resources. In these renewable resources, Sun is the biggest resource of energy. In active solar technique, electrical energy is produced by the phenomenon of Photoelectric effect. The Reliability and efficiency of solar power system can be improved by making sure that we are using this system properly. First of all, the main factor of solar power generation is the efficiency of solar cell that is made of Crystalline Silicon cell mostly. The efficiency of solar cell is not good yet, but the capability of solar cell to produce power is excellent. Secondly, there are many factors affecting the efficiency of PV system during installation and maintenance. This paper emphasizes on the efficiency of PV module affected by direction, angle, irradiance, shade, load and temperature. This paper describes the conceptual design of a smart battery health monitoring system along with protection of battery from over charging & over discharging using an embedded system. The working mechanism of this system is based on the input voltages to the embedded system from the battery which are further processed using ADC to convert them into Digital form which are then used to observe the state of battery's condition The deeply study of these factors is essential before using this system and implementation of these results after study, enhance the efficiency of this system.

I. INTRODUCTION

Renewable Energy: Energy which is produced by processes that are continuously replenished. There are the main following renewable technologies. [1]

- Wind Energy
- Hydro Power
- Solar Energy
- Biomass
- Bio fuel
- Geothermal Energy

A. Solar Energy

Solar Energy is the biggest source of energy. There are two basic techniques to get energy from Sun. One is passive solar technique and other one is active solar technique. In passive solar techniques, the orientation of building to circulate air and dispersing sunlight [2] is included shown in figure 1.

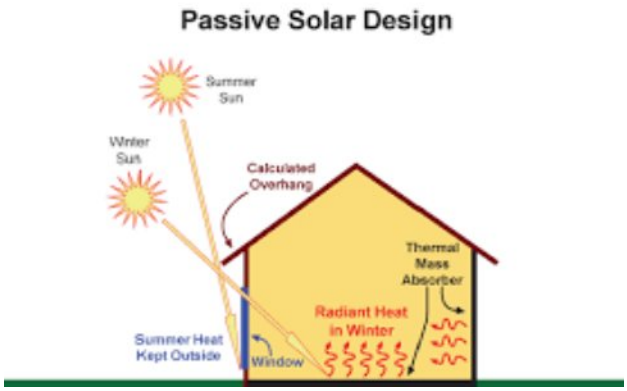


Figure 1: Passive Solar Technique

In active solar techniques the heating of fluid materials by thermal collector as shown figure 2.

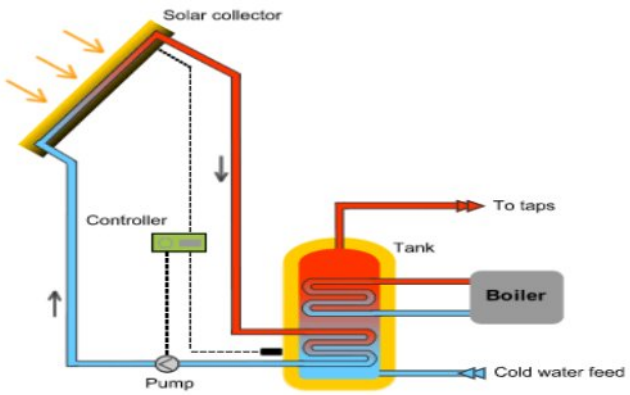


Figure 2: Active Solar Technique

Electrical energy is producing through photoelectric effect is shown in the figure 3.

