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EXPERIMENTAL ANALYSIS OF SHADING IN PV PANELS

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Abstract
The energy is an important issue that should be emphasized in terms of the development of countries. Population growth and the resulting increase in needs have also increased the number of studies on renewable energy. Solar energy stands as a renewable and environmentally friendly power source. Its significance in electricity generation is progressively growing, making research in this field increasingly crucial. Photovoltaic (PV) panels emerge as essential intermediary components in harnessing solar energy. PV panels have many advantages, the most important of which is that they use a clean, sustainable energy source. The efficiency of PV panels is a critical consideration as well.. The efficiency of PV panels depends on dust, humidity, pressure, dust, wind, rain, bird droppings, etc. seriously affects. In this experimental study carried out outdoors, PV panel cells were closed horizontally and vertically to create a shadowing effect and measurements were made. According to the measurements taken, the optimum power values for both the monocrystalline panel and the thin film panel decrease to 0.1 W, especially after 3 and 4 cells are turned off. Reliability analysis was performed on the Weibull distribution with the experimental results obtained. Measurements and analyzes have shown that the shading effect seriously reduces the efficiency of PV panels.
Keywords: PV Panel, I-V curves, Shadow Effect, Mppt

PV PANELLERDE GÖLGELENMENİN DENEYSEL ANALİZİ

Özet
Enerji, ülkelerin kalkınması açısından üzerinde durulması gereken önemli bir konudur. Nüfus artışı ve buna bağlı olarak ihtiyaçların artması, yenilenebilir enerji konusunda yapılan çalışmaların sayısını da artırmıştır. Güneş enerjisi yenilenebilir ve çevre dostu bir güç kaynağı olarak karşımıza çıkıyor. Elektrik üretimindeki önemi giderek artıyor ve bu alandaki araştırmaları giderek daha önemli hale getiriyor. Fotovoltaik (PV) paneller, güneş enerjisinden yararlanmada temel ara bileşenler olarak ortaya çıkıyor. PV panellerin birçok avantajı vardır; bunlardan en önemlisi temiz, sürdürülebilir bir enerji kaynağı kullanmalarıdır. PV panellerin verimliliği de kritik bir husustur. PV panellerin verimliliğine bağlı olarak toz, nem, basınç, toz, rüzgar, yağmur, kuş pisliği vb. faktörler ciddi şekilde etkiler. Dış mekanda gerçekleştirilen bu deneysel çalışmada PV panel hücreleri gölgeleme etkisi oluşturacak şekilde yatay ve dikey olarak kapatılarak ölçümler yapılmıştır. Yapılan ölçümlere göre hem monokristal panel hem de ince film panel için optimum güç değerleri özellikle 3 ve 4 hücre kapatıldıktan sonra 0,1 W'a düşmektedir. Elde edilen deneysel sonuçlarla Weibull dağılımı üzerinde güvenilirlik analizi yapıldı. Yapılan ölçümler ve analizler gölgeleme etkisinin PV panellerin verimliliğini ciddi oranda azalttığını göstermiştir.
Anahtar Kelimeler: PV Panel, I-V eğrileri, Gölge Etkisi, Mppt

1. Introduction

The one of the determining factors in the development of a country is energy. How this energy is produced and consumed is an important indicator. Renewable energy reduces the use of fossil fuels, develops domestic resources, reduces foreign dependency, complies with international agreements, and facilitates the supply of electricity to geographical areas where it is difficult to deliver electricity (Adıgüzel 2019, 2023).

Compared to other countries in the world, our country's solar energy potential and annual sunshine duration are quite high. Turkey has a significant amount of sunlight, 1,527 kWh/m2 per year, due to its geographical location (Monedero, 2003). Although our country has strong radiation, it also has different types of environmental factors due to its geographical location and characteristics. These factors also reduce panel efficiency.

Various elements like clouds, buildings, and trees have the potential to cast shadows on the solar panel, leading to a reduction in its efficiency. The shading phenomenon occurs when the panel is hindered by obstacles, causing a deviation from its usual radiation effect (Yakubu, 2023).

