"An Enhancement Of Solar Irradiance Effect On PV Array Performance"

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Abstract

Solar energy is most readily available source of energy. It is Nonpolluting and maintenance free. To make best use of the solar PV systems the output is maximized either by mechanically tracking the sun and orienting the panel in such a direction so as to receive the maximum solar irradiance or by electrically tracking the maximum power point under changing condition of insolation and temperature. The overall performance of solar cell varies with varying Irradiance and Temperature .With the change in the time of the day the power received from the Sun by the PV panel changes. Not only this both irradiance and temperature affect solar cell efficiency as well as corresponding Fill factor also changes. This paper gives an idea about how the solar cell performance changes with the change in above mentioned factors in reality and the result is shown by conducting a number of experiments.

Keyword:- Solar Energy, PV Systems, Solar Irradiance and temperature, Solar cell efficiency, MPPT

I.INTRODUCTION

To date, the implied assumption behind inverter protection loss calculation has been that the inverters enter downscaled protection mode as soon as over-irradiance events occur, thereby causing immediate power loss. However, there might be a time delay before inverters protect themselves from overcurrent due to high irradiance. During such time delay, which is determined by the protection scheme of the inverter, the inverter can still handle full input power without derating. The research contributions of this paper include the following:

• A new, dynamic viewpoint into over-irradiance events is proposed. This dynamic viewpoint is based on three factors that turn the inverter into protection mode:

1) Duration time of the over-irradiance events;

2) Thermal cycle of inverter;

3) Overload protection scheme of inverter. These factors are case specific and location dependent.

• The findings of this paper help develop guidelines for both system integrators and PV inverter designers to choose and to design inverters for specific locations. For system integrators, the protection scheme of inverters should be considered when choosing inverters. Overload protection schemes have substantial impacts to the total energy yields, especially under fluctuating irradiance.

A. Solar Irradiance Data used for analysis and discussion in this paper are available from the Solar Radiation Monitoring Laboratory, University of Oregon. For the discussion in this paper, the data are measured and recorded once every minute, in Eugene, OR, 2009. They are the horizontal global irradiance measured by one broad band sensor and six narrow band sensors [1]. (Similar analysis could be performed for other geographic locations if irradiance data is available.)

B. Effects of Time Threshold (TT) Time threshold (TT) in this paper is defined as the protection time delay when input power of inverter is 150% of its nominal power. For example, if TT= 2 mins and GTh=700W/m2 , when the irradiance is around 1000W/m2 , the inverter can handle the over-irradiance without entering protection mode for 2 minutes. Irradiance higher or lower than 1.5GTh decreases or increases the actual time delay, respectively. It should be noted that when irradiance is well below GTh, the inverter cools down and would be able to operate for a longer time during the next over-irradiance event occurs. Similarly, if over-irradiance events occur frequently, the protection time delay would be shortened. The simulation presented in this paper has not included such effects. Assume that we size the inverter with GTh=700W/m2 , the common wisdom would be that every watt exceeding 700W/m2 was wasted since the inverter would limit the power output of the PV array in accordance to 700W/m2 . As an example (Eugene, OR in 2009), Figure 3 presents a histogram of time duration of over-irradiance events. Notice that more than 25% of over-irradiance events (437 out of 1661) last less than 1 minute and more than 15% (252 out of 1661) last less between 1 and 2 minutes. This adds up to 40% of all over-irradiance events. This means that, if the inverter has a 2- minute overload protection delay, it would not waste energy due to entering protection mode in most of the over-irradiance events during the 2 minutes. If TT can be further increased, then even more energy can be recovered.

II. SOLAR IRRADIANCE

Solar irradiance is the power per unit area received from the Sun in the form of electromagnetic radiation in the wavelength range of the measuring instrument. The solar irradiance integrated over time is called **solar irradiation**, **insolation**, or **solar exposure**. However, insolation is often used interchangeably with irradiance in practice.

Irradiance may be measured in space or at the Earth's surface after atmospheric absorption and scattering. Irradiance in space is a function of distance from the Sun, the solar cycle, and cross-cycle changes. Irradiance on the Earth's surface additionally depends on the tilt of the measuring surface, the height of the sun above the horizon, and atmospheric conditions. Solar irradiance affects plant metabolism and animal behavior.

There are several measured types of solar irradiance [2].

