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Increasing the Output Power and Efficiency of Solar Panel by Using Concentrator Photovoltaics (CPV)

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***Abstract*—**Because of gradual depletion of non-renewable energy resources, scientists have been trying for decades to search for new alternative energy sources. Solar energy being a clean, environment-friendly and profusely available energy source can either be used as heat or electricity. Due to increase in population and industries electricity demand is increasing day by day. Pakistan is facing heavy electricity short fall for a decade. Therefore, government of Pakistan is encouraging people to investment money in solar system installation. Recently, a 100 MW Quaid-e-Azam solar park has started working in Bahawalpur through huge investment by government of Pakistan. Solar power conversion to electricity through PV cells has become more favored but high price of cells and lower efficiency has obstructed its use in developing countries. One way to reduce the high cost per kWh of electricity is to enhance the performance of PV module systems. Low cost reflecting mirrors, lenses and light focusing concentrators may be a good solution. These mirrors concentrate the light intensity over the whole surface of the panel. The effect is more electrons are generated and hence the output power of solar module increases. But the consequence of increased light radiation for longer time is the raised temperature of the panel which would inversely reduce the open circuit voltage (V_{oc}) and decrease the efficiency. To tackle this problem, a proper cooling system may be needed to sustain the PV module performance. This paper presents the comparison performance of a PV module without reflecting mirror and with reflecting mirror and manual tracking. The values of short circuit current and open circuit voltage were measured under different conditions of tracking. The output power was calculated and the values were obtained for different combinations. Findings from the experiments present that through using concentrators, a 25% mean rise of short-circuit (I_{sc}) currents with sun tracking, can be achieved. Results also show that PV module with only tracking gives higher output than the system without tracking; but the system with reflecting mirror and tracking gives greater output power. Attractive results were obtained with concentrators and mirrors installed with the PV module. With the help of negligible power consumption by concentrators and reduced complexity compared to sun tracking, use of concentrator or reflecting mirrors would be economical compared to sun tracking**.** In addition to that, setup of reflectors and concentrators is easy. They are cost-effective**,** easy as well as don't need any further maintenance or other complex equipments.

Keywords—Reflecting mirror, Concentrators, Panel cooling, Panel performance, Panel tracking

I. INTRODUCTION

Solar energy is a clean, eco-friendly and profuse resource available everywhere on earth and almost all year. It has estimated that in just one hour, the solar energy received by the earth exceeds the energy consumption of the world's requirement for whole year [1]. The potential of solar energy to reduce environmental change is equally impressive. Solar energy has the advantage of generating very small amount of greenhouse gases, and it is therefore liable that it will substitute large amount of fossil fuels. Modest amount of CO_2 is produced during the manufacture of conversion devices. Solar energy has broad range of applications ranging from lighting, heating, distillation and production of fuels.

Generation of electricity from solar energy was first made possible by photoelectric effect and later on by the development of PV cells. Electricity production by solar panels can widely be seen in those areas where extension of transmission and distribution lines seems impractical. Richard Evans Day and William Grylls Adams back in 1876 [2], discovered that when selenium was exposed to light it produced electricity; however, it had a small amount of efficiency. After that, scientists started attentive research and started experiments on improving the efficiency of solar cells. They are succeeded in reducing the high prices of electricity to only a few cents per unit of electricity now. It is now standing almost equal to other electricity generating sources and expected to drop in future with the implementation of new technologies such as titanium oxide (TiO_2) cells which has a peak efficiency of 32% in laboratory and 15-20% an average efficiency [3]. But as extraction of electricity from solar energy is still very expensive compared to the conventional fossil burned electricity [4]. It is therefore important to extract energy as much as possible from sun light.