The efficiency of photovoltaic panels can be affected by radiation, aging, shading, dust, etc. factors reduce it. Shadow is an important element that affects panel performance. Cloud, leaves, building etc. It may create a shadow on the panel (Monedero, 2003). This scenario results in a decline in the panel's efficiency, as the shading effect is brought about by the unequal distribution of radiation throughout the system due to obstacles on the panel. In this case, cells exposed to lower levels of radiation are expected to produce power, but on the contrary, they reduce system power.

The effect of variable shadow amounts on panel efficiency is a subject studied intensively by researchers in this field. Lijun Gao and his colleagues examined and compared the shading conditions on parallel and series connected PV panels. They adjusted the shading amount as 5%, 12.5%, 25% and 50% and measured the power values separately in series and parallel connected PV panels. If there is no shading, the same values were measured in parallel and series connected PV panels. When shading was applied, the amount of power measured in parallel connected PV panels was higher at every value of shading. For 50% shading, the power value decreased to 41.9% in series connected PV panels and 72.4% in parallel connected PV panels. Parallel connection of PV panels is more advantageous in terms of shading factor (Gao,2009).

Various simulations have been developed to analyze the shadowing situation in panels [Di Piazza 2010; Zegaoui 2011, Kaushika 2003). In their study, A simulation was crafted by A. Zegaoui and team, wherein they physically modeled the PV cell panel and radiation, incorporating models for both direct and reverse modes. The study aimed to derive the PV cell characteristics, particularly in instances of partial and overall shading. Additionally, the investigation delved into the impact of by-pass diode protection in PV panels, along with the examination of hot spots and associated heating effects.

When examining the issue of shading in solar energy, studies are generally carried out on photovoltaic cells. In some studies, this issue is done via PV panel. Bruno Andò and his colleagues, unlike the studies generally conducted on a cell basis, carried out their studies on a panel basis, as in our study. In this study, instantaneous and continuous shadowing, pollution and aging anomalies were addressed and monitored through sensors placed at different points on the panel. Random reasons affecting efficiency were evaluated with current and voltage. The measurements were carried out between 07:00 and 13:00 on 23 November 2013, and the changes in the saturation current, series resistance and shunt resistance are presented graphically. Accordingly, while the saturation current remained stable and decreased after 10:00, the STC factor showed the same behavior as the current. Parallel and series resistance showed differences during the day due to clouds, pollution and shadowing (Ando, 2015).

Another issue addressed in the case of shadowing is the serial and parallel connection of panels. In their study, Cheng-Chuan Chen and his colleagues modeled serial and parallel connection situations of PV cells. They accomplished this by subjecting the panel to varying temperatures (0°C, 25°C, 50°C, 75°C, 100°C) under consistent radiation while experiencing partial shading. The study unveiled alterations in the power and voltage of the panel corresponding to the temperature variations (Chen, 2013).

Due to shading, PV panels are evaluated in terms of efficiency, payback period and cost. In their study, M. Tripathy and his colleagues tried to find the period in which PV heater systems integrated into buildings pay for themselves economically by making cost analyzes on payback periods and lifetimes due to the shadowing effect. Nowadays, heating buildings with PV panels, which are considered green energy, and trying to earn a green label is an increasingly popular practice. The use of panels in building cladding has been studied in fifteen different states of India. Here, the change in temperature on the surface and the change in electrical efficiency with the placement angle of the panel are stated in detail depending on the building height and the distance between the buildings (Tripathy, 2017a, 2017b).

In the investigation of shading concerns in solar energy, the evaluation of PV panel performance involves altering the levels of shading. Partial shading in grid-connected PV systems creates serious problems in terms of the grid. In their experimental study, Chris Deline and his colleagues covered the cells with an opaque mask (10% 16% 20% 24% 31% 35% 39% of the cell was covered.) Performance was evaluated by shadowing 25 different cells. At the end of the experimental study, it was observed that the efficiency of the cell decreased (Deline, 2009).

Solar simulators are also frequently used in solar energy studies today. In his study, A. Ibrahim experimentally prepared a solar simulator and examined the I-V characteristics of a silicon cell. It has been reported that there is a power reduction between 5% and 15% for different climatic conditions, especially the phases are decisive in this. At the same time, his study reported that the Isc value decreased by 2.78% and the Voc value decreased by 0.863% daily (Ibrahim, 2011).