- **Total Solar Irradiance** (TSI) is a measure of the solar power over all wavelengths per unit area incident on the Earth's upper atmosphere. It is measured perpendicular to the incoming sunlight. The solar constant is a conventional measure of mean TSI at a distance of one astronomical unit (AU) [3].

- **Direct Normal Irradiance** (DNI), or *beam radiation*, is measured at the surface of the Earth at a given location with a surface element perpendicular to the Sun.[4] It excludes diffuse solar radiation (radiation that is scattered or reflected by atmospheric components). Direct irradiance is equal to the extraterrestrial irradiance above the atmosphere minus the atmospheric losses due to absorption and scattering. Losses depend on time of day (length of light's path through the atmosphere depending on the solar elevation angle), cloud cover, moisture content and other contents. The irradiance above the atmosphere also varies with time of year (because the distance to the sun varies), although this effect is generally less significant compared to the effect of losses on DNI.

- **Diffuse Horizontal Irradiance** (DHI), or *Diffuse Sky Radiation* is the radiation at the Earth's surface from light scattered by the atmosphere. It is measured on a horizontal surface with radiation coming from all points in the sky excluding *circumsolar radiation* (radiation coming from the sun disk). There would be almost no DHI in the absence of atmosphere.

- **Global Horizontal Irradiance** (GHI) is the total irradiance from the sun on a horizontal surface on Earth. It is the sum of direct irradiance (after accounting for the solar zenith angle of the sun *z*) and diffuse horizontal irradiance:
  - Average annual solar radiation arriving at the top of the Earth's atmosphere is roughly 1361 W/m^2. The Sun's rays are attenuated as they pass through the atmosphere, leaving maximum normal surface irradiance at approximately 1000 W /m^2 at sea level on a clear day. When 1361 W/m^2 is arriving above the atmosphere (when the sun is at the zenith in a cloudless sky), direct sun is about 1050 W/m^2, and global radiation on a horizontal surface at ground level is about 1120 W/m^2. The latter figure includes radiation scattered or reemitted by atmosphere and surroundings. The actual figure varies with the Sun's angle and atmospheric circumstances. Ignoring clouds, the daily average insolation for the Earth is approximately 6 kWh/m^2 = 21.6 MJ/m^2.
  - The output of, for example, a photovoltaic panel, partly depends on the angle of the sun relative to the panel. One Sun is a unit of power flux, not a standard value for actual insolation. Sometimes this unit is referred to as a Sol, not to be confused with a *sol*, meaning one solar day [4].

III.SOLAR POWER

- Solar irradiation figures are used to plan the deployment of solar power systems. In many countries the figures can be obtained from an insolation map or from insolation tables that reflect data over the prior 30–50 years. Different solar power technologies are able to use different component of the total irradiation. While photovoltaic panels are able to convert to electricity both direct irradiation and diffuse irradiation, concentrated solar power is only able to operate efficiently with direct irradiation, thus making these systems suitable only in locations with relatively low cloud cover [5].
- Because solar collectors panels are almost always mounted at an angle· Towards the sun, insolation must be adjusted to prevent estimates that are inaccurately low for winter and inaccurately high for summer.[29] This also means that the amount of sun falling on a solar panel at high latitude is not as low compared to one at the equator as would appear from just considering insolation on a horizontal surface.
- Photovoltaic panels are rated under standard conditions to determine the Wp rating (watts peak),[30] which can then be used with insolation to determine the expected output, adjusted by factors such as tilt, tracking and shading (which can be included to create the installed Wp rating). Insolation values range from 800 to 950 kWh/(kWp·y) in Norway to up to 2,900 kWh/(kWp·y) in Australia.

- Modifying model parameters for varying temperature and insolation when the performance of PV system is evaluated under certain operating conditions, such as the STC, the practical and theoretical results concur only if the modelling process uses PV parameters which have been extracted under the same operating conditions. Since datasheets only specify a PV module parameters at STC and since these parameters vary considerably with environmental conditions, such as insolation and temperature, adjustments have to be made to the PV module parameters to allow for varying operating conditions. The problem is further complicated by the variations in module parameters with partial shading [6-7-8].

However, this paper only focuses on the variations of module parameters with irradiance and temperature, and reviews various methods for catering with such variations for each parameter.

IV. PERFORMANCE AT PV SYSTEM LEVEL

Improving module efficiency is only one way to extract more energy from the module. However, what matters ultimately is the energy yield of the PV at the system level.so the question is: What can we do at the system level to increase the yield of PV systems?

