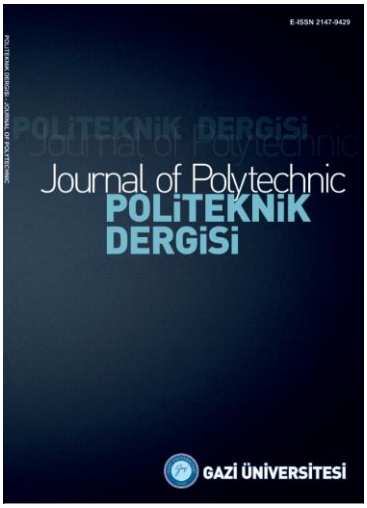

POLİTEKNİK DERGİSİ

JOURNAL of POLYTECHNIC

ISSN: 1302-0900 (PRINT), ISSN: 2147-9429 (ONLINE)
URL: http://dergipark.org.tr/politeknik

The experimental study of dust effect on solar panel efficiency

Tozlanmanın solar panel verimlilikleri üzerine deneysel çalışma

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Bu makaleye şu şekilde atıfta bulunabilirsiniz(To cite to this article): Coşgun A.E., Demir H., "The experimental study of dust effect on solar panel efficiency", ***Politeknik Dergisi***, 25(4): 1429-1434, (2022).

Erişim linki (To link to this article): http://dergipark.org.tr/politeknik/archive

DOI: **10.2339/politeknik.903989**

The Experimental Study of Dust Effect on Solar Panel Efficiency

Highlights

- *This study is one of the few studies about effect of dust on the PV panel efficiency in TURKIYE.*
- *It gives to the reader briefly information about the tremendously effect of dust on the panel efficiency as Daily and Yearly.*
- *It shows that how can use the tool in MATLAB to predict PV panels how much generate electricity. .*
- *It shows that how can measure dust intensity with a photodiode sensor. .*
- *It represents a primary design for those who intend to use robotic systems to detect dust particles.*

Graphical Abstract

The intensity of dust data gets the by photodiode sensor which works as the principle of reflection and it was carried on the linear platform from the left to the right side.

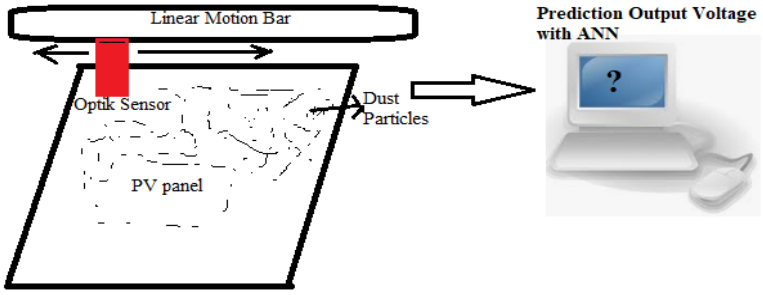

Fig. System block diagram

Aim

This study shows the dust effect on solar panel efficiency based on experimental measurements.

Design & Methodology

In order to investigate the efficiency of the PV panel which exposed to from dust particles a 40-Watt SUNNY polycrystalline panel has been placed under a 1000W/m^2 halogen lamp solar simulator. As the method, ANN tool was used to predict output voltoge of the panel depend on the dust.

Originality

It is a specific study about the efficiency of the PV panel because there was not encountered like this study in literature. The originality comes from using the photodiode and scans the panel at a specific time with the sensor. Also, using the NNtool could predict the output of the voltage, depend on the dust particle size.

Findings

It is understood that the panel that produces the most electricity on average is the clean PV panel and efficiency is decreasing depending on the size of the dust particle. The most losses were encountered on small size dust particles..

Conclusion

The PV panel is affected significantly by dust particles. This study indicated that how particle sizes affect the voltage output of the panel and to make inferences easily with the use of NNtool in MATLAB.