Weibull analysis is a method used in modeling radar systems, weather forecasts, and wind speed charts. In their study, Dokur and his team concentrated on the examination and modeling of the wind speed characteristics in the designated region before the installation of wind energy conversion systems. In this direction, wind speed modeling is proposed with the new probability and cumulative probability density functions obtained by calculating the Finsler metric functions, whose geodesics are the Weibull distribution, in this study. The proposed model can be used for wind data in all regions of the world by changing its parameters (Dokur, 2018).

In this study, the effect of shadow factor on the efficiency of photovoltaic panels was measured and evaluated experimentally in an open field. Sunlight falling on the panels was quantified using a pyranometer. To unveil the impact of shading, measurements of current and voltage were taken from the panel under identical irradiance values (1000 W/m2).. Special shading areas prepared for the same irradiance value were used to cover one cell each. The impact of the shading factor on the efficiency of photovoltaic panels was determined by comparing the measured power values with the optimum power of the PV panels. The obtained experimental results were analyzed for reliability using the Weibull distribution.

2. Material and Methods

In this study, two different types of photovoltaic panels were used. The first of these is monocrystalline panels, which are widely used in the industry, and the other is thin film panels, which have gained popularity in the last five years.

In this study, Benning PV 2 measuring device was used to measure the amount of sunlight. The sensitivity of the Benning PV 2 device is +5 V. The Benning PV 2 device is designed for measuring the resistance of protective earth conductors, employing a test current of 200 mA. It also performs open-circuit voltage measurement (Uo/c) for solar modules or PV arrays, handling up to 1000 V DC. With an internal voltage capability of up to 15 A DC, the device ensures user safety during operation. Additionally, it includes short circuit current measurement (Is/c) features across the circuit. Measurements were carried out under 1000 W/m2 radiation. The photo of the device used in the measurements is given in Figure 1.

Figure 1: Measuring Device Used in Experiments.

The angle of incidence of sunlight and the orientation of the panel are aligned to be perpendicular to each other. For Istanbul Avcılar region, Azimuth angle 40^0 was applied and the panels were brought to this position.

Clouds, trees, chimney etc. Without leaving any possibility, the cells of the panels were closed respectively with cardboard prepared with a thickness of 12.5x12.5 cm, which allows each cell to be closed in case of shading, as seen in Figure 2 and Figure 3.

Figure 2: Monocrystalline and Thin Film Panels.

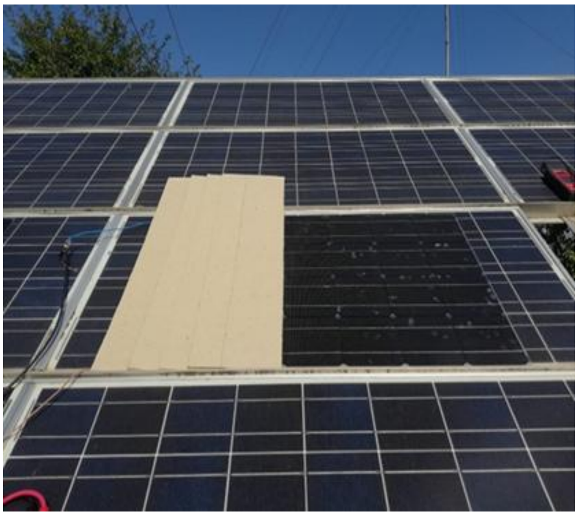

Figure 3: Creating a Shading Effect with Cardboards.

This study was carried out outdoors in a cloudless environment. The orientation of the solar rays' angle of incidence and the positioning of the panel are set to be perpendicular to each other. Measurements were taken with the Benning PV 2 device when solar radiation was 1000 W/m2. The power values we obtained were compared to the optimum power values of the panels.

3. Results

Measurements were taken with the Benning PV 2 device by covering the cells of our monocrystalline and thin film panels with cardboards measuring 12.5x12.5 cm, horizontally and vertically, 1 cell, 2 cells and 3 cells, respectively. The measurements taken were transferred to the software program of the Benning PV 2 device and graphs were obtained. Optimum power values were also read from these graphs.

