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Review Article

The Importance of Solar Panel Maintenance an experimental study on effectiveness of PV panels cleaning with deionized pure water in Turkey

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Abstract

Energy has a vital importance on the behalf of social and economic development. In more recent times and nowadays, solar power has been getting more important in the sense of its high flexibility and reliability when the potential of the MENA Region and geopolitical location of Turkey are considered. Photovoltaic (PV) technology has the largest share among the other solar technologies and in the regard of reliability of PV panels, accumulated Aeolian dust and dirt reduce system performance. Thus, this study intentionally aims to focus on efficiency and productivity of the panels associated with their periodical cleaning. For this purpose, voltage and current measures were scaled and fluctuant total outputs were observed. In accordance with the results, it is able to be asserted that cleaning of regarding PV modules is essentially needed. By doing so, overall productivity is being increased while operational lifetime of the entire power plant can be prolonged as well as avoiding degradation.

Keywords: Environment, clean energy, efficiency, energy, measurement, solar, photovoltaics.

Solar Panel Bakımının Önemi Türkiye'de iyonize edilmemiş saf su ile PV panel temizliğinin etkinliği üzerine deneysel bir çalışma

Öz

Enerji, sosyal ve ekonomik kalkınma için hayati bir öneme sahiptir. MENA Bölgesi'nin potansiyeli ve Türkiye'nin jeopolitik konumu düşünüldüğünde, son zamanlarda ve günümüzde yüksek esneklik ve güvenilirlik anlamında güneş enerjisi daha da önem kazanmaktadır. Fotovoltaik (PV) teknolojisi, diğer güneş enerjisi teknolojileri arasında en büyük paya sahiptir ve PV panellerinin güvenilirliği açısından, biriken Aeolian tozu ve kir, sistem performansını düşürür. Bu nedenle, bu çalışma, kasıtlı olarak, periyodik temizliği ile ilişkili panellerin verimliliği ve üretkenliğine odaklanmayı amaçlamaktadır. Bu amaçla gerilim ve akım ölçüleri ölçeklendirilmiş ve dalgalı toplam çıktılar gözlemlenmiştir. Eldeedilen sonuçlara göre, PV modülleri ile ilgili temizliğin esasen gerekli olduğu söylenebilir. Böylelikle, genel üretkenlik artırılırken, tüm santralin çalışma ömrü uzatılabildiği gibi bozulma önlenebilir.

Anahtar Kelimeler: : Çevre, temiz enerji, verimlilik, enerji, ölçüm, güneş, fotovoltaik

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1. Introduction

Energy is one of the most crucial needs of our modern lifestyle and in line with the latest technological developments; demand of regarding energy is ever-increasingly rising. However, as well as faced environmental problems, accessibility and availability of energy underline the importance of renewable energy sources, specifically solar energy recently [1].

The sun is the main source of energy for our world. We currently use fossil fuels as our main energy source, but fossil fuels are not suitable fuels for the future and health of our world. It is possible to use environmentally friendly solar energy as a renewable energy source [2].

To the use of solar energy, which is one of the environmentally friendly renewable energy sources; The interest increases as time progresses, as it is easy to manufacture and install from one watt to mega watts, appeals to every segment, and provides a quick solution to energy needs.[3, 4].

With respect to its geographical position with yearly high quantity of sun radiation and modern grid network, Turkey becomes center of interest on behalf of solar systems [5].Bright sunshine duration is perhaps the most important measured parameter. The use of meteorological satellites and earth data is of great importance in predicting solar irradiation. Estimation of the global solar irradiation on a horizontal surface is vital for the performance calculations of solar converters and for all related energy systems in building and urban applications. [32-35]. Moreover, in accordance with the potential, generated energy from solar power in Turkey has been increasing rapidly due to many beneficial circumstances as profitable feed-in tariff politics with additional governmental subsidies, suitable application locations and modularity [6].

Basically, PV panels or solar panels are required for us to convert solar energy into electrical energy. In parallel with the increase in the amount of energy obtained from solar energy, PV panel production is also increasing. [7]. Among the solar applications, PV technology has the flagship position with its application share [8-9]. “During 2016, 75 GW of solar PV capacity was added worldwide, which is equivalent to the installation of more than 31,000 solar panels every hour.” [6] Fast forward a couple of years and behold the rapid need of accessible energy, advanced PV systems are going to be spread all through entire Turkey. On the other hand, with these progressively expanding solar implementations, a very essential question has been rising currently; how it could be possible to maximize the energy yield in terms of getting better operation and maintenance actions done [6-7].

