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Effect of Derating Factors on Photovoltaics under Climatic Conditions of Istanbul

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***Abstract*—**As known that efficiency of photovoltaic cells is not high as desired level. Efficiency of PVs could be improved by selecting convenient locations that have high solar irradiation, sunshine duration, mild temperature, low level air pollution and dust concentration. Additionally, some environmental parameters called derating factors effect to decrease PV efficiencies such as cloud, high temperature, aerosol optical depth, high dust concentration, shadow, snow, humidity etc. In this paper, all parameters that effect PV efficiency are considered in detail under climatic conditions of Istanbul. A 750 Wp PV system with measurement devices is constructed in Maslak campus of Istanbul Technical University.

***Keywords*—**Efficiency, Derating Factor, Istanbul, Photovoltaic.

I. Introduction

LIFE is directly affected by energy and its consumption. Research to resolve problems related to energy is therefore important. The solar photovoltaic (PV) cell applications is one of the most alternative significant and rapidly developing renewable-energy technologies, and its potential future uses are notable.

With the growing significance of environmental issues, clean energy generation has become increasingly important. Solar radiation is a clean energy source, but it does not persist continually for long durations at a given location. Fossil fuel-based electricity generation is often completed with PV systems. But efficiency of PVs is generally low and many studies have addressed to increase this parameter [1].

During the last decade, PV applications have increased and extended to industrial use in some countries. The clean, renewable and in some instances economic features of PV systems have drawn attention from political and business decision makers and individuals. Advances in PV technology have also led to increased usage.

Photochemical energy converting systems, which include photoelectric devices and biological photosynthesis, operate by collecting a fraction of the radiation within some range of wavelengths. Photon energies greater than the cutoff, or band-gap, energy is dissipated as heat, and photons with wavelengths longer than the cutoff wavelength are not used by PV devices. Theoretical thermodynamic limits on the efficiency of photochemical solar energy conversion have been investigated by Ross and Hsiao [2]. Wurfel [3] also discusses thermodynamic limitations on solar energy conversion, based on an entropy concept, and calculates the upper efficiency as 0.86 for maximally concentrated solar irradiation. Smestad [4] examined concepts of hot carrier and light converter, indicating that electrons are ejected not only as heat but also as light. The Carnot factor in PV cell theory has been studied by Landsberg and Markvat [5]. They obtained an expression for open-circuit voltage which is equal to the bandgap multiplied by the Carnot efficiency. Physical and chemical principles of photovoltaic conversion are presented by Bisquert et al. [6]. They find the relation between chemical potential and open-circuit voltage of a PV cell to be dependent on Carnot and statistical factors. Markvart and Landsberg [7] also discuss the thermodynamics and reciprocity of solar energy conversion by considering PV, photochemistry and photosynthesis.

Dincer and Rosen [8] have investigated thermodynamic aspects of renewables for sustainable development. They explain relations between exergy and sustainable development. The energy conversion factor of a solar photovoltaic system sometimes is described as the efficiency, but this usage sometimes leads to difficulties. The efficiency of a solar photovoltaic cell can be considered as the ratio of the electricity generated to the total, or global, solar irradiation. In this definition only the electricity generated by a solar PV cell is considered. Other components and properties of PV cells, such as ambient temperature, cell temperature and chemical components of the solar cell are not directly taken into account.

Bergauer _Culver and Jäger [9] investigated the dependence of the yield of photovoltaic power plant (PVP) on the altitude of the site in the Austrian Alps. They observed a meaningful increased trend of energy yield with increasing altitude. They also noticed that haze and fog affect the yield especially in autumn. Besides the clearer sky and snow reflection at higher locations, the lower temperature and better cooling of the panels by the wind in the alpine area contribute to the higher energy output. They also used a ventilation factor to calculate the PV efficiency.

Wirth et al.[10] compared the satellite-based datasets with ground measurements from German and Swiss meteorological stations. They found a significant difference among the datasets in the error pattern shifting from too much snow (which results in an error due to underestimation of irradiance) to too little snow detection, causing a false alarm in PV monitoring. Because satellite does not have a flasher that recognizes, if it is snow or cloud.

Armstrong and Hurley [11] improved a methodology by combining hourly cloud observations with monthly sunshine hours data so they were able to decide if the sky is clear, partly cloudy or overcast.