3.1. Measurement Results of Monocrystalline Panel

3.1.1. Data Obtained as a Result of Closing Cells in Vertical Direction

In this section, the current and voltage graphs obtained as a result of closing the cells of the monocrystalline panel in the vertical direction are given. MPP points are shown as hollow circles in the graphs.

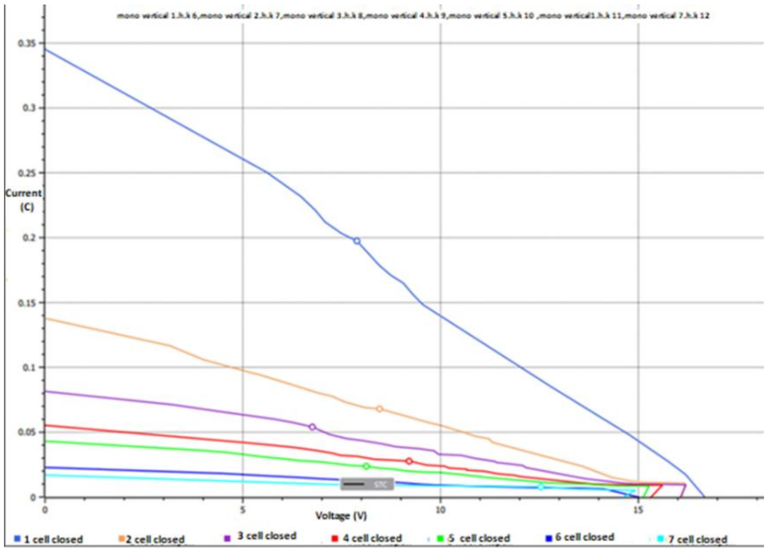

Figure 4: Current – voltage curve when 1, 2, 3, 4, 5, 6 and 7 cells of the monocrystalline panel are closed in the vertical direction, respectively.

Figure 4 shows the current voltage curve of the monocrystalline panel when 1, 2, 3, 4, 5, 6 and 7 cells are closed in the vertical direction. It was noted that as the number of cells turned off increased, the current gradually decreased in the current voltage curve and the mpp points gradually shifted and decreased, as shown by the circles in the figure.

3.1.2. Data Obtained as a Result of Closing Cells in Horizontal Direction

In this section, the current-voltage graphs obtained as a result of closing the cells of the monocrystalline panel in the horizontal direction, respectively, are given. MPP points are shown as hollow circles on the graphs.

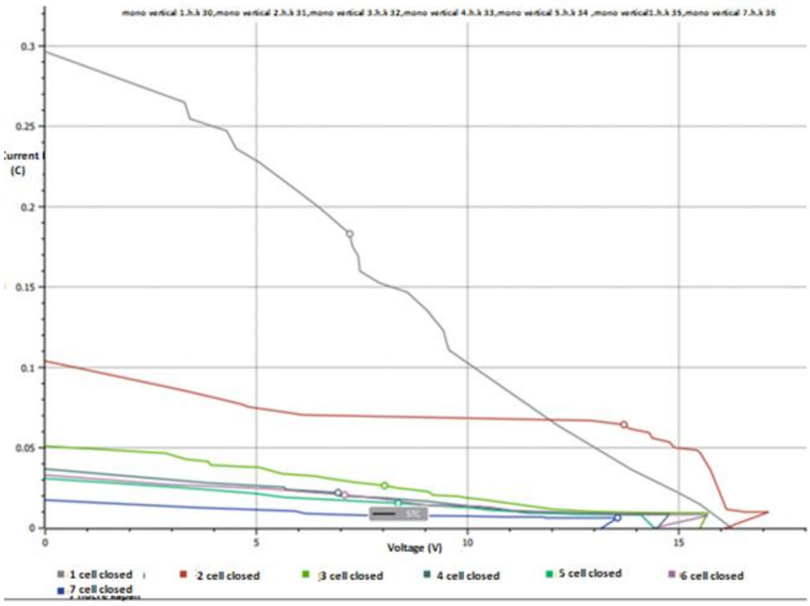

Figure 5:Closure of 1, 2, 3, 4, 5 and 6 cells of the monocrystalline panel in the horizontal direction, respectively.

