Kütahya Dumlupınar University
Institute of Graduate Studies

Journal of Scientific
Reports-A
E-ISSN: 2687-6167
Number 54, September 2023

RESEARCH ARTICLE

EFFECTS OF WIND SPEED AND MOUNTING TYPE ON PV MODULE IN UNBALANCED DISTRIBUTION SYSTEMS

Salman Ahmed NUR[1,*], Selçuk EMİROĞLU[2]

[1]Sakarya University, Electrical and Electronics Engineering, Sakarya, salmaanahmednuur@gmail.com,
ORCID: 0000-0002-8391-1170
[2]Sakarya University, Electrical and Electronics Engineering, Sakarya, selcukemiroglu@sakarya.edu.tr,
ORCID: 0000-0001-7319-8861

Receive Date: 01.05.2023 *Accepted Date: 03.07.2023*

ABSTRACT

This paper assesses the effects of wind speed and mounting type on the performance of photovoltaic (PV) modules in the three phase unbalanced IEEE 34 node distribution system. The study was conducted in OpenDSS considering ZIP load model and residential load shape. The module temperature was calculated considering the wind speed and mounting type of the PV panel. The impact of wind speed on PV has been analyzed using three different wind data sets. Furthermore, free standing and flat roof mounting types were considered to evaluate the effect of mounting configuration. It was found that integrating PV into the distribution system reduced substation demand and energy losses. Results also show that the PV produced more power in high wind speed scenarios than in low wind speed scenarios. Regarding the mounting configuration, the PV incorporated with free standing configuration generated more power than the flat roof mounting type.

Keywords: *Photovoltaic Systems, Wind Speed, Mounting Type, Ambient Temperature, Unbalanced Distribution System*

1. INTRODUCTION

The rising concerns about the impact of fossil fuel energy on climate change and global warming have led to increasing demand for clean and renewable energy sources. With the advancement of technology, industrial development and the increase in the world population, the need for energy is also increasing rapidly. In fact, the total amount of primary energy consumed in the world in 2022 reached 595 EJ [1]. Photovoltaics (PVs) is among the various renewable energy sources seen as to solution to these problems and it is expected to become one of the major energy resources due to the learning and cost reductions, large potential for solar PV expansion, and integration strategies that allow penetration of PV into the power grid [2]. Despite the significant advancements in PV technology, there is still a great deal of interest in studying external factors such as weather conditions that may impact the PV output. It is well understood that the cell temperature impacts the efficiency

JSR A
Journal of Scientific Reports

Nur, S.A. and Emiroğlu, S., Journal of Scientific Reports-A, Number 54, 94-107, September 2023