In the fixed homogenous working environment, similar solar modules receive similar radiation and give similar rated power output, as outside surface temperature of the modules seem steady [8]. However, under inhomogeneous conditions as partial shadow, dust or dirt, the formerly mentioned outcomes cannot be observed obviously [8-9]. The soiling over solar cells creates a barrier between radiation and the cells; and as a result of this accumulation of both dust and dirt and some other scales, efficiency reduces sharply, while degradation of the modules during the lifetime increases [10-11]. In addition to that, as the physical characteristics of these modules are considered under various working conditions, it is able to be realized that surrounding and environmental conditions play a critically important role for the point of better plant operation and maintenance actions as well [12].

There are many cleaning techniques that are presently used to clean the PV panel service, like wiping and brushing. Unfortunately, these methods are not very efficient in removing minuscule particles and pollutants most of the time. Also, they may raise the corrosion and new impurities due to abrasion. Because of this, there are many alternative methods that are much more suitable for cleaning PV panels such as electrostatic and dielectrophoretic forces, using a robotic device for cleaning PV panel arrays, and employing super hydrophobic nano-self cleaner [17-18].

This study aims to focus on efficiency and productivity of PV modules associated with their periodical cleaning. In the scope of this paper, working conditions of regarding modules were monitored and amount of produced power noted. With relation to the different cleaning schedule, efficiencies were calculated and the results were stated with operational suggestions.

2. Solar Power in Turkey

Turkey has quiet significant solar power potential due to its geographical location (36° and 42 °N latitudes). The country located on the Mediterranean Climate Zone, which is close to the MENA region; and receives 3.6 kW h/m2day average radiations yearly. In another words, Turkey has almost 2610 h total yearly radiation period (7.2 hours per day), which carries the country rank among the top three with Spain and Portugal in Europe [3-9].

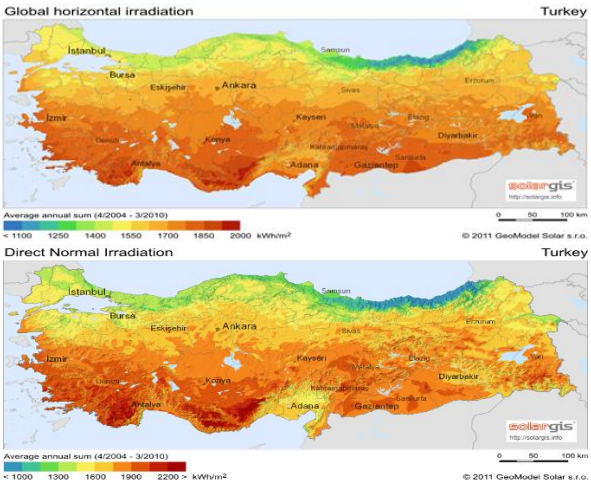


Figure 1: Irradiation maps of Turkey (GHI & DNI)

Formerly, Turkey was abandoned on the point of solar power, but in accordance with the potential as shown above (see Figure 1), Turkey has been officially trying to spread PV system technology throughout the entire country these days. Cumulated

with the new investments, the government aims to expand the total installed capacity from 600 MW to at least 3 GW by 2023 as a future plan [8-9]

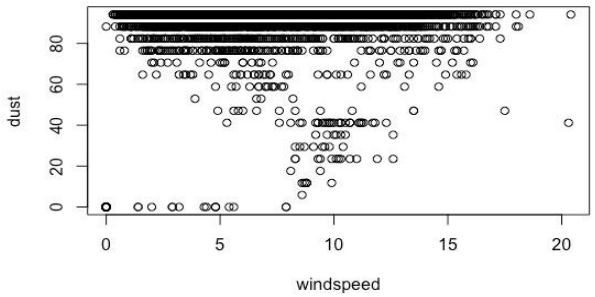


Figure 2: Wind speed (m/s) and dust (µm) interaction diagram

3. Research Aim and Methodology

In this study, via a statistical analysis, the main ambition was to see the real effects of dirt and dust, on outputs from a PV power plant, in terms of efficient operation and maintenance such as the cleaning process. As heretofore asserted in concerning literature, particles, which are carried by wind, cover the plants and decrease the power about 40% at least [19-20]. In addition to that, as if these particles heap together on a certain point, they cause partial shadow effect and lead to temperature increases on corresponding cells, which reduce the efficiency as well [21]

First of all, a suitable solar power plant was chosen for condition monitoring and data gathering. The expected main criteria from the selected solar power plant were to reflect the general solar radiation characteristics of Turkey in accordance with the Mediterranean climate belt. The Aegean Region was one of the most important alternative options and therefore, it was decided on 250 kW powered solar power plant of Izmir KatipCelebi University (IKCU) in Cigli, Izmir (see Picture 1).