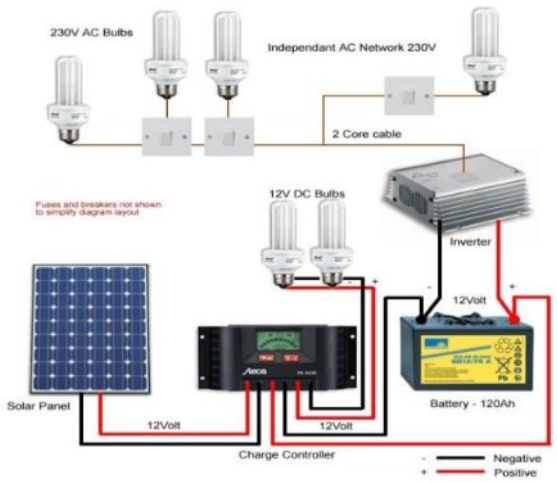


Figure 3: Active Solar Technique

B. PV module specification:

In the world, 90% PV module is of crystalline silicon. Solar cell made by czharlski process by some chemical reaction and after obtaining silicon crystal in the form of ingots, a solar cell is made by some extra processes like cutting, slicing, wayfaring etc. A solar cell is of 0.5 to 0.6 volts .To make a PV module solar cells are connected in series. The size of solar cell decides the capacity of current in solar cell. The size of solar cell is 3 inches to 6 inches and current is 3 amps to 9 amps accordingly. When PV modules are connected together, a PV array is made. Table 1 shows the comparison of specification of different PV module.

PV Module type	Mono-crystalline	Poly-crystalline	Thin Film
Theoretical efficiency	25.0%	20.4%	18.7%
Practical efficiency	15-20%	13-16%	9-11%
Area/kW	6-9 ? ?	8-9 ? ?	10 ? ?
Warranty	25 years	25 years	10-25 years
Lowest price	0.75$/w	0.62 $/w	0.7$/w
Temperature resistance	Performance Drops but good	Slightly better	Not good
Fill factor	70-75%	70-75%	50-60%

Table 1: Specification Comparison

C. Battery requirement:

By focusing on the present energy crisis in Pakistan, we can see how much important it has been to store charge for which batteries are being used from several years & gaining more importance with time in our solar system and for other purposes. Just like any appliance or any house hold thing being use frequently, batteries also require proper maintenance.

If they are not carefully handled they may result in short life of battery or may damage permanently even batteries can explode in case of inappropriate charging voltages. But battery can get damage from over discharging also which is actually a bigger issue as compared to overcharging. So it is really important to connect such protections & control system with our battery which may protect battery from over or inappropriate charging & over discharging as well.

If the battery is not allowed to discharge below 50% it would improve battery's life more than 3x as compared to a battery which is sometimes drained to 0% charging level (as it damages batter's cells permanently).

D. Battery protection

It is really important to connect such protections & control system with our battery which may protect battery from over or inappropriate charging & over discharging as well.

The basic goal of this smart system is to provide battery will all necessary protections controls in a cheap price with control over battery's charging if there is any malfunctioning in the charging circuit or if the battery has drained to 50% charging

II. PROCEDURE

In Solar PV system, there are proper procedure to maintain the efficiency and reliability of this system. There are following steps to design an efficient system. [3]

- Selecting location
- Find azimuth angle
- Calculate tilt angle
- Irradiation measurement
- Load calculation
- Module calculation
- Find required area
- Battery sizing
- Charge controller sizing
- Inverter sizing

Now in first five steps, there are the factors discussed above. By practical approach we conclude some results accordingly for the purpose of solar Photovoltaic system efficiency.

A. Types and components of PV system

1) *On-grid PV system*
2) *Off-grid PV system*
3) *Hybrid PV system*

And the basic components of solar system are

- PV module
- Charge controller
- Battery
- Solar inverter
- Load

B. Efficiency of PV system

Now this system requires deeply study of all the factors which affects its efficiency in which solar cell efficiency is the main factor. In this factor, solar cell efficiency is maximum 25%. But if we see about the capability of solar cell to produce power is about 1000W/? ?.

In simple words, area of a mono crystalline PV module of 250Watts has a capability to produce 1000watts which is the most important factor affecting the efficiency of solar PV system. Solar cells are manufactured in China, Japan and Germany. According to current research on solar cell, the efficiency record is 43.6%. And due to this progress, solar will become the most important source of energy in future.

Now the discussion is to point out the other factors affecting the efficiency of solar PV system. The Nomenclature of these given factors is pointed out by proper methods.