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The generation of electricity from solar energy varies morning to evening in a day, depending upon the intensity of light. More power can be extracted at noon when the intensity of light is at its peak. Moreover, the orientation of panel is also very important factor to taken into consideration. If the panel is mounted in such a way that it receives maximum power at noon, then the received power will be minimum in the morning and evening because of the radiation falling over solar panel. If panel is mounted perpendicular to light, it will generate maximum power as compared to other incident angels. So, it is desirable to fix the panel in such a way that it will face the sun for longer period or a sun-tracking mechanism should be designed for the panel. Tracking system is designed in such a way that it tracks the sun on a single axis (azimuth angle) or on two axes (azimuth and altitude angles). As electricity produced by PV module is directly related to the intensity of light radiation it is receiving, so in order to increase the efficiency of the system a concentrating technique may be a better solution. This would considerably decrease the cost of generation of electricity by PV panels [5]. It has been found by Sungur C. [6] that tracking system with multi-axes could generate 42.6% more energy than fixed panel system.

One easy way to improve the performance of PV system is to use cost effective reflecting mirrors and light concentrators like concentrator photovoltaics (CPV). Due to minimum cost and simplified assembly of reflecting mirrors, conventional technologies make low price manufacturing possible. In this generation, theoretical efficiency of a PV cell is said to be near 25% to 30% while a practical efficiency is around 17% [7]. By cooling the panel through air or water, efficiency of the system can be increased to a greater value [8]. Figure 1 below shows the inclination of solar panel to the trajectory of the sun in Pakistan.

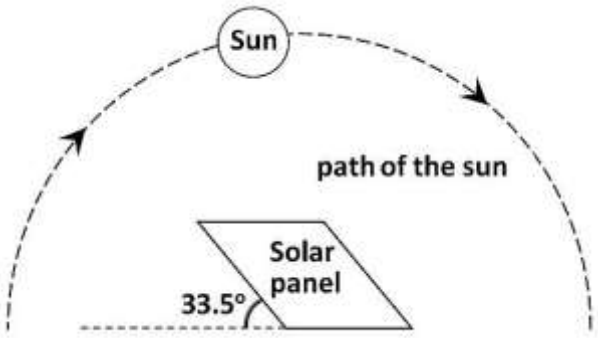

Fig. (1) Trajectory of the Sun

II. IMPROVEMENT OF PV SYSTEM BY DIFFERENT METHODS

Performance improvement of PV panel by means of all the systems nearly involves the process of increasing the sun light radiation intensity over the panel, which in turn increases the output current accordingly and output voltage is somewhat increases. The relation between voltage and current of a PV cell is shown below [9]:

$$V_{OC} = \frac{kT}{e} ln\left(\frac{I_{ph}}{I_{01}} + 1\right) \quad (A)$$

Where,
V_{OC} = Open circuit voltage
k = Boltzmann constant
T = Device temperature
e = Elemental charge
I_{ph} = Photo current
I_{01} = Current due to recombination of bulk charge carriers

In this experiment, the method which is used is simply the tracking of sun. While another mean for improving output of PV module is using the concentrator or simple reflecting mirrors. In this paper we will be using commonly used reflecting mirrors for performance improvement of PV module. Cooling solar panel is another way for performance enhancement which has been shortly overviewed below.

Precise overviews sun tracking, light reflection and panel cooling methods for performance enhancement are illustrated below:

I. Tracking of Sun

Solar tracking is a very important method for enhancing the solar panels output. But truly, it has not become that much popular. Sun tracking is done in order to get the maximum amount of sun light. Experiments have shown that, it is a very simple and effective way for improving the yield of solar panel system by almost 20% [10]. However, drawback of this system is that, during running, it dissipates some electric power which is itself produced by the PV panel**.** It requires very advanced machine and much trained personnel as well as maintaining employee on daily basis**.** Those details tend to increase the setting up cost and tracking system maintenance.

Other drawback in addition is that, if there is any breakdown falls in the system which is specifically situated in the rural parts of the country, for example Pakistan etc., then that will be really laborious to arrange the trained personnel for the required maintenance or repair. Or if, a fault appears in the circuit and the solar panel is aligned towards the west before noon, the entire output would fall down drastically from the solar panel. So, the PV solar system will then not be able to convey even 24% of the rated out put power during mid-night.