Picture 1: IKCU solar power plant

At the beginning of this study, real time operational data under expected conditions was collected as time series during the electricity generation from the power plant and subsequently merged with the core plant data. Respecting time series data contain the outputs, which comes from 3 different groups of plants according to their cleaning regularity.

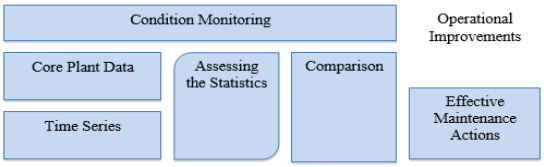
As the interaction between the wind and dust were observed, it was clear to see with increasing speed of wind carries more dost on the modules in the test area.

Coefficients:

	Estimate	Std. Error	t value	Pr (>|t|)	
(Intercept)	89.57398	0.25135	356.367	2e-16 *	(1)
Wind Speed	0.20822	0.03282	6.345	2.34e-10 *	(2)

Here, p-values are smaller than 99% significance level (0.01) therefore, wind speed parameter seems significant.

While these statistics were being assessed, operational loses, due to dirt and dust on the plants, were determined. Afterwards, the results were compared with other experiments and at last, suggestions were given in connection with operational improvements and effective maintenance actions under cleaning subtitle as shown below (see Table 1):



4. Case Study

In spite of the fact that there are many highly radiated locations in Turkey, the power plant of IKCU was chosen because of its suitable terrain and climate variety under the Mediterranean climate belt. The power plant has 250 kW generation capacity with new type SunPower E20 series monocrystalline (E20-245) panels, which have the highest efficiency rate in the market as asserted by the National Renewable Energy Laboratory (NREL) in the USA. General technical specifications are given below (see Table 2):

Table 2: General technical specifications of the PV panels

SunPower E20-245 Solar PV Panels	
Nominal Power	245W
Power Tolerance	+5/-0%
Avg. Panel Efficiency	20.0%
Rated Voltage (Vmpp)	40.5 V
Rated Current (Impp)	6.05 A
Open-Circuit Voltage (Voc)	48.8 V
Short-Circuit Current (Isc)	6.43 A
Max. System Voltage	600 VUL&1000 V IEC
Power Temp Coef.	-0.38%/C
Voltage Temp Coef.	-132.5mV/C
Current Temp Coef.	3.5mA/C
Cell type	Monocrystalline

Preliminarily, according to the test suite structure and main purpose, the same type series panels were divided into 3 main groups homogenously, which haven't had any cleaning action in defined time dilemma (see Table 3).

Table 3: Experiment groups

250 kW IKCU Solar Power Plant	Uncleaned Time
Group I	2 weeks (14 days)
Group II	4 weeks (28 days)
Group III	8 weeks (56 days)

In conjunction with shown division on Table 3, there was no specific criterion literally. The time intervals were chosen randomly and only data and comparison axiom accuracy were targeted in this regard.

Therefore, total power outputs of these panels were measured daily under the same sun angle, which can be seen below (see Figure 3), and the statistics were noted.

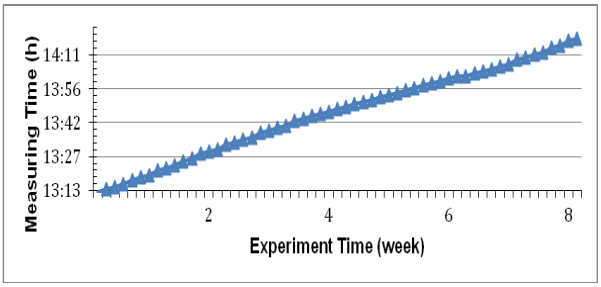
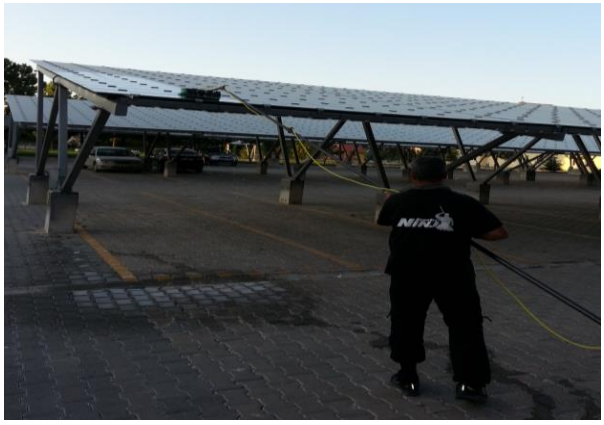