Figure 5 shows the current voltage curve of the monocrystalline panel when 1, 2, 3, 4, 5, 6 and 7 cells are closed in the horizontal direction. It was noted that as the number of cells switched off increased, the current gradually decreased in the current voltage curve and the MPP points gradually shifted and decreased, as shown by the circles in the figure.

3.2. Measurement Results of Thin Film Panel

3.2.1. Data Obtained as a Result of Closing Cells in Vertical Direction

Figure 6 shows the current and voltage graphs obtained as a result of sequentially closing the cells of the thin film panel in the vertical direction. MPP points are shown as hollow circles on the graphs.

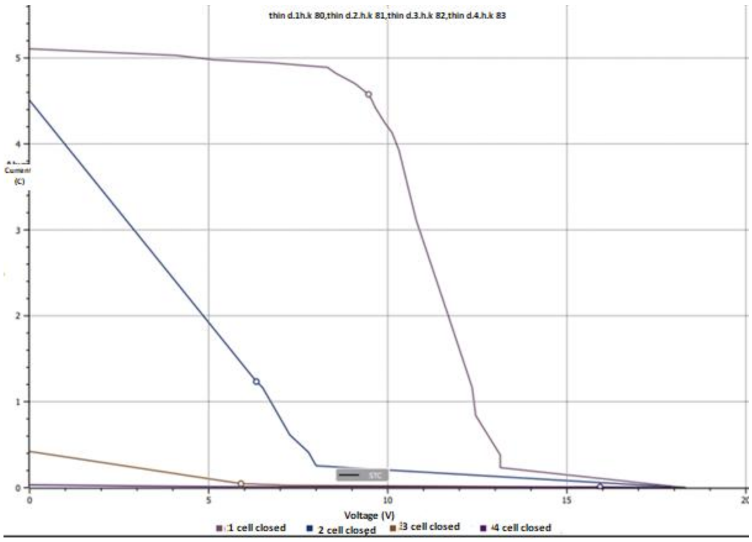

Figure 6: Closing of 1, 2, 3 and 4 grain cells respectively in the vertical direction of the thin film panel.

Figure 6 shows the current voltage curve when 1, 2, 3, 4 cells of the thin film panel are closed in the vertical direction. It was noted that as the number of cells turned off increased, the current gradually decreased in the current voltage curve and the mpp points gradually shifted and decreased, as shown by the circles in the figure.

3.2.2. Data Obtained as a Result of Closing Cells in Vertical Direction

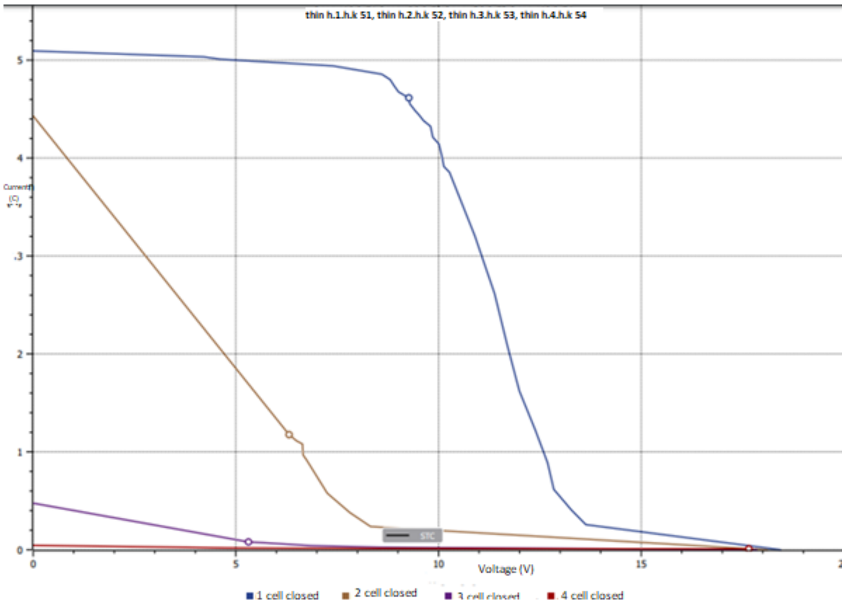

Figure 7: Closing of 1, 2, 3 and 4 cells in the thin film panel horizontally, respectively.