Declaration of Ethical Standards

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

The Experimental Study of Dust Effect on Solar Panel Efficiency

Research Article

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(Geliş/Received : 26.03.2021 ; Kabul/Accepted : 26.05.2021 ; Erken Görünüm/Early View : 03.06.2021)

ABSTRACT

This study shows the dust effect on solar panel efficiency based on experimental measurements. Sieve analysis has been performed to investigate the effect on the efficiency of the panel. Dust particles have been divided into different sizes such as (-75), (+75/-105), (+105/-250), (+250/-450). In addition, each piece weighed 20 g, uniformly sprinkled onto a 40-Watt SUNNY polycrystalline panel. In order to obtain the output voltages of the PV panel used a data acquisition card. Additionally, a photodiode sensor has been used in order to obtain the light reflection data from the panel to the outside while there had covered different diameters of dust particles on the panel. The data set consisting of electrical parameters have been used to compered both experimental study and Artificial Neural Network (ANN) output. There were 5 different data sets with the clean PV panel in this study (randomly selected data from it used as %40 training - %60 test) and the clean panel data have been used twice in the training and test part of the ANN. In this study, it has been observed that the ANN method can be used to estimate panel efficiency due to the linearity (The R-value was gotten nearly equal to 1 and it shows that there is a linear relationship between outputs and targets.) if the appropriate transfer function is selected. Also, this study shows that as the particle diameter covering the panel gets smaller, the output voltage of the panel decreases linearly.

Keywords: Artificial neural network, dust, pv, sieve.

Tozlanmanın Solar Panel Verimlilikleri Üzerine Deneysel Çalışma

ÖZ

Bu çalışma, deneysel ölçümlere dayalı olarak güneş paneli verimliliği üzerindeki toz etkisini göstermektedir. Panelin verimine etkisini araştırmak için elek analizi gerçekleştirilmiştir. Toz partikülleri (-75), (+75/-105), (+1105/-250), (+250/-450) gibi farklı boyutlara ayrılmış ve her bir toz parçacıkları 20 g olarak ayarlanmıştır. Toz parçacıkları, 40-Watt'lık bir SUNNY polikristal panel üzerine homojen bir şekilde dağıtılmıştır. PV panelinin çıkış voltajını elde etmek için veri toplama kartı kullanılmıştır. Ayrıca panel üzerinde farklı çaplarda toz parçacıkları kaplanmışken, panel yüzeyinden yansıyan ışıkların toplanması için fotodiyot sensör kullanılmıştır. Elektriksel parametrelerden oluşan veri seti hem deneysel çalışma hem de Yapay Sinir Ağı (YSA) çıktısının karşılaştırılması için kullanılmıştır. Bu çalışmada temiz PV panel ile 5 farklı veri setinden yararlanılmış (veriler rastgele % 40 eğitim -% 60 test olarak kullanılmıştır) ve temiz panel verileri YSA'nın eğitim ve test kısmında iki kez kullanılmıştır. Ayrıca çalışmamızda YSA metodu kullanılarak, uygun transfer fonksiyonu seçildiği takdirde panel verimliliğini tahmin edilebilecceği gözlemlenmiştir (veriler doğrusal olmasından dolayı R değeri 1'e yakın çıkmış, çıktılar ile hedefler arasında doğrusal bir ilişki olduğunu görülmüştür). Ayrıca bu çalışmada, paneli kaplayan toz parçacıklarının çapı küçüldükçe, panelin çıkış voltajının doğrusal olarak azaldığını görülmektedir.

Anahtar Kelimeler: Güneş enerjili hava kollektörü, konik yay, bulanık mantık, modelleme, çıkış sıcaklığı, termal verim.

1. INTRODUCTION

With the increase of technology usage, humankind's quality of life is increasing, too. As a result of this, all over the world energy consumption and greenhouse gas (GHS) emissions are increasing dramatically. Currently, the worldwide use rate of fossil fuels, which is the primary cause of carbon emissions, is approximately 80% [1]. Besides, the power sector contributes 38% to this [2]. Although, many countries promote renewable energy sources for healthy generations and a livable world. Therefore, especially the installation of solar plants in the world has been increasing. Also, the trend in energy technology is shifting to PV panels. More than half of the renewable energy resource installed (56%) in 2018 are solar plants. Although it is very difficult to know the total electricity produced by countries with PV panels, it is an easy way to measure data from PV plants. It is estimated that 670TWh of electricity produces with the 512.3GW PV facility established all over the world in 2018. This figure corresponds to 3% of the total electricity consumed in the world [2]. Even though its popularity has increased so much, the efficiency achieved through the panel is still around between %15-20% [3],[4]. In addition to the efficiency of the panel due to its internal structure, it also affects the efficiency of environmental factors. Because the areas where the panels are installed are environments that are exposed to physical effects. Some of these factors