and electrical output of PV cells [3]–[6]. Various factors affect this temperature including wind speed, ambient temperature, and irradiance [7]. In particular, the temperature of the PV module is highly sensitive to wind speed and to a lesser extent to wind direction [8]. Numerous studies have discussed the impact of wind on cell temperature in different environmental conditions. Al–Bashir et al [9] analysed the effects of cell temperature, solar irradiance and wind speed on PV system's performance. They found a linear relation between the irradiance, cell temperature, wind speed and the PV power. Because of the low wind speed in the area where the experiment was conducted, the impact of the wind speed was not significant. Goverde *et al.*[10] investigated the influence of wind on the temperature of PV mini-modules. They found that the module's surface temperature decreased on average by 11 °C, 16 °C, and 21 °C at a wind speed of 1 m/s, 2 m/s, and 5 m/s at an illumination of 400 W/m^2. Tahir et al [11] examined the Impact of wind speed and temperature on five types of PV panels for various regions in Pakistan. The obtained results observed a decrease in PV efficiency when considering only the effect of temperature. However, the efficiency increased when was considered the impact of both wind speed and temperature. Even though PV module efficiency is determined based on standard test conditions (STC), it is crucial to observe how these modules perform in actual field conditions to accurately predict their efficiency and power output [12]. Although solar irradiance and ambient temperature are commonly used as the sole parameters to calculate the PV module operating temperature in the literature, studies [13]–[15] indicate that wind speed may also have a significant impact on increasing efficiency by lowering PV cell temperature because of its cooling effect. Ambient wind speed has positive and negative aspects. In the USA, a wind speed of 10 m/s can reduce the operating temperature by 3.5°C. However, in a hot place like Saudi Arabia, a 10°C drop is possible at a wind flow of 2.8-5.3 m/s [16]. Therefore, accurate solar cell temperature estimations are required for reliable energy yield simulations. Various researchers ([7], [17], [18], [19]) proposed models incorporating wind's effect on PV module performance. Skoplaki *et al* [7] proposed simple mathematical equations for calculating the temperature and electrical efficiency of PV modules considering wind effect and arbitrary mounting. The PV mounting design, whether free standing, BIPV, BIPV/T, or BAPV, is a further factor to consider because it has a big impact on cell temperature and the passing air flow across the PV sides [20]. A solar system's energy output can be maximized by selecting the proper solar mounting system and installing it correctly, as this will ensure structural support and determine the best orientation and elevation for the system [21]. Various approaches exist for integrating solar PVs into buildings. Two techniques used to mount PV arrays are roof-mounted systems and ground-mounted systems [22]. Awan et al. [23] compared ground-mounted and rooftop PV with optimal interrow distance between parallel arrays, and found that rooftop systems performed better and had more economic advantages than ground-mounted systems in urban environments. Cura [24] evaluated the economical and technical considerations of PV plants operating under various environmental conditions. Various case studies were conducted at two different solar plants with ground mounted and roof mounted installation. The results of the simulation demonstrated that ground-mounted PV arrays had higher efficiency than the those with roof-mounted PV arrays. Tamoor [25] investigated the design and energy estimation of a ground mounted PV with interrow spacing and optimal tilt angle installation. The study assessed the efficiency of the solar system and aided in determining how to make the best use of the space that is available, both of which are critical for the financial viability of the PV power plants. Kazim [26] has also compared the performance of PV panels mounted on flat surfaces and roof tops in UAE and found that the flat surface mounting structure had a lower efficiency due to the tilt angle, but also a lower temperature and dust accumulation than the roof top mounting structure. The author also reported that the flat surface mounting structure had a higher power output per unit area than the roof top mounting structure.

The impact of wind speed is frequently disregarded when modeling PV systems, but it is crucial to determine the modules' temperature and, consequently, their efficiency [7]. The literature review [24] revealed that the potential of solar energy systems is more than the other renewable energy systems. The installation of PV plants has grown steadily due to lower costs of equipment, higher government subsidies and increased public consciousness of the fossil fuel related environmental issues. Moreover, estimating the energy production of PV plants during real climate conditions is important both for researchers and investors. For this purpose, this study aims to investigate the effects of wind speed and the mounting type on the PV module performance under real environmental conditions. To test this, a PV is connected to the IEEE 34 test feeder and power flow analyses were performed using OpenDSS (Open Distribution System Simulator)[27]. Various case studies have been conducted by using three wind speed data namely high, moderate, and low along with free standing and flat roof mounting configurations. Moreover, 10-minute temperature data and irradiance have been used to model the PV in OpenDSS. It should be noted that the time resolution of 10-minute was considered based on the ground measurements of solar radiation, wind speed, and ambient temperature that were available. To assess the influence of wind alone on the output of the PV, the same temperature and irradiance have been used for all case studies. By comparing the case studies, the impact of wind speed and mounting type on the power output of the PV has been observed. The contribution of this paper is to study the effect of wind speed and mounting type on the PV system integrated into the distribution network. The sections of this paper are organized as follows: in Section 2, the meteorological data of solar irradiance, temperature, and wind speed to calculate panel temperature is presented. The design of the PV system, the distribution test system, the load modelling, and the cell temperature calculation considering wind speed are also covered in this section. In Section 3, Several case studies are created to analyze the impact of wind speed and mounting types on PV power output. This section also discusses daily energy generation and power losses of the PV system at free standing and flat roof mounting configurations. Finally, the conclusions which highlight the main findings of this study are presented in Section 4.