II. Concentrated and Dispersed Light Reflection

Concentrated and dispersed light reflectors tend to reflect intense as well as focused sun light radiation but

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expends them approximately unvarying over the solar panel by means of dispersed light radiation. That's a convenient method which is so useful especially on bright days, as it considerably enhances output of PV module**.** Moreover, in addition to that, it also tends to minimize the hazards of hot spots development because of intensity of thrown back radiation on some section of panel, which therefore, not only enhances the performance but also increases life-time of PV modules. Taking the advantage of little cost as well as lightweight, it is unchallenging to stand it erect. Another drawback is, its mechanical strength, because of gusty winds, diffused reflectors are subjected to damage easily.

A. Selection of Cooling Site

As the panel surface gets heated with extra light radiation, it needs fast cooling for better performance. Cooling of the panel could be performed either from downside or topside. In this design, to avoid extra cost system has been placed in a site where natural air could cool it.

III. Reflecting Mirrors

Reflection of light through mirrors is the easiest and most effective way of light reflection. By reflecting light over the solar panel, output currents and nominal voltage increases, therefore, improves the performance of the PV panel system. After obtaining the field data, it was observed that improvement of output current by panel after using reflecting plane mirror was greater than the tracking of sun. Secondly, plane reflecting mirrors are very economical and easily available everywhere.

IV. Experimental Setup

Considering the geometry of sun and earth and position of Pakistan on map, a PV module was kept inclined at 34.5 degree to horizontal axis**.** Solar panel was positioned to the north-southern direction. The reflecting mirrors had attached to the edges of the solar panel. The mirror was aligned in such a ways that maximum amount of sun radiation was reflected over the solar panel. If size of the reflecting mirror is identical to the size of the solar panel then experiments show that it must be inclined at 120^0 to get the maximum output of the panel, but if, the size of the mirror is twice the size of the solar panel then there is no need of exact 120^0 inclination.

Below are the some mentioned electrical specifications of the solar panel used in the experiment:

[At STC (1000 W/m^2, AM 1.5 spectrum and 25 degree of cell temperature)]

Peak Power (Pmax) : 10.0W
Voltage (Vmp) : 17.0V
Current (Imp) : 0.58 A
Open Circuit Voltage (Voc) : 21.6 V
Short Circuit Current (Isc) : 0.68 A
The dimension of PV panel used was 0.357mx0.302m
And the dimension of each mirror was 0.55m×0.6m

Two reflecting mirrors were used for reflection of sun-light over the panel at any time of the day. The dimensions of the reflecting mirrors used are 0.55m x 0.6m.

The experimental setup is shown below in the fig. 2.

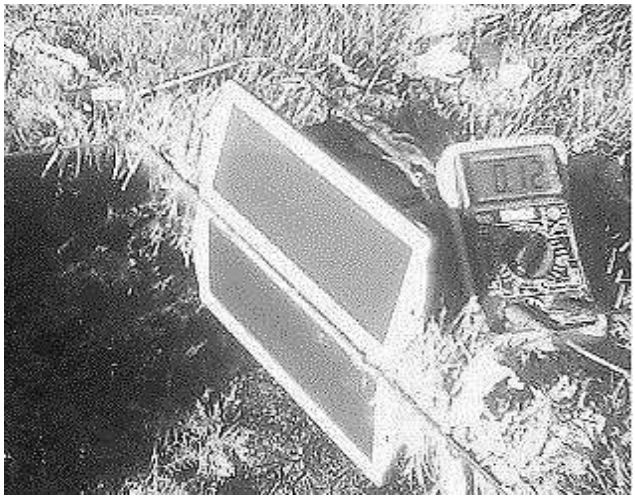

Fig. (2) Solar Panel with reflecting mirror and digital multimeter

V. Results

The experiments were performed on a clear bright and sunny day. The obtained data, was recorded, and summarized graphically and represented below in Fig. (3), (4) and (5) respectively.