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summarized as: situation of the geographical area where the panel is installed (because it affects the temperature, humidity, wind, shade and dust on the panel), the angle of sunlight and the distance of the water because it is necessary to clean PV panels [5]. There are lots of studies conducted by many researchers about the experimental efficiency of the PV panels. In the light of these studies, we have the opportunity to access many valuable information. When the sunlight comes from a 90-degree angle on the PV panels the temperature of the modules rises because solar radiations are absorbed by the PV. This is the reason why the panel efficiency is reduced by 10% to 25% [6]. In addition, the cloudiness of the sky decreases the production of electricity due to reduces the solar radiation reach on the PV panel, too [7],[8]. Also, it permanently decreases its efficiency in moisture penetrating into the panel [9], [10]. Generally, despite PV panel performance studies conducts to measure the efficiency of the panel, environmental parameters such as dust, shading, wind speed, installation tilt angle of the panels have a large effect on the efficiency and power productivity of PVs [11]. In the literature, dust particles are defined as particles smaller than 500 microns [12]. The nature of these particles is varying to a great degree, as they may occur via divergent natural sources in the atmosphere, and the particles may include cells, organic matters, clay, sand, ash, etc. [13], [14]. Efficiency decreases of PV panels caused by dusting. When looked at studies in the literature accumulated dust on the PV's causes a significant reduction of efficiency output of the panels. A study conducted by researchers shows that the PV panel output efficiency decrease between 8-12% per month depends on accumulated dust. Another finding in the same study is that there is a relation between wind speed and relative humidity on the performance of the panels [15]. In the same way, due to accumulated dust, the performance of the PVs has been decreased by nearly 13% in Abu Dhabi, UAE [16]. In addition, performance decreases have been calculated due to daily dust exposure in different parts of the world (see Fig.1).

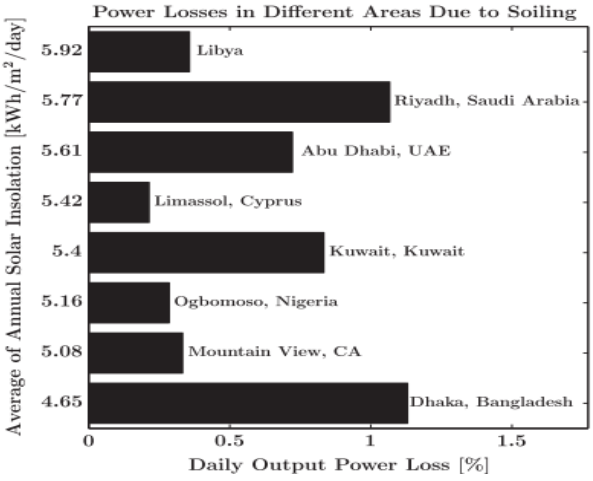

Fig.1 Daily power loss of solar plants

In this figure, daily dusting losses are occurs consecutively between 0-05% in Libya, Limassol, Nigeria and CA, 0.5-1 in Abu Dhabi and Kuwait, 1-1.5% in Bangladesh and Saudi Arabia [16];[17]; [18] ; [19]; [20] 21; 22; 23). Also, there are lots of studies to determine the accumulated rate of dust on the panels depends on installation locations, rate of precipitation, atmospheric dust concentration, etc.

In this study focus on the effect of dust on the efficiency of PVs in term of produced electrics and prediction of the output voltage at a panel with ANN. The ANN are used for decades in practical engineering problems the data of different sized powder particles distributed homogeneously on the panel has been collected by an infrared sensor at a certain time to train in NNTool. To doing this, four different dust particles were chosen such as; (-75), (+75/-105), (+105/-250), and (+250/-450). The "-" symbol means smaller particles than the following number and "+" means bigger particles than the following numbers, too. The surface of the panel was covered by different types of dust particles and each of the particles selected 20g. Additionally, NNTool was used in Matlab to predict the output voltage of the PVs depend on the dust. In MATLAB, 5 different data sets were prepared with 60% training and 40% test rates in NNTool randomly. Generally, researchers only get power data from a panel in terms of the covered panels with dust. However, in this study was taken periodically reflected light data to use in NNTool with together linear motor and photodiode, too. Due to this, the novel method was used in this study.