2. MODELLING APPROACH

2.1. Meteorological Sample Data

As a sample input, data from [28] has been used. These data have been recorded by nine automated solar stations in Pakistan from 2014 to 2017 and it consists of daily 10-minute values of wind speed, solar irradiance, and temperature. In order to evaluate the influence of wind speed on the output of the PV power, the data measured in the station in Lahore has been used and three different days (23/10/2014, 21/02/2015, and 20/06/2015) with an average wind speed of (1.18 m/s, 4.1 m/s, and 6.9 m/s, respectively) has been selected. The wind speed graph for these days is given in Figure 1.

JSR A
Journal of Scientific Reports

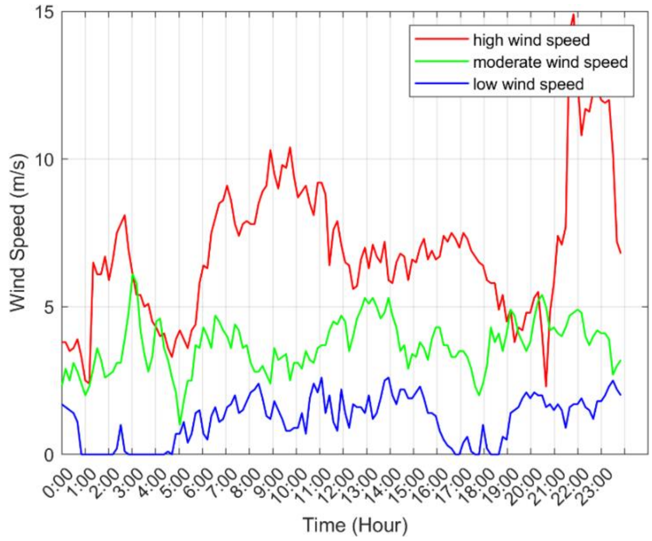

Figure 1. The wind speed data [28].

As the study aims to evaluate the influence of wind speed on PV power output, the same temperature, and irradiance have been used for all scenarios. The irradiance and the temperature are shown in figures (2) and (3) respectively.

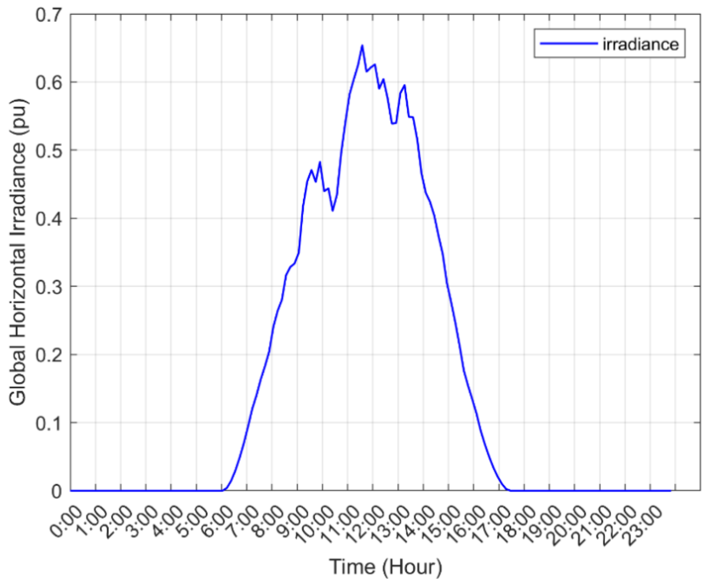

Figure 2. The irradiance data [28].