Besides the semiconductor material used for PV modules, there are only two parts that play roles in improving the performance of a PV system: electrical and mechanical. The electrical part is responsible for tracking the maximum power point (MPP), which is a tool to ensure that the PV module operates at the MPP on its I-V curve under a given set of irradiance and temperature. This unit is not something a designer can optimize or change to improve performance during the design phase of a PV system. For those who are not familiar with MPP tracker, you may refer to EME 812 (6.2 Main components of the PV systems) and EME 812 (11.3 DC/DC Conversion).

The other piece is the mechanical part of the PV system that indeed can be optimized by the designer to improve the amount of light falling on a PV array. The simplest way to maximize the solar utility is done by physically changing the orientation and tilt angle of the module as discussed in EME 810 (Lesson 2: Collector Orientation) and EME 810 (Lesson 6: Project Locale).

As a result, we see the need for tracking the sun using a mechanical tracking system. You may refer to EME 812 (Lesson 3: Tracking Systems) for details about the types and technologies of tracking systems. As the majority of PV systems are fixed mounted, a single choice for orientation and tilt throughout the year changes depending on the geographical location, as discussed in EME 810 (Lesson 6: Project Locale).

Irradiance and PV output

The question remains, how does irradiance affect the PV output? We learned in our review of EME 812 how irradiance and temperature affect the output of a PV cell. A quick recap will tell us that when all parameters are constant, the higher the irradiance, the greater the output current, and as a result, the greater the power generated. Figure 6 shows the relationship between the PV module voltage and current at different solar irradiance levels. The image illustrates that as irradiance increases, the module generates higher current on the vertical axis. Similarly, we can observe the voltage and power relationship of a PV module at different irradiance levels. We can see that as irradiance increases, the module is able to generate more power represented by higher peaks [9]

The relationship between irradiance and modules' current and power can be expressed as the following:;

$$G1/G2=I2/I1=P2/P1$$

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Where G1 and G2 are the irradiances (in W/m2), I1 and I2 are the modules' corresponding current (in A), and P1 and P2 are the resultant power when irradiance changes (in W).

V.TILT AND PV OUTPUT

The following example illustrates how to find the optimal tilt angle for a fixed mount PV system. If we go to State College, PA and use the chart that was developed in EME 810 (Lesson 2: Sky Dome and Projections)we can see that State College, PA has a latitude around 40.79° in the northern hemisphere. In this case, the lowest elevation angle of the sun at solar noontime is around 26° and the highest is around 75°. If we have a tilt tracker, it would vary the range of angles throughout the year between 26° to 75°.

How can we find the tilt corresponding to the maximum yield? This is done using tools developed to calculate the annual energy generation from a PV array given the design tilt and azimuth angles. Some references and designers prefer to set the tilt angle to match the latitude of the selected location as a rule of thumb. However, that does not necessarily maximize the annual energy production of the PV system, as discussed in EME 810 (Lesson 6: Project Locale)[10].

In general, a lower tilt angle helps improve production in the summer months, whereas higher tilt angles favor lower irradiance conditions in the winter months. Designers should take into account the cost of racking and mounting hardware, which can be minimized by lower tilt angle and also minimize the risk of wind damage to the array. So without tedious mathematical calculations, and in order for us to find the optimal tilt and azimuth angles, solar designers can use simple tools developed by NREL. As you were exposed to in Lesson 1, PV Watts is a freely available online design tool and it helps designers calculate the annual energy production using simple parameters to maximize the solar utility for the location.

Going back to State College, PA, and since we have fixed panels oriented towards the South, the optimized tilt angle that will give the maximum energy yield is around 30-35 degrees[11].