Al-Hasan [12] investigated the effect of sand dust layer on beam light transmittance at a photovoltaic module glazing

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surface. In this paper the transmittance coefficient for beam light with respect to the number of sand dust particles per unit area of glazing surface, size of the particles, beam light incidence angle and wavelength is defined. Finally, the direct solar radiation received by a tilted photovoltaic panel covered with sand dust particles is evaluated [12].

Bücher [13] found that the module operating conditions change the efficiency of PV modules. The module performance ratio as a function of various meteorological parameters describing the installation site is described.

Sangpanich et al. [14] compared a PV grid-connected system with a simulation of pv power using a DC generator. They examined slow or fast changes in PV DC power output due to cloud movements.

Topič et al. [15] studied pv module performance and they defined the effective efficiency of PV modules based on the local irradiance and temperature data.

Ketz [16] noticed the effect of dust on photovoltaic cell productivity is amount of rain and location of PV panels. He determined that the most important factor in the amount of performance degrading dust accumulation is rain.

California Energy Commission has stated that temperature reduces the pv efficiency with the rate of 89 %, and dust and dirt on the panel have a reduction factor as 93 % [17].

Şahin et al. [18], suggested a new formulation for PV exergy efficiency depend on chemical and physical properties of solar cells. In this paper the main losses of the PV cells and solar irradiation limitation are considered in detail. Thermodynamic properties of solar irradiation are taken very important role during electricity generation from PV cells.

II. System and Steady Area

A PV solar power measurement system is constructed in the meteorological park of Istanbul Technical University in Istanbul. This system has a 750 W power solar panel and direct to diffuse solar irradiation measurement devices. There are 1.5 kW wind turbine, 4.8 kW battery system, regulator, inverter and generated electricity is used for lighting of the park. Istanbul, where both continental and maritime climatic effects can be observed, is located in the northwestern part of Turkey. This area comes under the influence of mild Mediterranean climate during the summer months, and consequently experiences dry and hot spells for about 4-5 months. Virtually, there is rainfall throughout each year, but comparatively small amounts are measured in the summer months. During the wintertime, this region comes under the influence of high pressure at Siberia and Balkan Peninsula, low-pressure system from Iceland. Hence, northeasterly or westerly winds influence the study area with high rainfall amounts in addition to snow every year with cold and wet spells. Air mass originating over the Black Sea also penetrates the study area, Şahin [19].[Fig. 1a and 1b].

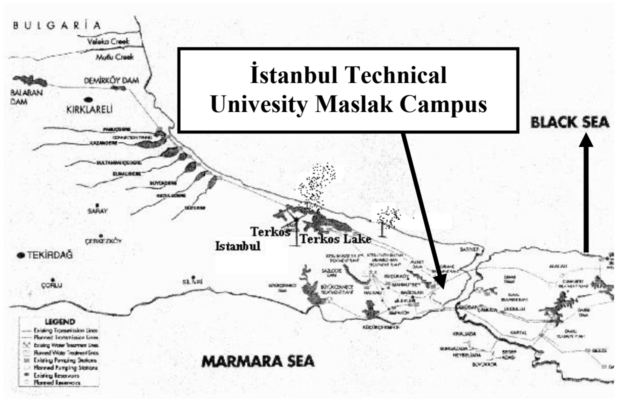

Fig. 1(a) Study location of this project

Fig.1(b) Considered system

III. Application

As mentioned in the previous section, a new hybrid system has been constructed in meteorological park of Istanbul Technical University. This system is constructed to search general characteristic of renewable energies under climatic conditions of Istanbul. As a result of performance a new suggestion will be given to construct this kind of small-scale solar photovoltaic cell in Istanbul or not. Additionally, one of the other aims is to see the best conditions for electricity generation by PV panel. In this paper, only electricity generation by PV is considered. The power curve of this PV system is given in Figure 2.