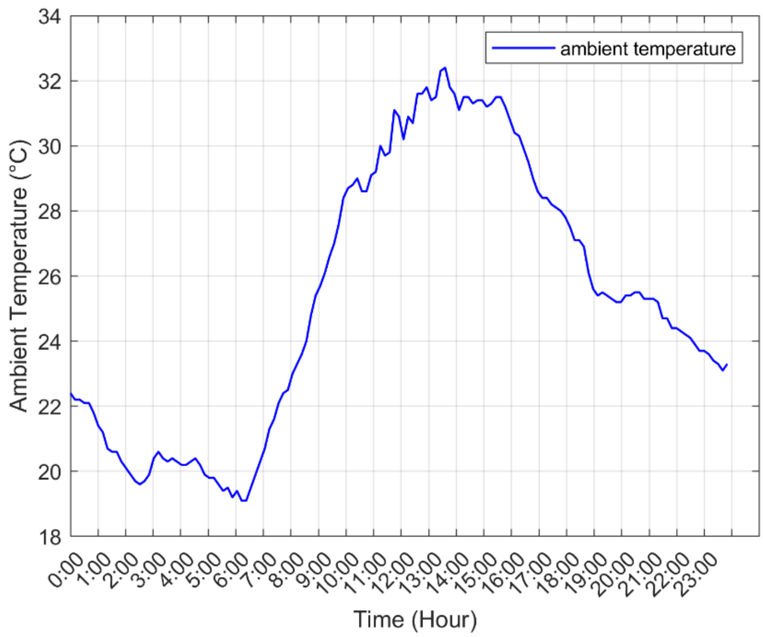

Figure 3. The ambient temperature data [28].

2.2. Test System and Load Modelling

The IEEE 34 node test feeder has been used in this study as a base network. It consists of light and unbalanced loads, an inline transformer, two voltage regulators, and shunt capacitors [29]. The modified IEEE 34 with a PV connected to node 858 is shown in Figure 4.

JSR A
Journal of Scientific Reports

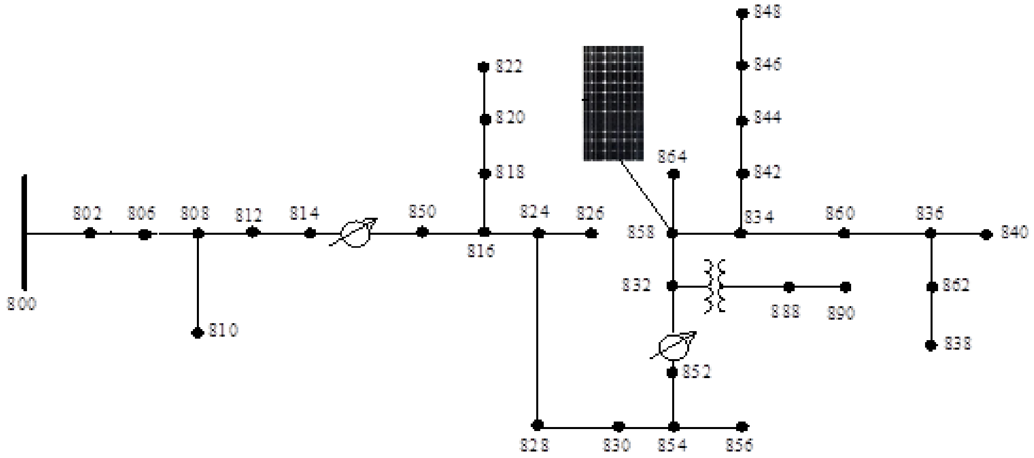

Figure 4. The modified IEEE 34 node feeder [29].

Load modelling has a significant impact on the results of the analysis performed. To accurately characterize the system, a ZIP model load has been used. ZIP stands for the three defined load types: constant impedance (Z), constant current (I), and constant power (P) [30]. The ZIP model considers the voltage dependency of loads. The ZIP coefficients for a residential customer used in this study are given in Table I.

Table 1. The residential ZIP coefficients [30].

Class	Zp	Ip	Pp	Zq	Iq	Pq
Residential	0.85	-1.12	1.27	10.96	-18.73	8.77

In order to precisely model the consumption behavior of network customers, a 10-minute interval of a residential load shape obtained from [31] has been used. The daily residential load curve is shown in Figure 5.