Figure 7 shows the current voltage curve when 1, 2, 3 and 4 cells of the thin film panel are closed in the horizontal direction. It was noted that as the number of cells switched off increased, the current gradually decreased in the current voltage curve and the MPP points gradually shifted and decreased, as shown by the circles in the figure.

3.3. Reliability Analysis

In this experimental study, since the voltage levels obtained from the panels were different from 0, analyzes were made on the voltage values. In other words, first Weibull compatibility analyzes were performed for 4 different situations arising from each closed cell, and then their reliability was calculated. Graphical method and Maximum Likelihood methods were used to estimate Weibull parameters. The examinations were made on 4 different situations. These;

- Case 1: Monocrystalline horizontal,
- Case 2: Monocrystalline vertical,
- Case 3: Thin-film horizontal,
- Case 4: Thin-film vertical is selected.

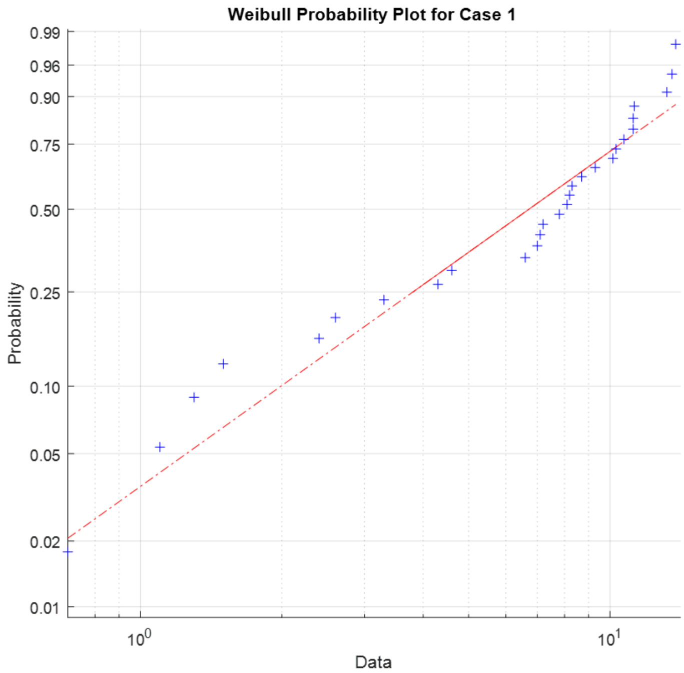

Figure 8: Weibull compatibility plot for Case 1.

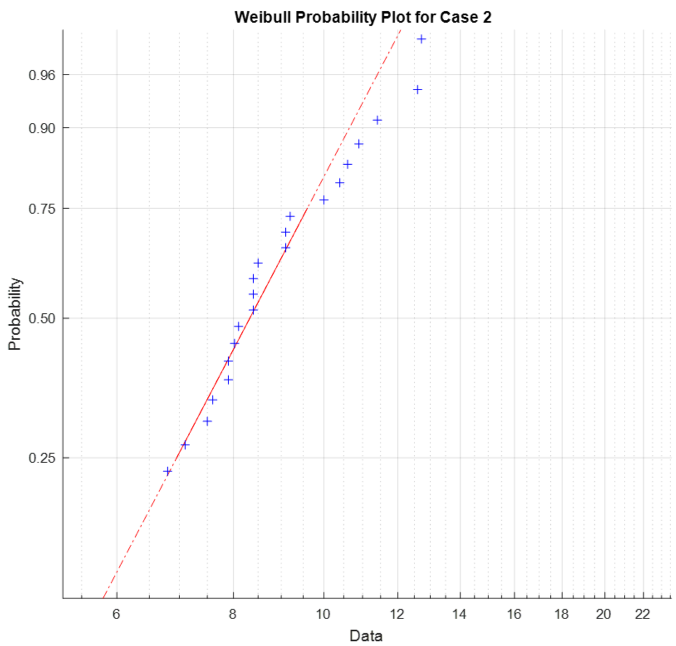

Figure 9: Weibull compatibility plot for Case 2.