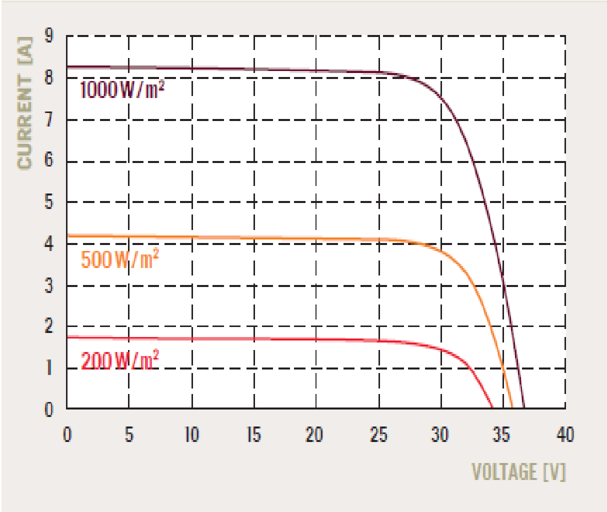

Fig. 2 Power curve of the considered system

This area has moderate solar irradiation potential conditions. But during summer seasons in other words in June, July and August high potential solar irradiation is observed. Generated electricity by the system and measured solar irradiation values could be seen for August in Figure 3. It is seen that 1100 W/m^2 solar irradiation under clear air conditions is observed during considered time interval. Additionally, linearity and certainty of the system is disturbed with some data that mostly under imaginary linear equation curve. These uncertainties should be investigated to understand ability and capability of the system (Figure 3).

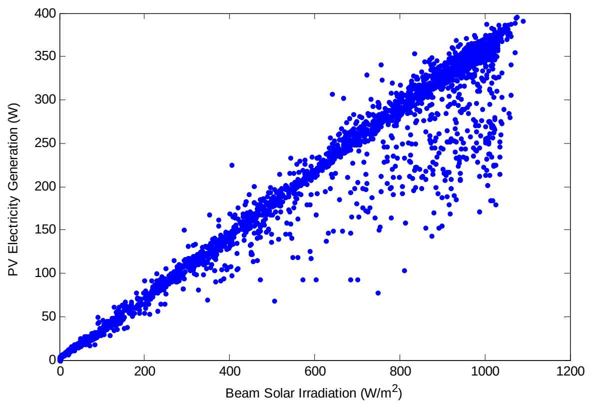

Fig. 3 Measured direct solar irradiation and generated electricity by 750 Wp PV system.

In addition to direct component, diffuse solar irradiation is also measured during this project. Not only in İstanbul but also in Turkey it is not easy to find diffuse solar irradiation measurement and to understand PV systems behavior under cloudy conditions. It is seen that there is no linear relation between diffuse solar irradiation and PV system electricity generation. Especially at lower diffuse solar irradiation data in other words during clear air conditions electricity generation amount is high. In Figure 4, there are two groups of data, one of them represents minimum diffuse irradiation and other one represent maximum values of this component and especially a linear relation could be seen for electricity generation at second group.

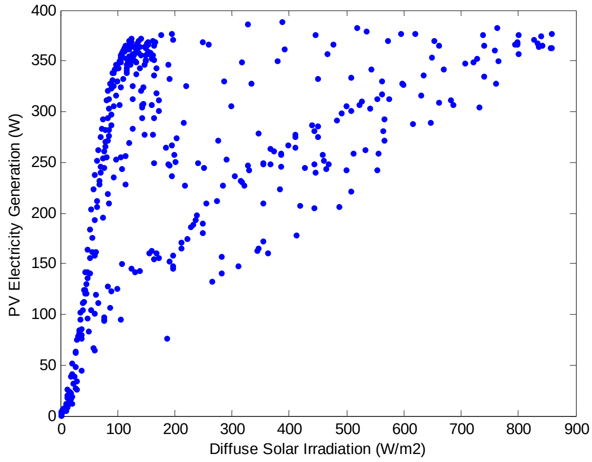

Fig. 4 Diffuse solar irradiation and PV electricity generation for considered system

Another important parameter for PV panel system is the cell temperature and as known that high temperature values cause to heat losses and as a result of this efficiency of the system is decreased. When heat losses are increased the expected electricity generation could not be occurred (Figure 5). Theoretical details of heat losses and efficiency relation is also given by Şahin [18] based on exegy approach.