JSR A
Journal of Scientific Reports

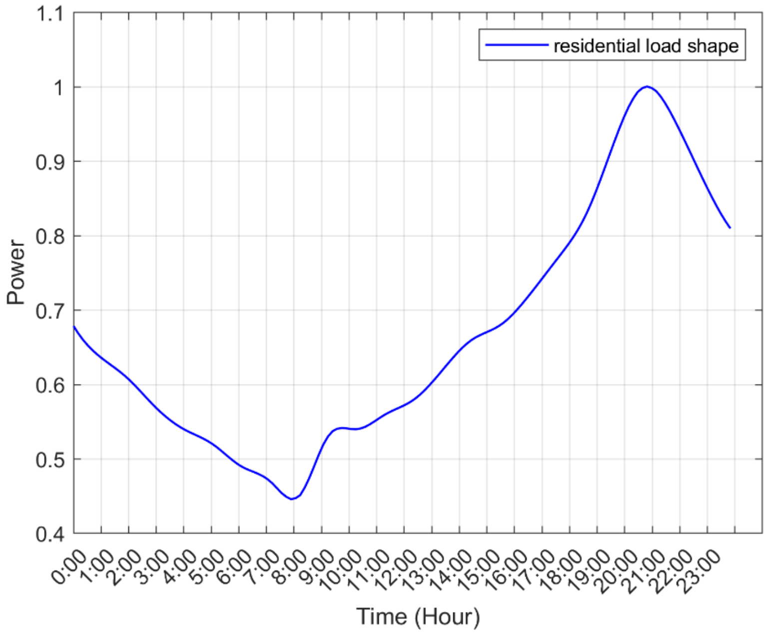

Figure 5. The 24-h load shape of residential customers [31].

2.3. PV Modeling in OpenDSS

The Open Distribution System Simulator (OpenDSS) is a powerful simulation tool for electrical distribution systems. It supports almost all steady state analyses commonly performed for utility distribution systems. The key advantage of OpenDSS is that it supports unbalanced multi-phase power flow analysis and distributed generation integration. In OpenDSS, the PV model consists of a PV panel and an inverter element with an ideal maximum power point (MPP) tracker. This model injects an active power (P_{out}) into the network. To calculate $P_{out}(t)$., the model requires the data of module/cell temperature, irradiance, inverter efficiency, and the rated power. The active power $P_{out}(t)$ injected into the grid is given in Equations (1) and (2).

$$\mathrm{P_{out}}\,(\mathrm{t}) = \mathrm{P(t)} \times \mathrm{eff(P(t))} \tag{1}$$

$$P(\mathrm{t}) = P_{mpp} \times \mathrm{irradiance} \times \mathrm{factor(T(t))} \tag{2}$$

Where $P(t)$ is PV array power output, $P_{mpp}(1kW/m^2)$ is the rated power at the MPP, *irrad(t)* is per unit irradiation value, *factor(T(t))* is the Pmpp correction factor as a function of the temperature and *eff(P(t))* is the inverter efficiency. The PV system has a P_{mpp} of 1000 kW and a power factor of 1 and is connected to node 858 of the IEEE 34 node test feeder.

JSR A
Journal of Scientific Reports

Nur, S.A. and Emiroğlu, S., Journal of Scientific Reports-A, Number 54, 94-107, September 2023

2.4. Modeling of Cell Temperature

The cell temperature is affected by the local wind speed, ambient temperature, and irradiance on the plane of the array [7]. The OpenDSS uses the module temperature when modeling the PV element. However, the obtained temperature data is ambient temperature. Therefore, the cell/module temperature T_c is calculated using Equation (3) proposed by [7]. Equation (3) calculates the operating temperature for any mounting type and wind speeds higher than 0 m/s.

$$T_c = T_a + \omega \left(\frac{0.32}{8.91 + 2 \times V_f} \right) G_T \tag{3}$$

Where T_c is the cell/module temperature, T_a is the ambient temperature, ω is the mounting coefficient, V_f is the wind speed and G_T is the irradiance on the panel. In this study, two mounting types have been used namely, free standing and flat roof. The values of ω presented in Table II were obtained from [7].