2. EXPERIMENTAL SETUP

First of all, the dust samples were collected near the agricultural area in Aksaray. In the second stage, to separate micro size scale of dust particles was performed sieve analysis by the Department of Geological Engineering at Aksaray University (see Fig. 2-a). The sieve analysis (also called gradation) is used as an exact method to determine the particle size distribution depending on the fine and coarse of dust. The sands, crushed rock, clays, granite, feldspars, coal, soil from organic or nonorganic granular could be analyzed with this method. Although this method is simple, it is used to determine size particle distribution commonly in civil engineering and chemical engineering. Besides this, to observe relation between dust particles size and efficiency of the panel the experimental setup has been prepared (see Fig. 2-a). The experimental setup consists of step Motor, step motor driver, one-meter ball screw, microcontroller, power supply and photodiode. Reason of used the photodiode is observation to reflection of the light on the panel. Arduino UNO control card has been used as a microcontroller. The Arduino has 10-bit analog reading resolution so input signal data vary from between 0 and 1023. Its writing resolution value is 8-bit so output signal data could be max 255. In addition, the speed of the step motor was adjusted soft.-wise, approximately 5

mm per second. The distance of the photodiode sensor from the surface is about 3 cm. Lastly, the study started inside the laboratory by scattering dust particles. In table 1 the PV panel characteristic has been given.

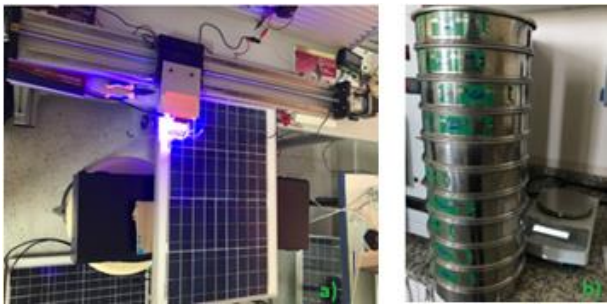

Fig.2 a) Experimental setup and b) sieve analysis

been collected for each different size of dust particles and it is called number of samples in the figures. Fig.3 is shown the platform to perform experimental studies.

Fig.3 Test studies

Table 1. The electrical characteristics of the PV panel**.**

Electrical Data	Tecnical Specifications
Open circuit voltage - Voc	24 V
Optimum operating voltage - Vmp	21V
Short circuit current - Isc	1.7 A
Optimum operating current - Imp	1.3 A
Operating temperature	-40 to 85 C

3. TEST PROCEDURE

In order to investigate the efficiency of the PV panel which exposed to from dust particles a 40-Watt SUNNY polycrystalline panel has been placed under a 1000W/m^2 halogen lamp solar simulator. The reason of chosen halogen lamp is why it is an artificial source that produces wavelengths closest to sunlight. The solar simulator has been placed perpendicular to the PV panel with the distance of 80 cm (see Fig. 3). To obtain measuring data includes current-voltage curves of the clean and dirty panel, a resistor which is values 100 ohms,1000Watt has been used as an electronic load. Dust particles were separated into four micro sizes groups with Sieve method such as: (-75), (+75/-105), (+105/-250), and (+250/-450). Additionally, each of group parts was divided 20gr. The reason of choose 20 g in this study is the best result given in terms of coverage on surfaces of the PV panel when compared 5g, 10g, and 15g dust mass. Thus, 5 different data sets have been prepared for use at NNTool in MATLAB with the aim of %40 training and %60 test. The clean PV panel data have been used twice. One of the data is in the training part, the same data have been also used in the prediction part. Sensor data were obtained with a microcontroller and graphs were drawn on the MATLAB platform. The PV panel gives maximum 24-volt output, depends on light intensity. However, at the microcontroller analog pin operating voltage is maxed 5-volt. In order to overcome this situation, the voltage divider circuit was established and converted into a suitable input signal for the microcontroller. The sampling frequency was selected as 10 Hz in the data acquisition card. Totally 30 data have The panel was carefully cleaned before making observations for each data set. After that, dust particles have been homogeneously sprinkled on the panel. This study, conducted from total 5 different case studies. Data sets are divided into two groups for use in NNTool and they were chosen randomly. The first group is the training part which has been used training to neurons with a backpropagation learning rule, the second group is the test part which has been an observation of the success rate of training. The indicator of the performance criterion is the low error rate. The Tansig transfer function was used for the first layer and Purelin transfer function was used for the second layer, too. The tansig function's dynamic range is [-1 1] and the function shows a nonlinear change, in this range depending on the neuron total input. Although the Purelin function has a similar dynamic range, its output neuron linearly changes according to the input neurons varies. The reason of choosing Tansig-Purelin function was the give best result when compared different variations (Tansig-Logsig, Logsig-Purelin). Also, in the literature Tansig-Purelin functions is the most commonly used technique for the activation in terms of the average number of iterations and number of networks that learn-based in ANN. Besides this, Levenberg-Marquardt (LM) algorithm was preferred due to the stability and speed it provides in the training of artificial neural networks.