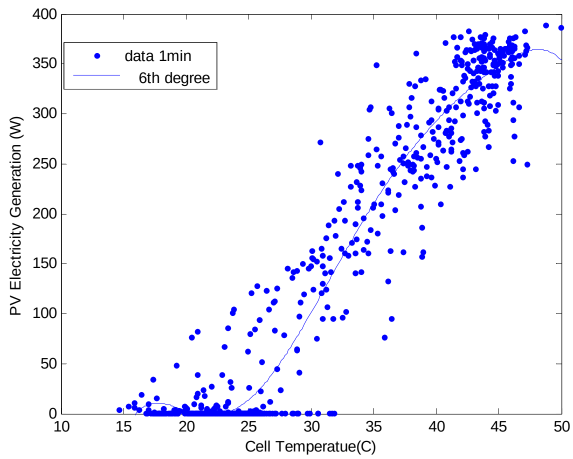

Fig. 5 PV cell temperature and electricity generation

A. PV Efficiency

The expressions for energy (η) efficiency for the principal types of processes considered in the present study are based on the following definitions:

η = (energy in products/total energy input)

For solar PV cells, efficiency measures the ability to convert radiative energy into electrical energy. The electrical power output is the product of the output voltage and the current out of the photovoltaic device, taken from the current-voltage curve (I-V curve). This conversion efficiency is not a constant value, even under constant solar irradiation. However, there is a maximum power output point, where the voltage value is V_m, which is less than the open-circuit voltage, V_{oc} but close to it, and the current value is I_m, which is less than the short-circuit current, I_{sc} but close to it as well (Figure 2). The maximum power point is restricted by a "fill factor", which is the maximum power conversion efficiency of the photovoltaic device:

$$FF = \frac{V_m I_m}{V_{oc} I_{sc}} \qquad (1)$$

In addition, there is a dependence on the fill factor solar cell power conversion efficiency *pce*, which is estimated as

$$pce = \frac{V_m I_m}{H_T} \qquad (2)$$

With Eq. (2), *pce* can be written as

$$pce = \frac{FF \times V_{oc} I_{sc}}{H_T} \qquad (3)$$

where H_T is solar irradiation.

In this paper, relation between PV efficiency and other components are considered and unexpected situations occurred at the first view. After that it is understood that there is no problem relation between PV efficiency and other components. Especially in the main idea, if direct solar irradiation is high solar PV efficiency should be high. This approach is true for electricity generation but for efficiency, received direct solar irradiation amount to the total area is taken most important role. In other words, PV system could not protect or increase its efficiency ratio at high direct or diffuse solar irradiation components (Figure 6a-6c). If PV system has this ability generated electricity should be twice or three times higher than the present situation.