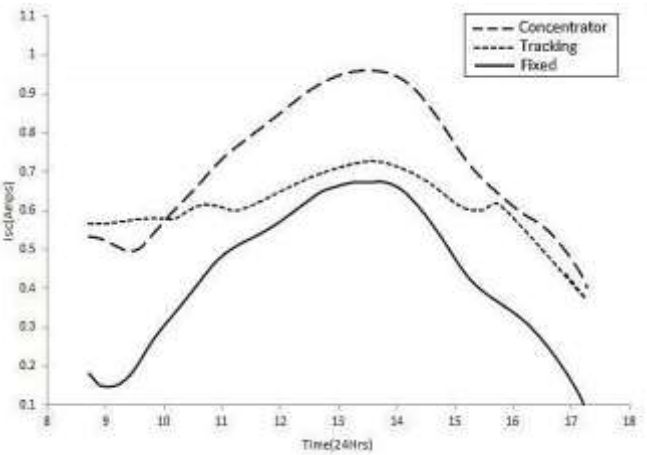

Fig. (3) Short circuit current (Isc) timely changes of PV module at various circumstances: i) When PV module is fix at 33.5^0 to x-axis, ii) Tracking of

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PV module with sun-light, iii) Reflection of sun light rays over the solar panel surface by reflectors

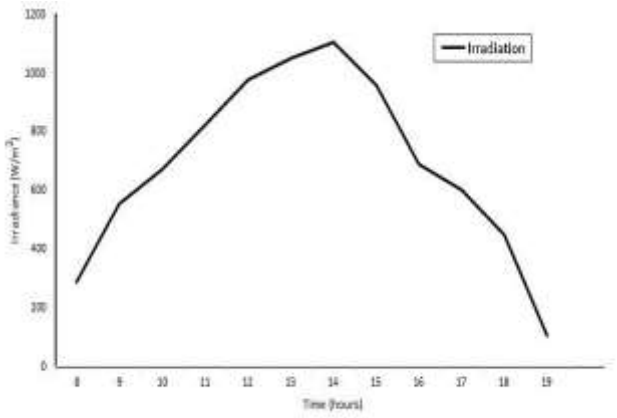

Fig. (4) Solar Irradiance vs. Time graph determined by pyranometer

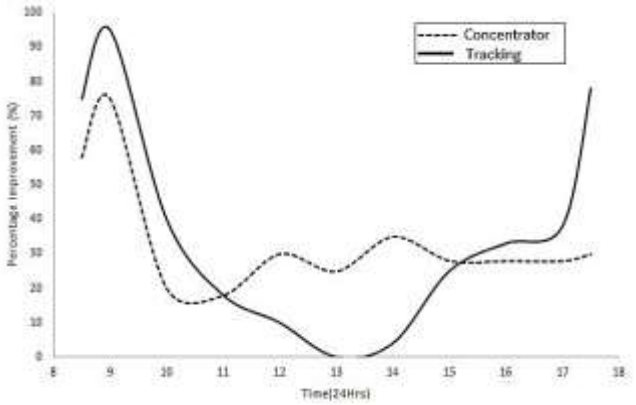

Fig. (5) Percent enhancement of Isc of PV module due to reflection and tracking

VI. Discussion of the Results

From curves in fig. 3, it can be concluded that, for any said time during a day, the value of short circuit current Isc with reflector is always higher than the Isc without reflectors. When the day is sunny and clear, it is obvious that radiation intensity will be maximum at noon so the power output will more. Power increases gradually from morning to noon, however, it starts decreasing in the afternoon. In fact, improvement of solar panel best occurs with the mirror during the mid-day, when short circuit current with reflectors goes higher than the short circuit current with tracking over a wide range. It occurs roughly from 12 pm to 3 pm that is for 3 hours a day. In these hours, we get the maximum solar radiation. So, improvement in this part of the day is more beneficial as compared to morning and afternoon. It has been seen that, the average increase in Isc was about 20% more than sun tracking and 25% more than above that of the fixed panel without using the mirrors, in major part of the day. However, optimization of mirror size can make the panel to perform even better. In those cases, an additional 5-10 % performance enhancement from the solar panel system can be expected. Another point that is worth mentioning, regarding the experimental data that has been recorded, that the readings were noted under different methods but with some time gap, and during that passage of time, the pyrometer readings were almost unchanged, which suggests that there was nearly no alteration in solar irradiance during the transition period.