- Effect of direction on PV module
- Effect of angle on PV module
- Effect of irradiance on PV module
- Effect of temperature on PV module
- Effect of shade on PV module
- Effect of load on PV module

C. Effect of Direction

By changing the direction of module, short circuit current changes. If the direction of the PV module is not according to Azimuth angle then the overall power is reduced.

Practically, the location of installation has a specific azimuth angle, if we do not place the module according to azaimuth angle of that location [4]. Then current will reduce which reduce the power produced.

According to location of Uet Lahore, the results of 250W module panel model JC250 M-241Bb are shown in table 2.

Direction	E-S ???	E-S ???	S ???	S-W ???	S-W ???	S-W ???
? ? ? ??? ???	27.2	27	25.4	25.9	25.9	25.8
? ? ? ??? ??	4.8	5.2	4.43	3.9	3.78	3.6
? ??(volts)	33	33.5	33.2	32.8	32.8	32.8
? ??(amp)	6.84	6.32	4.95	4.45	4.33	3.98

Table 2: Effect of Direction

When the azimuth angle is not calculated then the variation in current reduces the power generated. For the problem of this solution, there are two methods of finding Azimuth angle.

First method is manually to use compass and by finding the E-S direction and 15 degree angle, we have to place PV module. And the Best solution is to connect a Solar Tracker which moves our module in the direction of maximum Sunlight automatically. Solar tracker is good but expensive and consumes power to operate.

So, before installation we have to make sure about the direction.

D. Effect of Tilt Angle

After placing the module in true south direction, the angle is a factor which changes the current and finally results in reducing the power of the System.

Tilt angle corresponds to Latitude of earth. If the latitude is below ??? then the tilt angle is 0.87 times the latitude. If the latitude is in between of ??? And ??? Then tilt angle is

Tilt angle=???+ (0.87 times latitude)

And if the latitude is above from ??? then the tilt angle is suppose to ???.By the angle variation, current is affected which affect the power of the system. First one is discussed above that we change the tilt angle manually.

In a year we have to change tilt angle four times after three month.

February to March	Latitude
April to July	Latitude-???
August to October	Latitude
November to January	Latitude+???

Tilt Angle	???	???	???	???	???
?? ?? ????	25.5	25.6	25.6	25.6	25.4
?? ?? ???	4.77	4.8	5.15	5.27	5.5
??(volts)	34	33.9	33.4	33.2	33.3
??(amp)	5.7	5.8	5.93	5.98	6.06

Table 3: Effect of tilt angle

And the Best method is to use solar tracker which also changes Tilt angle automatically where the Sun shine is maximum. [5]

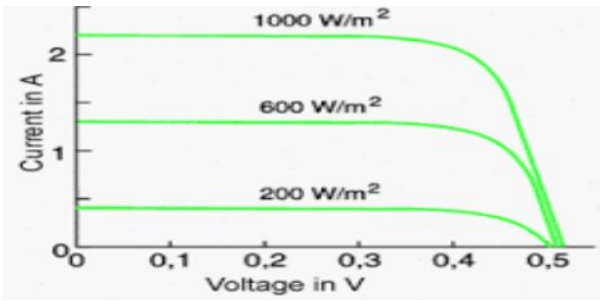
E. Effect of Irradiance

when the irradiance changes then the power generated is changed. Solar irradiance record at 10am in Uet, Lahore is 558. And current is changed by changing the irradiance. So the result is shown in table 4. that solar irradiance affects the power.

Irradiance	558(10:20am)	569(10:25am)	580(10:45am)
?? ?? ????	25.1	25.13	25.9
?? ?? ???	1.89	2.6	2.64
??(volts)	33.2	33.1	33.19
??(amp)	5.69	5.76	5.9

Table 4: Effect of irradiance

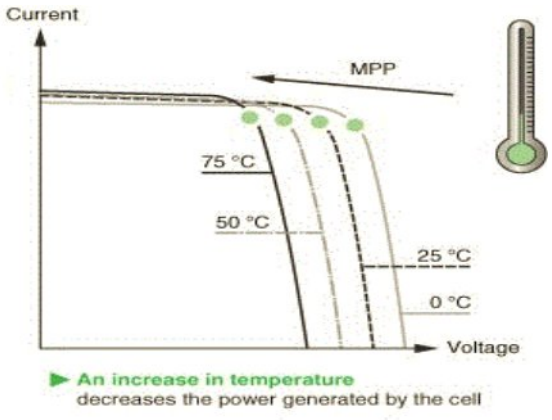
So, the study is always under consideration for overall efficiency of the system [6]. The effect of irradiance is shown in general graph 1.