Figure 3: Measuring time of the outputs

The first group of panels was cleaned only once in 2 weeks, the second group was cleaned once in 4 weeks and following third group was cleaned once in 8 weeks during the 8 weeks experiment. During the cleaning process, deionized water was used because of its purity with a special brush [16] (see Picture 2-5).



Picture 2: Cleaning of PV panels with deionized water and a special brush

Picture 3: Cleaning of Group I (after 2 weeks)

Picture 4: Panel Group II (after 4 weeks)

Picture 5: Panel Group III (after 8 weeks)

And overall outputs were illustrated with I-V curves, which show the interaction between current (I) and voltage (V) (see Figure 4).

5. Experimental Results

From Current and Voltage information, generated power was observed essentially.

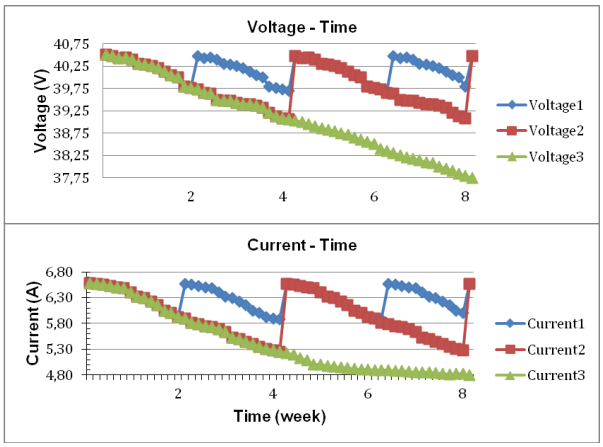


Figure 4: Voltage - Current comparison

In the graph below (see Figure 5), power outputs were illustrated as panel Group I colored blue, Group II red and Group III green. According to the results, overall power losses were statistically proven and calculated for Group I as about 11%; for Group II as 23%; and for Group III as 33%. This diversity of power looses shows the productivity deficiency [20-21]. Moreover the degradation due to outer surface wear failure of the panels was calculated between 1.2 – 2.1% for entire panels proportional to their proper cleaning schedule [22-23]. These results can also be analyzed in curve fitting statistical approach. According to curve fitting analysis, data can be visualized and illustrated in a special curve structure. Decreased tended curve will be obtained in this approach.

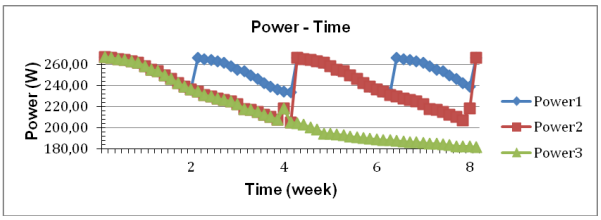


Figure 5: Power comparison of each panel group

On the other hand, this experiment has been repeated in the same region on polycrystalline solar panels and hot spot effect was measured as well [12-23]. It was statically verified that, there is no significant efficiency difference between mono-and-polycrystalline PV modules, when the modules were covered by dust and dirt after minimum 2 weeks time interval and at the end, almost the same energy inefficiency were seen on both different types [24].

6. Conclusion

Subsequently, it was understood that a continuous cleaning of PV modules is essentially needed. By doing so, overall productivity is able to be increased while operational lifetime of the entire power plant is prolonged as well as avoiding mentioned degradation.

Further to that, with this study, the awareness against the importance of regular cleaning of PV plants can be raised as well. Despite of the fact that, there was no accurate answer for the frequency of cleaning process of the panels, this study provides an insight into it. Under Mediterranean climate conditions, panels must be cleaned at least once in 2 weeks. However, for a windy and dusty area, frequency can be once in 3 or 4 days as well [25-26].

For cleaning process, pressurized deionized (demineralized) water should be used with special brushes, as the best medium rather than chemical solutions and tap water because purified water doesn't leave any scale or salt on the cells [27-28]. Automatic cleaning by means of robots will provide a cheap and safe periodic maintenance as well as the increase in efficiency achieved by cleaning. Moreover, in accordance with respected literature (see the ref. 29-30-31), during the experiment, it was noticed that cleaning of the panels made a cooling impact, which enhance the efficiency positively as well.