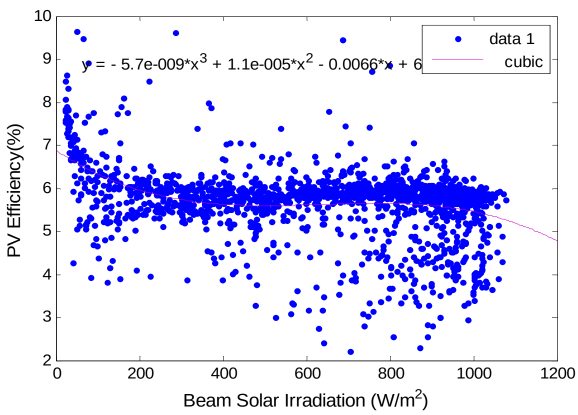

Fig. 6 (a) Relation between direct solar irradiation and PV

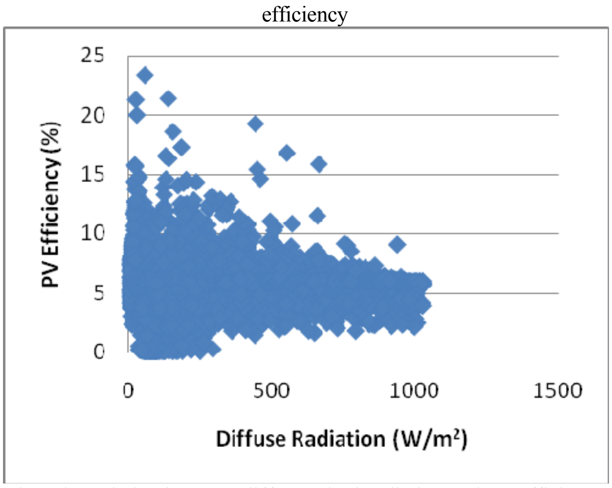

Fig. 6(b) Relation between diffuse solar irradiation and PV efficiency

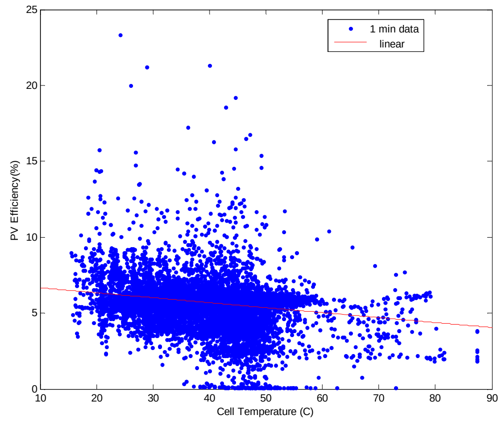

Fig. 6 (c) Relation between cell temperature and PV efficiency

IV. Conclusion

In this paper a 750 Wp PV system application is considered under climatic conditions of İstanbul. Addition to PV system, direct and diffuse components of solar irradiation and cell with air temperatures are measured. It is clearly seen that during high direct solar irradiation in other words at low diffuse component electricity generation is getting higher. But in contrast to this, depend on received high amount of direct solar irradiation efficiency is not high. Additionally, cell temperature effect to PV efficiency is not clear and in the further works this subject will be focused for understanding real attitudes of the system.

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References

[1] Z. Şen, Progress in Energy and Combustion Science, 30(4) (2004) 367-416.

[2] R.T. Ross and T.L. Hsiao, Journal of Applied Physics, 48(11) (1977) 4783-4785

[3] P. Wurfel, Physica E, 14 (2002) 18-26

[4] G.P. Smestad, Solar Energy Mater. & Solar Cells, 82, (2004) 227-240.E. H. Miller, "A note on reflector arrays (Periodical style—Accepted for publication)," *IEEE Trans. Antennas Propagat.*, to be published.

[5] P.T. Landsberg, and T. Markvart, Solid-State Electronics, 42(4) (1998) 657-659.C. J. Kaufman, Rocky Mountain Research Lab., Boulder, CO, private communication, May 1995.

[6] J. Bisquert, D. Cahen, G. Hodes, S. Ruhle and A. Zaban, Journal of Physical Chemistry B, 108(24) (2004) 8106-8118.

[7] T. Markvart and P.T. Landsberg, Physica E, 14, (2002) 71-77.J. U. Duncombe, "Infrared navigation—Part I: An assessment of feasibility (Periodical style)," *IEEE Trans. Electron Devices*, vol. ED-11, pp. 34–39, Jan. 1959.

[8] I. Dincer and M.A. Rosen, Renewable & Sustainable Energy Reviews, 9, (2005) 169-189.R. W. Lucky, "Automatic equalization for digital communication," *Bell Syst. Tech. J.*, vol. 44, no. 4, pp. 547–588, Apr. 1965.

[9] B. Bergauer-Culver, C. Jäger, "Estimation of The Energy Output of A Photovoltaic Power Plant in The Austrian Alps," *Solar Energy*, vol. 62, no:5, pp. 319-324, 1998.

[10] G. Wirth, M. Schroedter-Homscheidt, M. Zehner and G. Becker, "Satellite-based snow identification and its impact on monitoring photovoltaic systems," Solar Energy 84(2010) 215-226

[11] S. Armstrong, W.G. Hurley, "A new methodology to optimize solar energy extraction under cloudy conditions," *Renewable Energy*, vol. 35, pp. 780-787, 2010.

[12] A. Y. Al-Hasan, "A new Correlation for direct beam solar radiation received by photovoltaic panel with sand dust accumulated on its surface," *Solar Energy*, vol. 63, no. 5, pp. 323-333, 1998.

[13] K. Bücher, "Site dependence of the energy collection of PV modules," *Solar Energy Materials and Solar Cells,* vol. 47, pp. 85-94, 1997.

[14] U. Sangpanich, J. Thongpron, K. Kirtikara and C. Jivacate, "Study of Moving Cloud Effects on th Power Quality of Grid-Connected Photovoltaic System Compared with Simulation of PV Power Using a DC Generator," *Technical Digest of the International PVSEC-14*, pp. 959-960, 2004.

[15] M. Topič, K. Brecl and J. Sites, "Effective Efficiency of PV Modules under Field Conditions," *Progress In Photovoltaics: Research and Application,* vol. 15, pp. 19-26, 2007.

[16] G. Katz, "The effect of dust on photovoltaic cell performance," unpublished.

[17] California Energy Commission. "A Guide to Photovoltaic System Design and Installation". June 2001

[18] A. D. Şahin, I. Dincer, and M. A.Rosen. "Thermodynamic Analysis of Solar Photovoltaic Cell Systems" *Solar Energy Materials and Solar Cell,* 91, 153-159, (2007).