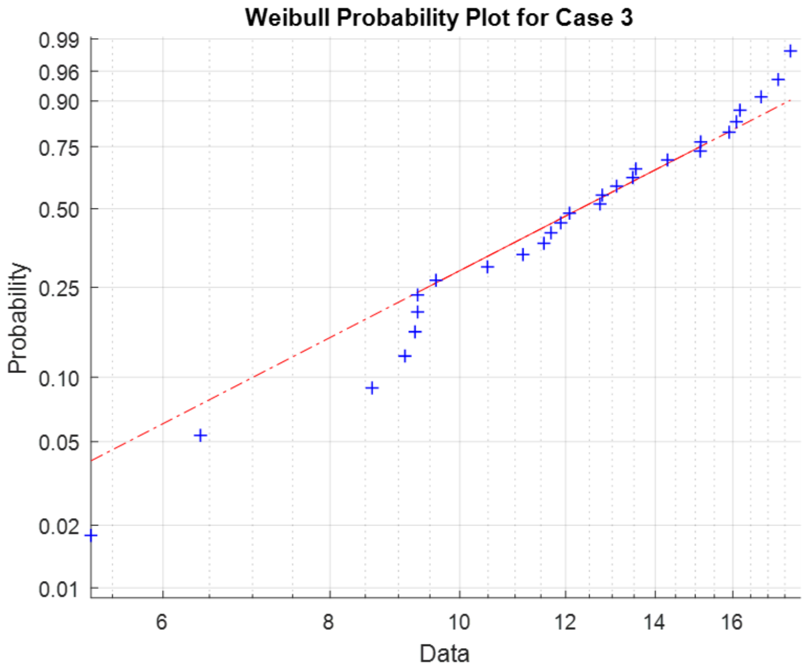

Figure 10. Weibull compatibility plot for Case 3.

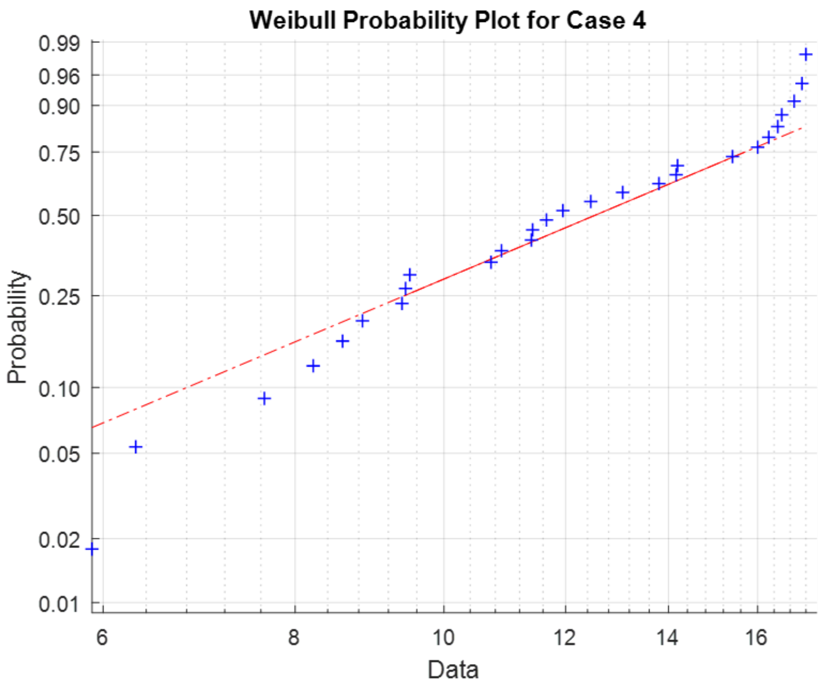

Figure 11. Weibull compatibility plot for Case 4.

Table 1: Comparison of the values of the shape and scale parameters obtained by GM and MLM methods.