VI.RESULT AND SIMULATION

1. IDEAL CONDITION AREA 12WATT PANEL EFFECTIVE AREA (A=2.15)

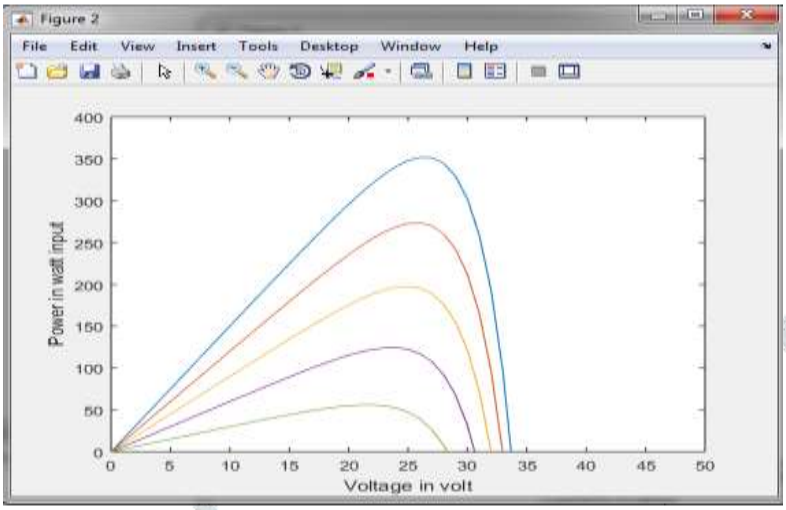

Fig. (1) Power in watt input Vs Voltage in volt. (Effective area A=2.15).

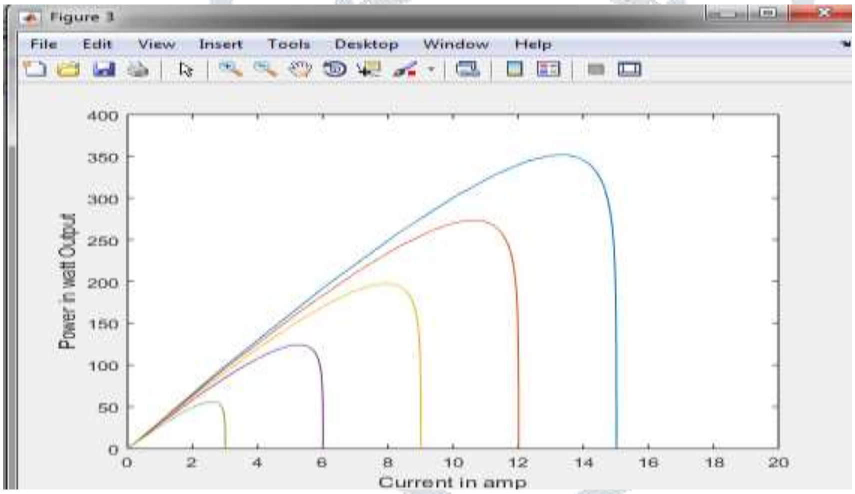

Fig. (2) Power in watt output Vs current (Effective area= A=2.15).

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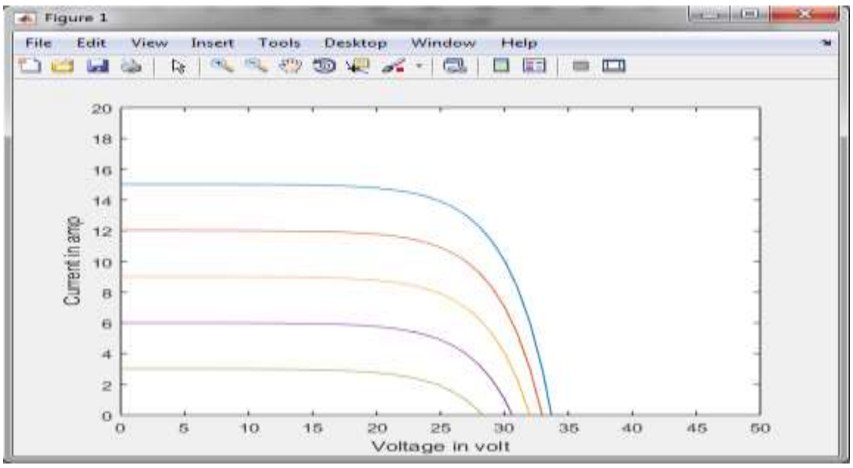

Fig. (3) Current Vs Voltage in volt. (Effective area= A=2.15).