7. References

[1]Bakirci K. Correlations for estimation of daily global solar radiation with hours of bright sunshine in Turkey. Department of Mechanical Engineering, University of Ataturk, Erzurum: Elsevier Ltd; 2009.

[2] AminmohammadSaberian, H. Hizam, M. A. M. Radzi, M. Z. A. Ab Kadir, and Maryam Mirzaei, "Modelling and Prediction of Photovoltaic Power Output Using Artificial Neural Networks," International Journal of Photoenergy, vol. 2014, Article ID 469701, 10 pages, 2014. doi:10.1155/2014/469701.

[3] Mahdi M. M. El-Arini, Ahmed M. Othman, and Ahmed Fathy, "A New Optimization Approach for Maximizing the Photovoltaic Panel Power Based on Genetic Algorithm and Lagrange Multiplier Algorithm," International Journal of Photoenergy, vol. 2013, Article ID 481468, 12 pages, 2013. doi:10.1155/2013/481468.

[4] R. Mazón-Hernández, J. R. García-Cascales, F. Vera-García, A. S. Káiser, and B. Zamora, "Improving the Electrical Parameters of a Photovoltaic Panel by Means of an Induced or Forced Air Stream," International Journal of Photoenergy, vol. 2013, Article ID 830968, 10 pages, 2013. doi:10.1155/2013/830968.

[5]Dincer I. Renewable energy and sustainable development: a crucial review. Dhahram: Elsevier Ltd; 1999.

[6]Ren21. 2017. Renewables 2017 Global Status Report, Paris: REN21 Secretariat; 2017.

[7] L.Martin, L. F. Zarzalejo, J. Polo, A. Navarro, R.Marchante, and M. Cony, "Prediction of global solar irradiance based on time series analysis: application to solar thermal power plants energy production planning," Solar Energy, vol. 84, no. 10, pp. 1772–1781, 2010.

[8]Sozen A, Arcaklioglu E, Ozalp M, Kanit E G. Solar energy potential in Turkey. Ankara: Elsevier Ltd; 2004.

[9]Uyan M. GIS based solar forms site selection using analytic hierarchy process (AHP) in Karapinar region, Konya. Directorate of Construction and Technical Works, Selcuk

[10]Mazumder M., Electrodynamics removal of dust from solar panels: effect of surface mass density, micro-structural deposition pattern, and adhesion of dust on PV performance. Department of Electrical and Computer Engineering, Boston University, Adhesion Society Meeting, 14–16 February; 2011.

[11]Dorobantu L, Popescu MO, Popescu Cl, Craciunescu A. The effect of surface impurities on photovoltaic panels. International conference on renewable energies and power quality, European Association for the Development of Renewable Energies Environment and Power Quality (EA4EPQ), Electrical Engineering Faculty, Politehnica University of Bucharest, 13–15April; 2011.

[12]Zorrilla-Casanova J, Piliougine M, Carretero J, Bernaola P, Carpena P, Mora- López L, et al. Analysis of dust losses in photovoltaic modules. University de Málaga, Spain: World renewable energy congress; 2011.

[13]Sulaiman SA, Hussain HH, Nik Siti H, Leh N, Razali MSI. Effects of dust on the performance of PV panels. World Academy of Science, Engineering and Technology, vol. 58; 2011. p. 588–93.

[14]Kimber A, Mitchell L, Nogradi S, Wenger H. The effect of soiling on large grid connected photovoltaic systems in California and the Southwest region of the United States, PowerLight Corporation, 2954 San Pablo Avenue, Berkeley; 2005.

[15]Mavroidis C, Hastie J, Grandy A, Anderson M, Sweezy A, Markpolous Y, Robotic device for cleaning photovolatic panel arrays. Department of Mechanical and Industrial Engineering, Northeastern University, Green Project – Sustainable Technology and Energy Solutions, Patent Number 61/120097, 2009.

[16]Abd-Elhady, M.S., Zayed, S.I.M., Rindt, C.C.M., 2011. Removal of dust particles from the surface of solar cells and solar collectors using surfactant. In: International Conference on Heat Exchanger Fouling and Cleaning, 5–10 June. Crete, Greece, pp. 342–348

[17] Chaichan, Miqdam T., Bashar A. Mohammed, and Hussein A. Kazem. "Effect of pollution and cleaning on photovoltaic performance based on experimental study." International

Journal of Scientific and Engineering Research 6.4 (2015): 594-601.