Method	***Case 1***		***Case 2***		***Case 3***		***Case 4***	
	K	**C**	**K**	**C**	**K**	**C**	**K**	**C**
GM	1.4522	7.5102	1.9014	8.0744	4.2473	13.0179	4.0611	12.8508
MLM	1.8508	8.1999	2.7614	8.6369	4.4530	13.5702	4.1133	12.8508

Comparison of the values of the shape and scale parameters obtained by GM and MLM methods was given in table 1. Case 1 gives the lowest value for both methods used in the study. Thin film panels performance much more better than monocrystalline panels due to this also the weibull performance has the highest values. It has been determined through measurements and reliability analysis that shading is a serious factor that negatively affects the efficiency of the panel. As the number of switched off cells increased, there was a decrease in the current values in the current voltage graphs. It was observed that MPP points decreased and shifted. In this experimental study, since the voltage levels obtained from the panels were different from 0, analyzes were made on the voltage values. Weibull graphs were used for the relationship between the number of closed cells and reliability. Weibull parameters were appropriate values to express the results of my experiment. In other words, first Weibull compatibility analyzes were performed for 4 different situations arising from each closed cell, and then their reliability was calculated. In the reliability analysis, the curves were found to be almost coincident when the thin film panel was shaded horizontally and vertically. The difference between the curves of the monocrystalline panel is greater than the thin film panel, and the reliability value is the same when the ten cells are closed both vertically and horizontally and is between 0.2 and 0.3. A significant negative impact of the shading effect on the efficiency of the panels was measured. In this study, it has been confirmed that for the efficiency of photovoltaic panels, precautions must be taken against the harsh shading effect and that strict cleaning activities must be carried out to prevent these negativities as well as the importance of the panel area selected for this purpose.

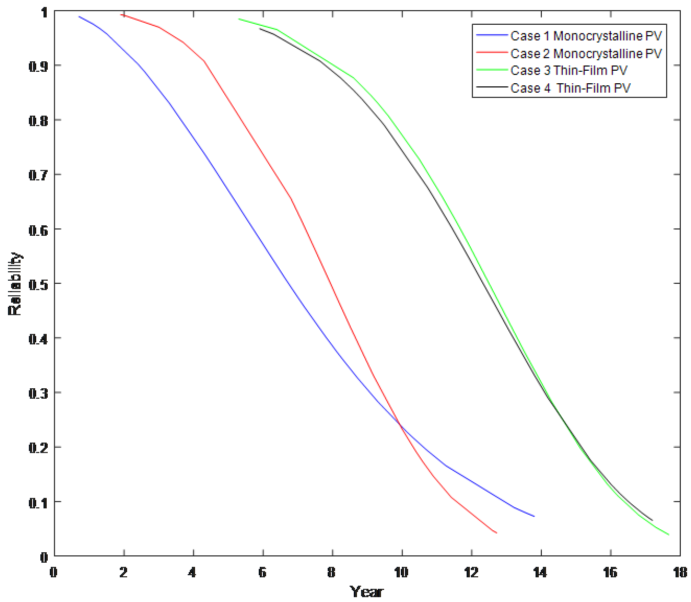

Figure 12: Comparative Weibull plots under shading effect.

4. Conclusion

Clouds, buildings, distance between buildings, chimneys, trees, etc. on photovoltaic panels. factors create a shadowing effect. The shading effect seriously affects the efficiency of the panels. This study investigated the impact of shading on the panel's efficiency, revealing significant decreases in efficiency during the measurements. In the experimental study carried out outdoors, the cells were closed horizontally and vertically to create a shadowing effect and measurements were made. According to the measurements taken, the optimum power values for both the monocrystalline panel and the thin film panel decrease to 0.1 W, especially after 3 and 4 cells are turned off. It has been determined through measurements and reliability analysis that shading is a serious factor that negatively affects the efficiency of the panel. As the number of switched off cells increased, there was a decrease in the current values in the current voltage graphs. It was observed that MPP points decreased and shifted. The frequently used MLM method was preferred because it gave better results to the reliability analysis method that was most compatible with the data we obtained.

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