Graph 1: Behavior due to irradiance

F. Effect of Temperature

The solar module operates at its outstanding performance at ??? ? temparature and 1000W/ ? ? according to the laboratory standard. When the temperature increases, the current increases and voltage decreases as shown in above graph. By increasing temperature ?? C, the current is increased by 0.05% but the Voltage is decreased by 0.37%.Therefore, Overall Power is decreased by 0.5% per degree Celsius. It is most important factor which also affects the life of solar cell. The solar cell maintains its efficiency as well as its life below ???C. Above this temperature Solar cell Efficiency is decreased badly. The behavior of solar module with change in temperature is simply defined by the graph between current and voltage. Graph 2. Shows the behavior



Graph 2: Behavior of temperature

By the practical result after varying the temperature of PV module as shown in table conclude that temperature of cell is an important factor to enhance the efficiency of solar PV system. Mono-Crystalline PV module is best for low Temperature areas. Poly-Crystalline is affected by high temperatures more than mono-crystalline.

Temperature	???	???
?? ?? ????	25.7	25.4
?? ?? ???	5.17	5.2
??(volts)	34.3	33.9
??(amp)	3.39	3.7

Table 5: Effect of temperature

So, the selection of PV module is always according to the temperature and other weather conditions of the location.[7]

G. Effect of Shade

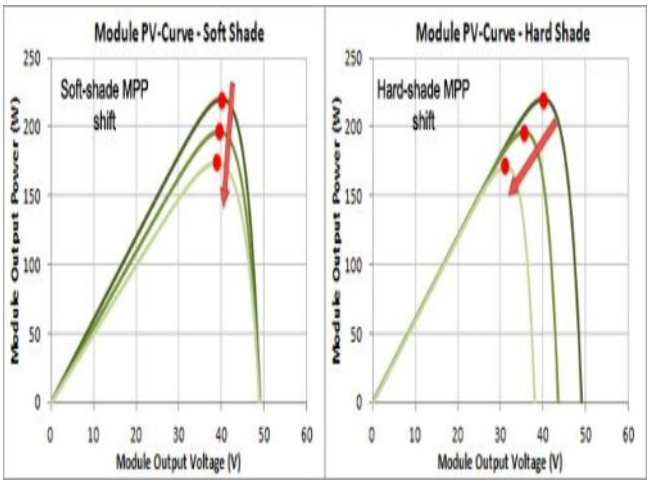
Solar module is fabricated with solar cells connected in series. There is a Bypass diode between two columns of solar cells which is actually placed because when the breakage or fault of solar cell occurs then these diodes bypass the remaining circuit but overall power of module decreases badly.

Same phenomenon happens when shade is fall on solar module. Due to this shade the current or voltage of solar

module decreases according to the type of shade. There are two kinds of shades

- Soft shade
- Hard shade

When solar module is covered by soft shade, current decreases due to which power of the module decreases. And in case of hard shade, voltages drop badly and Power decreases.



Due to disturbance in power generation, there is a need of Bypass circuits which can improve the efficiency of solar system. Effect of soft shade observed practically is shown in table 6.

Shade	One cell	Two cells of different columns	Three cells of different columns
? ? ? ?? ? ????	25.1	25.09	25.05
? ? ? ?? ? ? ?	2.49	2.11	1.61
? ??(volts)	33.2	33.1	33.03
??(amp)	5.8	5.69	2.06

Table 6.Effect of shade

The output of a system is directly related with the stability of that system. The problem of shade effect is solved by using trackers or by performing proper arrangement of module so that there will be no effect of shade.