2. IDEAL CONDITION AREA 12WATT PANEL EFFECTIVE AREA (A=1.00)
(WHEN CRACK OCCURE THEN REDUCTION OF EFFECTIVE AREA)

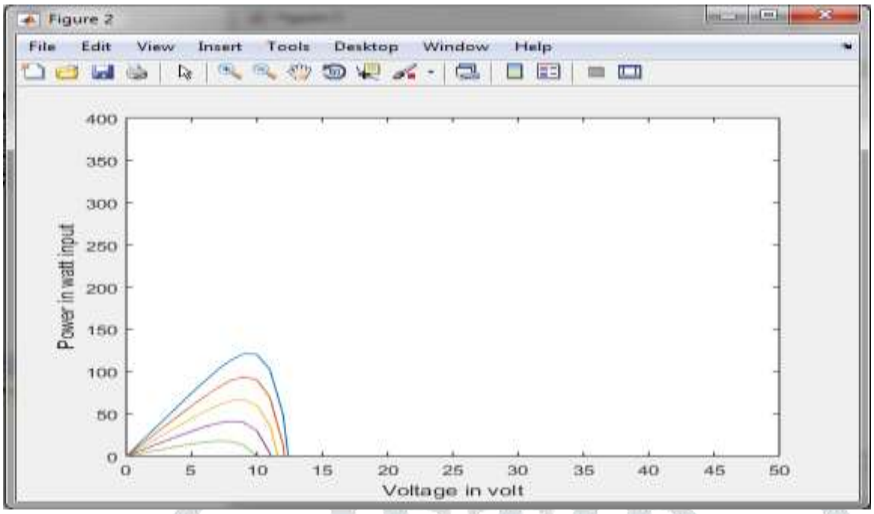

Fig. (1) Power in watt input Vs Voltage in volt. (Effective area A=1.00).

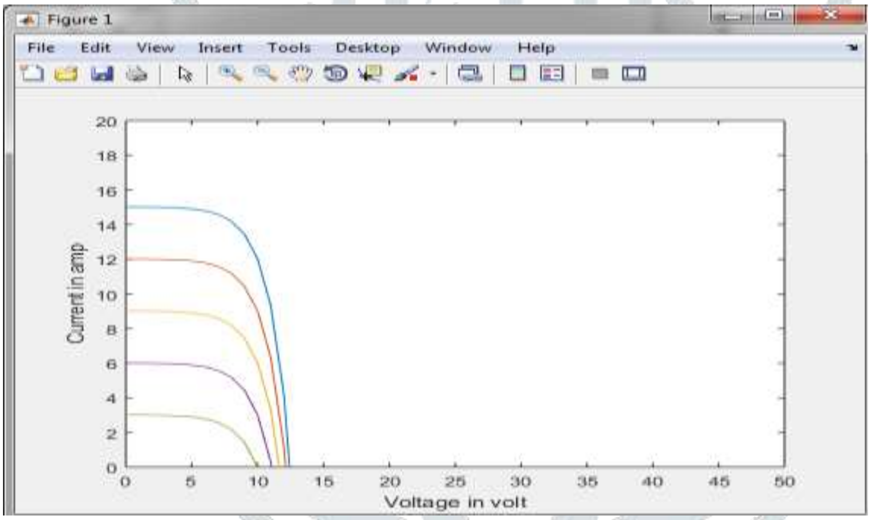

Fig. (2) Current Vs Voltage in volt. (Effective area= A=1.00).

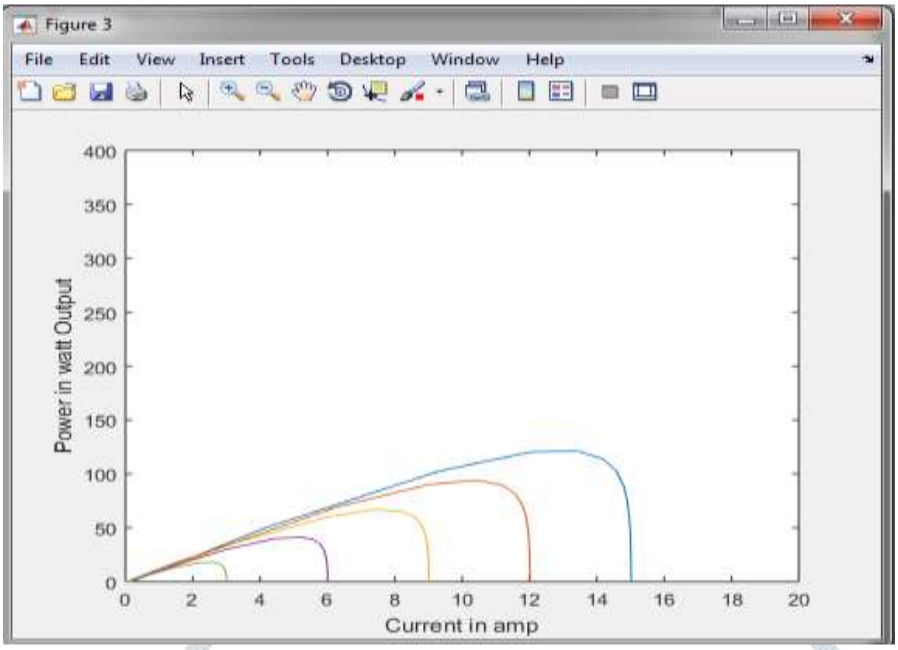

Fig. (3) Power in watt output Vs current (Effective area A=1.00).