4. RESULT AND DISCUSSION

It is noticeable from the Fig.4 that ANN structure with 3 inputs, 3 output and 8 neurons interlayer. In the

validation performance graphs is given the Mean Squared Error (MSE) of Artificial Neural Network model for training, validation (check), and test steps (see Fig. 5). It is clear that from the figure the model has the best validation performance equal to 3.3134 at epoch 4.

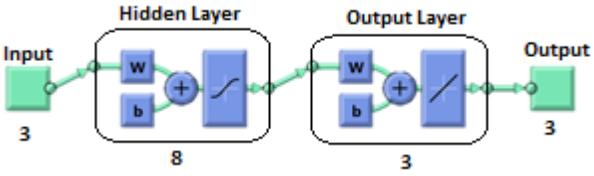

Fig.4 ANN Structure

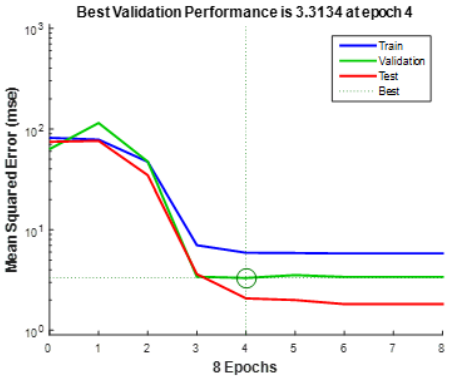

Fig.5 Validation Performance

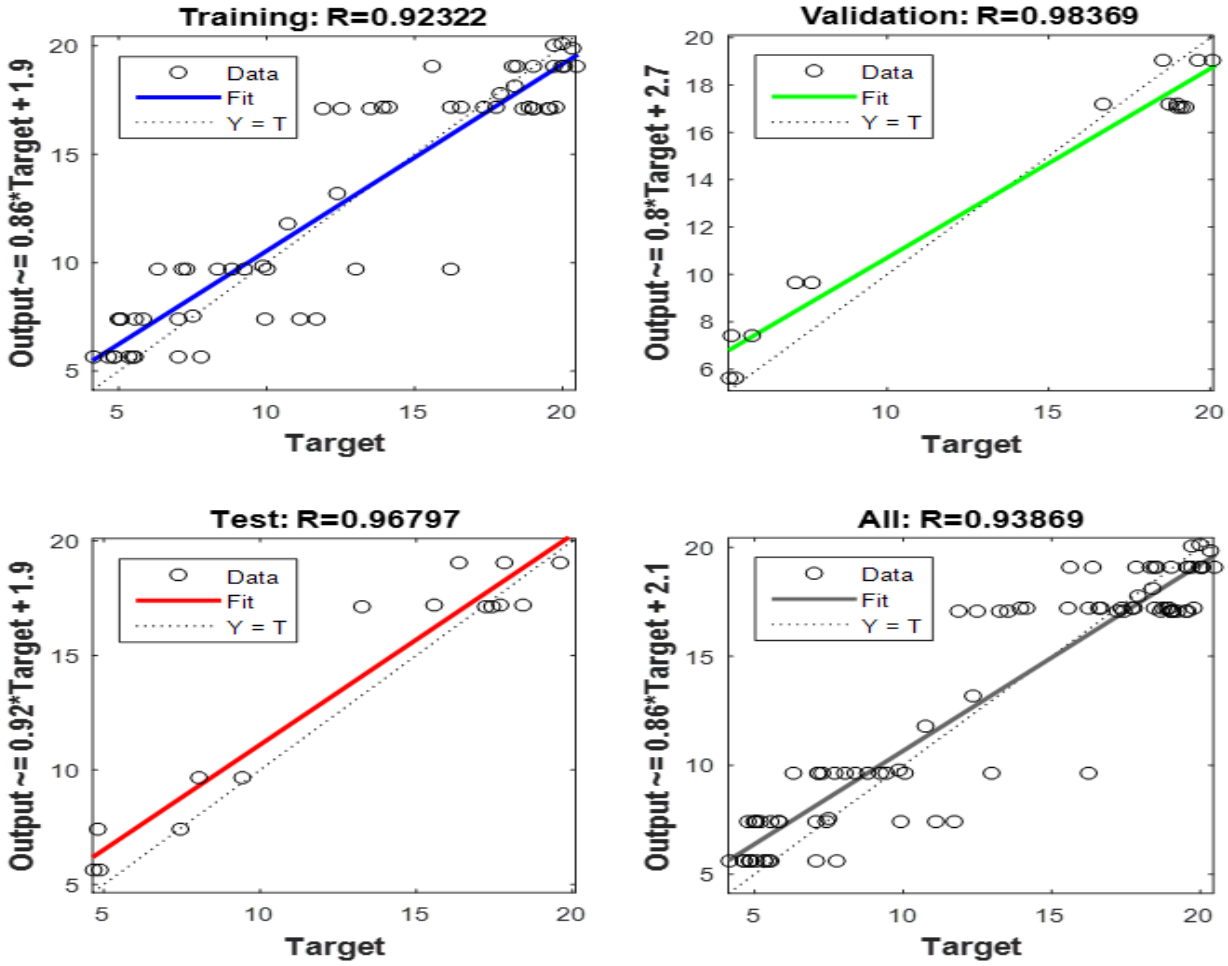

Fig.6 Regression of training, validation, test and all subsets in ANN model

The brain is composed of connections of neurons and similarly, NN is also composed of connections of nodes. The human brain uses the association of neurons whereas NN uses connection weights of the neuron. The aim of this study to predict to voltage output of the PV panel. In Fig. 6. there is an ANN result in MATLAB. According to the figures training, data indicates the good results. In addition, the results of the test and validation give large R values. The R is a value which shows the relationship between the outputs and targets. The means of R equal to 1 is that there is an exact linear relationship between outputs and targets. Also, R is close to zero means that there is no relationship between outputs and targets as linear. In this study, R-value is equal to 1 and it is clear that there is a linear relationship between outputs and targets.The comperation of ANN Voltage output and experimentel study (PV panel voltage output) is shown in Fig.7. Orange line is the output of the model developed with ANN. Additionally, the blue line is the results of the experimental studies. The used DAQ resolution and preferred sampling time is the reason of the oscillations

in the curve of experimental results. According to this figure, the results are satisfactory. The reason why the effect of the 425 micron powder is not given in the graph is that it has been used for training purposes.