The effect of partially shaded effect is clear from the figure 4.

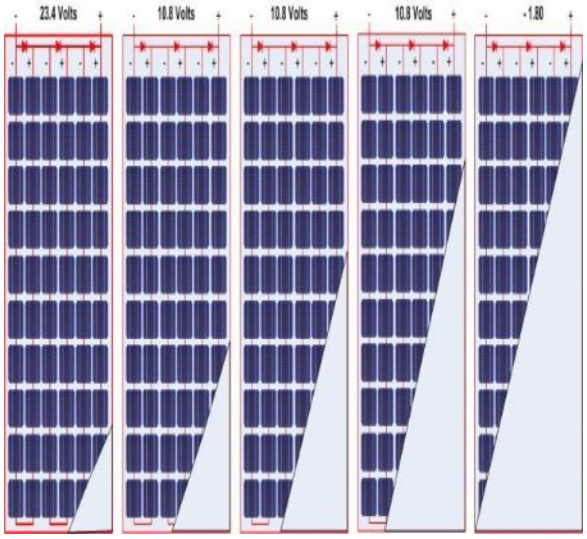


Figure 4 shade effect on voltages

H. Effect of load

When solar system is being installed then load calculation is compulsory part for the reliability of the solar system because Off-grid PV system which is also called stand-alone system dependent on battery capacity corresponding to load and back up hours at which sun is not available. Load is the factor which makes our system reliable. If our load consumes more power than system capacity when sun is not available then the output of the system becomes zero soon due to which efficiency becomes zero. So, as we increase the load beyond the capacity requirements then battery life as well as module efficiency reduces. Due to this we have to increase the size of system and cost of system is also increased as shown

Load affect on Stand-Alone System size and cost

I. Battery life protection

Using such an embedded system for controlling the battery's charging & discharging is quite efficient if considered the health of battery on long term basis. Since a very major reason for battery's short life & eventually decreasing efficiency is usually the abrupt charging/discharging behavior with no proper control & the discharging of battery.

J. Working of Smart System:

Its main working is based on the voltages of battery while charger is connected or disconnected. It will consistently fetch data using ADC to keep track of battery voltages. Once it has calculated battery voltages using formulas used in

coding, it will take decision based on the conditions programmed in PIC. If the voltages are greater than 12.9v then it will disconnected the charger from the battery using a relay but it the charging voltages are lower than 12.7v it will connect the charger with the battery using same relay until the battery voltages have reached 14.1v. Similarly for the stages between below 12.7v the charger will remain connected with battery. Another conceptual feature of this system is to keep track of battery voltages & current at each instant & using formulations, calculating the power supplied by battery & comparing the statics with the graph in fig 1 shown below & displaying the battery condition accordingly.

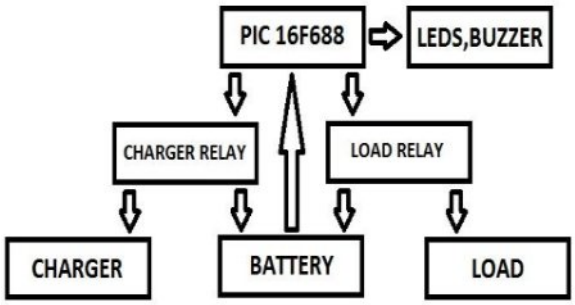


Figure 5 charging and discharging control

III. CONCLUSION

It is concluded from this paper that every factor affecting on PV system must be under consideration while using the system because Photovoltaic system requires much maintenance then other power generation systems. Solar system will become the largest source of power generation by improving the efficiency of solar cell which is about 43% now but the manufacturing of this cell and fabrication of these cells is not completed yet. A battery will never discharge below 50% which will stop battery's cells from weakening & hence the life span of battery will increase. It is obvious that twice amperage battery will have to be used instead of battery of equal power as demand The efficiency of solar system is depending upon all these factors, so by improving the efficiency of solar system, the power system stability can be increased. So we can say this method is expensive on contrary basis but much cheaper & more reliable than usual practice.

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