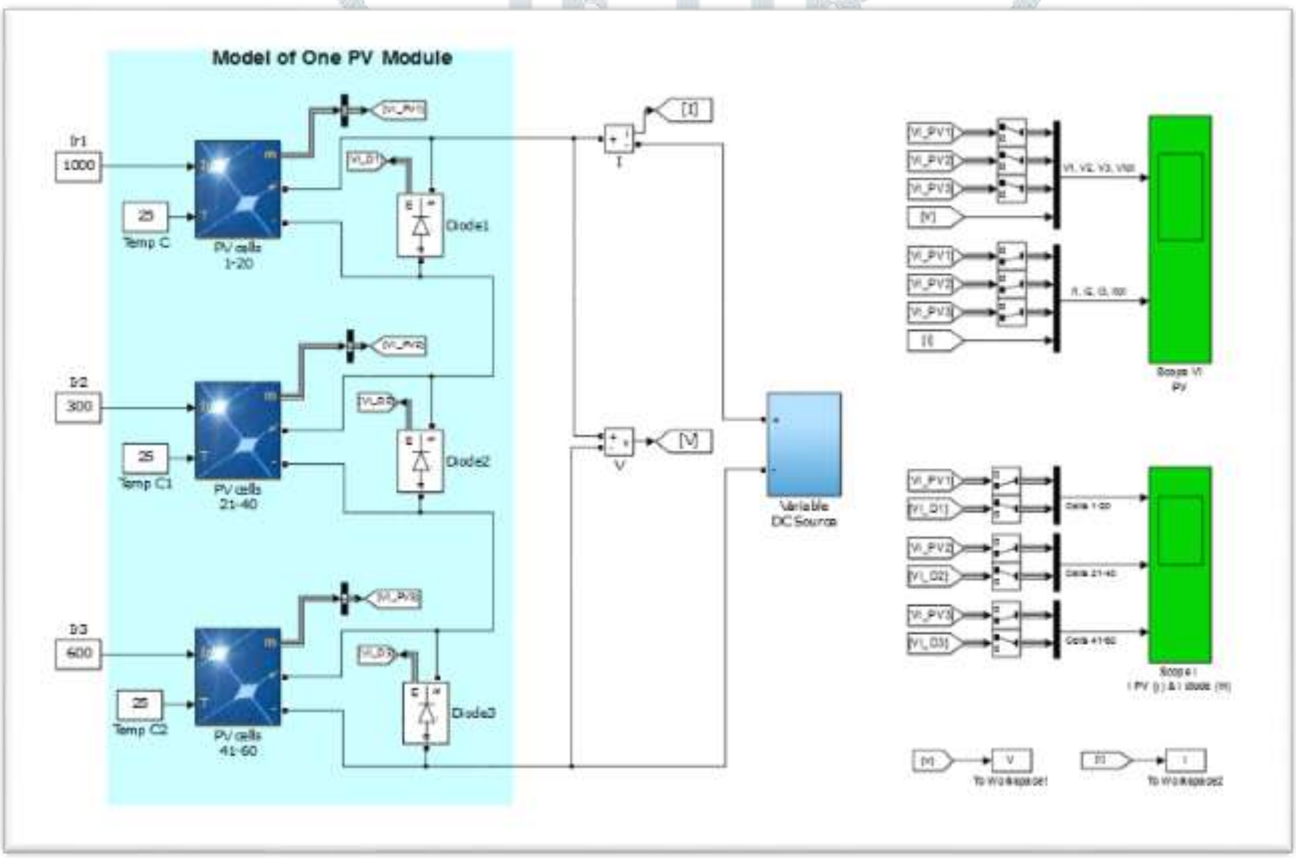

Fig. (4)PVs array with irradiation.