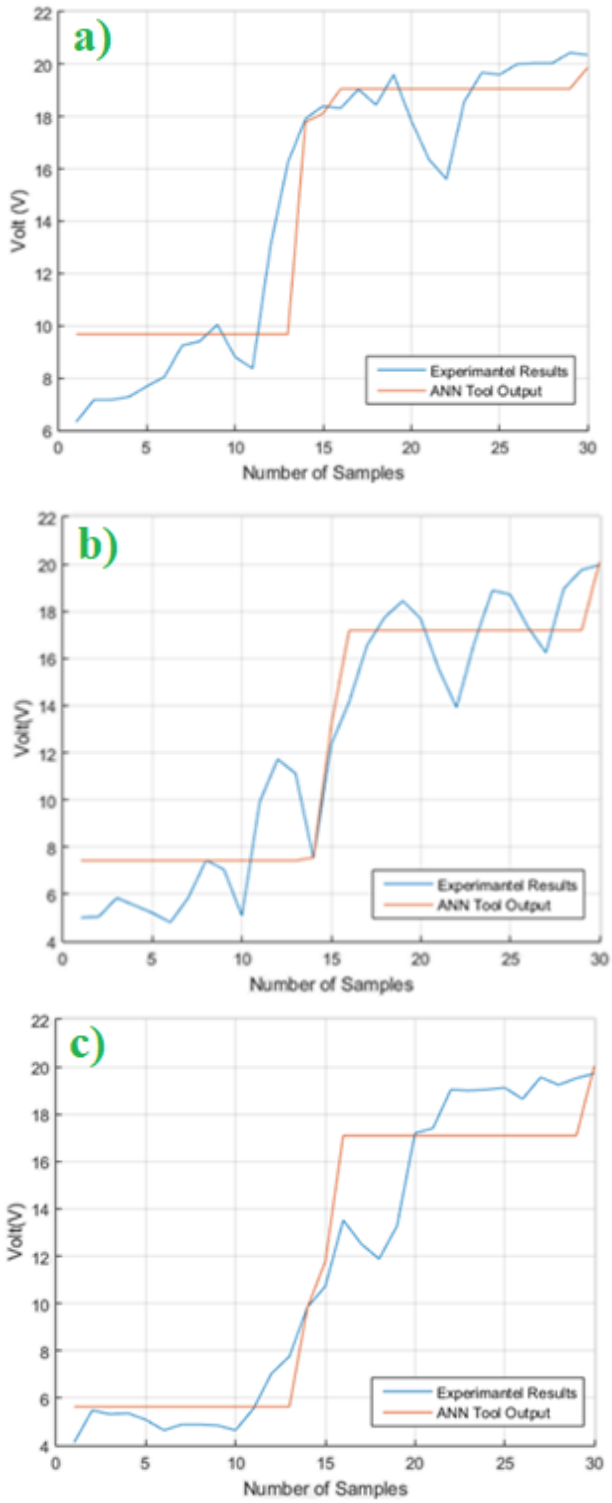

Fig.7 a) The output of Clean PV, b) The output of PV with covered 106 Mikrometer dust particles, c) The output of PV with covered 75 Mikrometer dust particles

Also, according to the data obtained in the experimental study, it is understood that the panel that produces the most electricity on average is the clean PV panel, 425 Micrometer and finally 75 Mikrometer sequently (see Fig. 8).

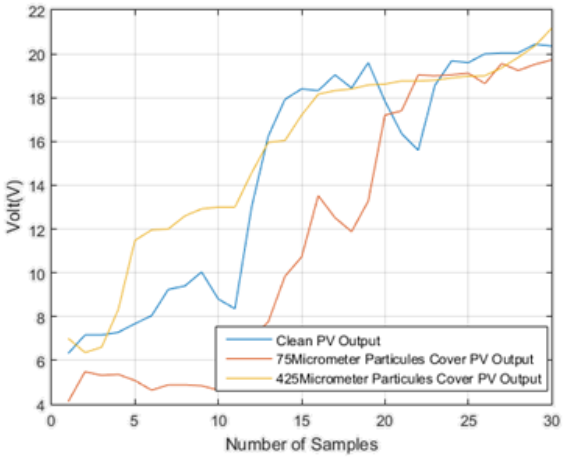

Fig.8 The Voltage outputs of PV panels which depend on dust particles

5. CONCLUSION

The PV panel is affected significantly by dust particles. This study indicated that how particle sizes affect the voltage output of the panel and to make inferences easily with the use of NNtool in MATLAB. This study is also important in terms of being a comparison of the measurement of the radiation from dirty panels and their efficiency. There is a strong correlation between radiation from dirty panels and producing voltage. The radiations have been obtained by photodiode sensors. It was used as a data set in ANN in the range of 0-5 by scaling. Additionally, this Matlab tool is a very promising method to estimate efficiency loss due to dusting. This method could be used to determine the Solar power installation locations. For example, by the Turkish State Meteorological service dust transport estimation is made every day in Turkey. In the light of these data, average efficiency losses can be calculated with this method.

DECLARATION OF ETHICAL STANDARDS

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

AUTHORS' CONTRIBUTIONS

Atıl Emre COŞGUN: Performed the experiments and analyse the results.

Hasan DEMİR: Performed the experiments and analyse the results.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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