[18] HussamKhonkar, AbdulazizAlyahya, MazzenAljuwaied, Mohammad Halawani, Abdulrahman Al Saferan, Fawwaz Al-khaldi, FawazAlhadlaq, Brent A. Wacaser, Importance of cleaning concentrated photovoltaic arrays in a desert environment, In Solar Energy, Volume 110, 2014, Pages 268-275, ISSN 0038-092X, https://doi.org/10.1016/j.solener.2014.08.001.

[19]Adinoyi, M.J., Said, S.A., 2013. Effect of dust accumulation on the power outputs of solar photovoltaic modules. Renew. Energy 60, 633–636.

[20]Al-Hasan, A.Y., 1998. A new correlation for direct beam solar radiation received by photovoltaic panel with sand dust accumulated on its surface. Solar Energy 63 (5), 323–333.

[21]Al-Hasan, A.Y., Ghoneim, A.A., 2005. A new correlation between photovoltaic panel's efciency and amount of sand dust accumulated on their surface. Int J Sustain Energy 24 (4), 187–197.

[22]Appels, R., Muthirayan, B., Beerten, A., Paesen, R., Driesen, J., Poortmans, J., 2012. The efect of dust deposition on photovoltaic modules. In: 38th IEEE Photovoltaic Specialists Conference (PVSC), 3–8 June. Austin, TX, pp. 001886–001889.

[23]Bajpai, S.C., Gupta, R.C., 1988. Performance of silicon solar cells under hot & dusty environmental conditions. Ind. J. Pure Appl. Phys. 26, 364–369.

[24]Bethea, R.M., Barriger, M.T., Williams, P.F., Chin, S., 1981. Environ-mental effects on solar concentrator mirrors. Solar Energy 27 (6), 497– 511.

[25]El-Shobokshy, M.S., Mujahid, A., Zakzouk, A.K.M., 1985. Effects of dust on the performance of concentrator photovoltaic cells. IEE Proc. I (Solid-State Electron Dev.) 132 (1), 5–8.

[26]Hee, J.Y., Kumar, L.V., Danner, A.J., Yang, H., Bhatia, C.S., 2012. The effect of dust on transmission and self-cleaning property of solar panels. Energy Proc. 15, 421–427.

[27]Elminir HK, Ghitas AE, Hamid RH, El-Hussainy F, Beheary MM, Abdel-Moneim KM. Effect of dust on the transparent cover of solar collectors. Energy Convers Manage 2006;47:3192–203.

[28]El-Shobokshy MS, Hussein FM. Effect of the dust with different physical properties on the performance of photovoltaic cells. Sol Energy 1993;51(6):505–11.

[29]Bock JP, Robison JR, Sharma R, Zhang J, Mazumder MK. An efficient power management approach for self-cleaning solar panels with integrated electrodynamic. In: Proceedings of ESA annual meeting on electrostatics, Paper O2; 2008.

[30]Sims RA, Biris AS, Wilson JD, Yurteri CU, Mazumder CU, Calle CI, et al. Development of a transparent self-cleaning dust shield for solar panels. NASA Kennedy Space Center, FL, 32899: Department of Applied Science, University of Arkansas at Little Rock; 2002.

[31]Park Y-B, Im H, Im M, Choi Y-K. Self-cleaning effect of highly water-repellent microshell structures for solar cell applications. J Mater Chem Korea Adv Inst SciTechnol 2010;21:633-6.

[32]D.Cano, M.J. Monget, M. Albuisson, H. Guillard, N.Regas, L.Wald "A method for the determination of the global solar radiation from meteorological satellite data" Solar EnergyVolume 37, Issue 1, 1986, Pages 31-39

[33]Selmin Ener Rusen, Annette Hammer, Bulent G. Akinoglu "Coupling satellite images with surface measurements of bright sunshine hours to estimate daily solar irradiation on horizontal surface" Renewable EnergyVolume 55, July 2013, Pages 212-219

[34]Selmin Ener Rusen, Annette Hammer, Bulent G. Akinoglu "Estimation of daily global solar irradiation by coupling ground measurements of bright sunshine hours to satellite imagery" EnergyVolume 58, 1 September 2013, Pages 417-425

[35]Selmin Ener Rusen, Aycan Konuralp "Quality control of diffuse solar radiation component with satellitebased estimation methods" Renewable EnergyVolume 145, January 2020, Pages 1772-1779