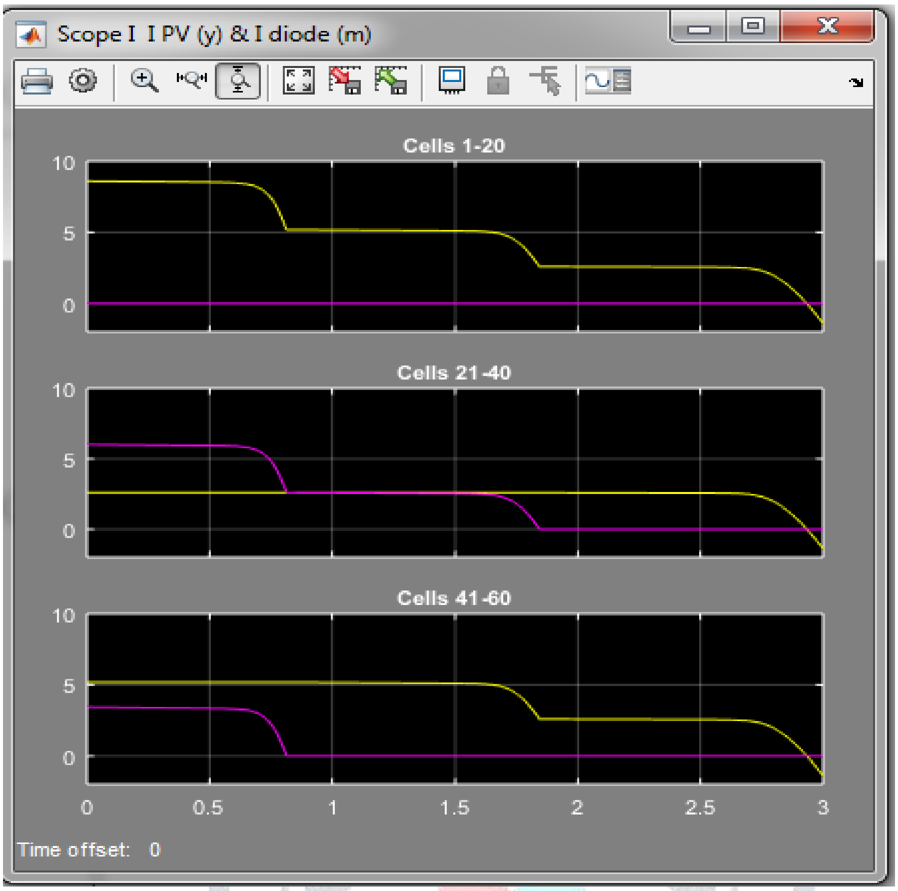

Fig. (5)Output current, voltage and power of boost converter without P&O algorithm

Table 1: A COMPARISION BETWEEN REDUCTIONS CRACK OF EFFECTIVE AREA OF SOLAR PANEL WITH REDUCTION OF SOLOR EFFICIENY.

S.no.	EFFECTIVE AREA	OUTPUT VOLTAGE	OUTPUT CURRENT Amp.	P_{out}	P_{in}	Irradiation
1	1.00	15	8	150	250	40
2	1.50	20	9	200	300	50
3	1.90	25	11	250	370	60
4	2.00	30.1	13	300	390	70
5	2.15	35	14	350	400	80

Table 2: Efficiency effect

S.no	EFFECTIVE AREA REDUCTION OF CRACK	EFFICIENCY
1	1.00	60%
2	1.50	66.66%
3	1.90	67.5%
4	2.00	76.90%
5	2.15	87.5%

VII.CONCLUSION

The outdoor PV module testing system developed by United Solar Ovonic dramatically increased the organization's capabilities to test the performance of its competitors' and its own PV modules including prototypes. USO also relies on Spire simulators, accelerated testing and other means of testing PV in order to better understand and ultimately facilitate the advancement of PV technology. The USO test-bed is effective at testing PV modules with Isc. A practical simulation of sun radiation effect on the output performance of photovoltaic module was introduced in this paper. The results show that the sun radiation plays an important rule on the output of photovoltaic module. A solar module tester was used for generating different values of solar irradiance. The output of PV module increases as the simulated sun radiation increases. The PV module can be used for measuring the sun radiation based on G-I curve introduced in this paper. Different parameters were extracted automatically by using the solar module tester and they played an important rule for evaluating the PV module.

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