Conclusions

The results obtained show that, use of plane mirror for improving the performance of the solar panels have shown impressive results. An important advantage of using of plane mirror is that, they are inexpensive, cost-effective and easily available in the market. It is making the usage of solar panel more feasible in developing countries of the world like Pakistan, reducing the overall cost of electricity generation and improving the efficiency by PV solar system at home. Another advantage, is the easy installation and cheapness of this system.

As output of average power has increased considerably during mid-day using mirrors, so the panels which are equipped with mirrors are also able to be used for those equipments which require high rating power inputs during that part of the day time. An example of such kind of load is the running of water pumps which are being used for irrigation purposes. Setup of these reflectors is very simple, they can be attached to any kind of wood, or even bamboo would be able to support the whole structure. In spite of the better performance advantage that have been mentioned, there are also some shortcoming which have been highlighted with some possible solutions:

i) Because of the uneven distribution of light radiation on the surface of solar panel, formation of heated spots is very liable. This is, however, can be overcome by making the size of the reflecting mirror a little bit bigger than the size of the panel, setting as well as maintaining it in a careful manner so that a uniform distribution of reflected light can be ensured.

ii) By using reflectors with large surface area, strong and gusty winds may cause damage to them by making them unstable. But this can also be overcome by setting up strips of reflectors in louvers way on the extreme edges of solar panels.

One maintenance which is mostly required, is the cleansing of these mirrors. They need to be cleaned on daily

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basis and have to be set satisfactorily so that the reflected rays are distributed uniformly over the entire solar panel for giving the favorable performance.

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REFERENCES

[1] A special report on direct solar energy. Available Web-link: http://srren.ipccwg3.de/report/IPCC_SRREN_Ch03.

[2] "The history of Solar Energy, Energy Efficiency and Renewable Energy," U.S. Department of Energy.

[3] Mitchell K, Rizk J, Nagrial M, Development of planning procedures with embedded solar systems, Australian Journal of Electrical & Electronics Engineering, vol 3, no.1, pp 57-64, 2006.

[4] Jiménez V. 2004 [online]. World Sales of Solar Cells Jump 32 Percent. Earth Policy Institute. Retrieved: August 7, 2000.

[5] Özge Demir Baúak, Bekir Sami Sazak, Effect of components on a solar panel system Efficiency, Volume: 03, Special Issue: 17, page: 8,| IACEIT-2014 | Dec-2014, Available @ http://www.ijret.org.

[6] Sungur, C., Multi-axes Sun-tracking System with PLC Control for Photovoltaic Panels in Turkey, Journal on Renewable Energy, vol. 34, pp. 1119-1125, 2009, Published by Elsevier Publications.

[7] Kalogirou SA, Tripanagnostopoulos Y. Hybrid PV/T solar systems for domestic hot water and electricity production. Energy Convers Manage 2006; 47:3368–82.

[8] Tang, X., Zhenhua. Q., Zhao, Y., Experimental Investigation of Solar Panel Cooling by a Novel Micro Heat Pipe Array, Journal of Energy and Power Engineering, vol. 2, pp. 171-174, 2010.

[9] "Introduction to PV Technology," *Photovoltaic Technology for Bangladesh*, pp. 62-63. Department of Mechanical Engineering, Bangladesh University of Engineering & Technology, Dhaka, Bangladesh, March 2003

[10] Ali Al-Mohamad, "Efficiency improvements of photo-voltaic panels using a Sun-tracking system," Atomic Energy Commission of Syria