Table 2. Values of mounting coefficient for two mounting types [7].

PV panel mounting type	ω
Free standing	1
Flat roof	1.2

3. SIMULATIONS AND RESULTS

As the study aims to demonstrate the impact of wind speed and mounting types on PV output, various scenarios are created. The same ambient temperature and irradiance are used for all case studies to evaluate the effect of wind speed and mounting type. The scenarios analyzed in this study are presented in Table III. The simulation scenarios are divided into seven case studies, as follows:

- Base Case: The simulation was conducted on IEEE 34 node test feeder using a residential ZIP load, and no PV connection to the network.
- Case A: The PV is connected to node 858 and simulated with high wind speed data and free standing mounting coefficient.
- Case B: The PV is connected to node 858 and simulated with moderate wind speed data and free standing mounting coefficient.
- Case C: The PV is connected to node 858 and simulated with low wind speed data and free standing mounting coefficient.
- Case D: The PV is connected to node 858 and simulated with high wind speed data and flat roof mounting coefficient.
- Case E: The PV is connected to node 858 and simulated with moderate wind speed data and flat roof mounting coefficient.
- Case F: The PV is connected to node 858 and simulated with low wind speed data and flat roof mounting coefficient.

JSR A
Journal of Scientific Reports

Table 3. Case studies.

Wind speed	Mounting type	
	Free standing	Flat roof
High	Case A	Case D
Moderate	Case B	Case E
Low	Case C	Case F

The simulation results of substation demand, PV panel output, load consumption, and the total power losses over a 24-hour period for all case studies are given in Table IV. The results show that in the free standing mounting case studies, Case A had the highest power production at the highest wind speed, followed by Case B and Case C. The PV panel generated 2.21% more power in the scenario simulated with the high wind speed data set (Case 1) than in the scenario simulated with the low wind speed data set (Case C). Also, relative to the Base Case, the substation power demand reduced by 12.44 %, 12.33%, and 12.17% in Case A, Case B, and Case C respectively. When the active power at node 858 is compared to the power measured at the PV panel output, it was observed a 69 kWh energy loss due to the inverter. The highest loss reduction was achieved by 12.66% in the free standing high wind speed scenario (Case A).

Table 4. The simulation results for all case studies.

	Substation Demand (kWh)	Panel Output (kWh)	Energy at Node 858 (kWh)	Load Consumption (kWh)	Network Losses (kWh)
Base case	31502	-	-	28478	3025
Case A	27582	3612	3543	28485	2640
Case B	27617	3578	3509	28484	2642
Case C	27666	3532	3463	28483	2645
Case D	27600	3595	3526	28484	2641
Case E	27643	3555	3486	28484	2644
Case F	27702	3500	3431	28485	2648

Using the flat roof mounting coefficient for the panel temperature, Case D had the highest power output of 3595 kWh due to the high wind speed. Conversely, Case E and Case F had lower power outputs of 3555 kWh and 3500 kWh respectively. It is worth noting that the PV panel power output was 2.64% higher in the case with the high wind speed (Case D) than in the case with the law wind speed (Case F). This demonstrates the impact of wind speed on PV production since the wind cools the cell temperature and thus reduces the power loss due to temperature. In addition, as the power

JSR A
Journal of Scientific Reports

produced by the PV module increased, the substation power demand decreased by 12.38%, 12.25%, and 12.06% for Case D, Case E, and Case F, respectively, compared to Base Case.

The results show that the mounting type affects the PV power output, as the free standing mounting configuration produced more power than the flat roof mounting configuration by 0.47%, 0.64%, and 0.9% for high, moderate, and low wind speed conditions, respectively. This is due to the higher mounting coefficient of the flat roof than that of free standing (see Table II), which results in a higher cell temperature as shown in equation 3. The daily PV panel output for Case A, Case B, and Case C is presented in Figure 6, while Figure 7 displays the daily PV power output for Case D, Case E, and Case F.

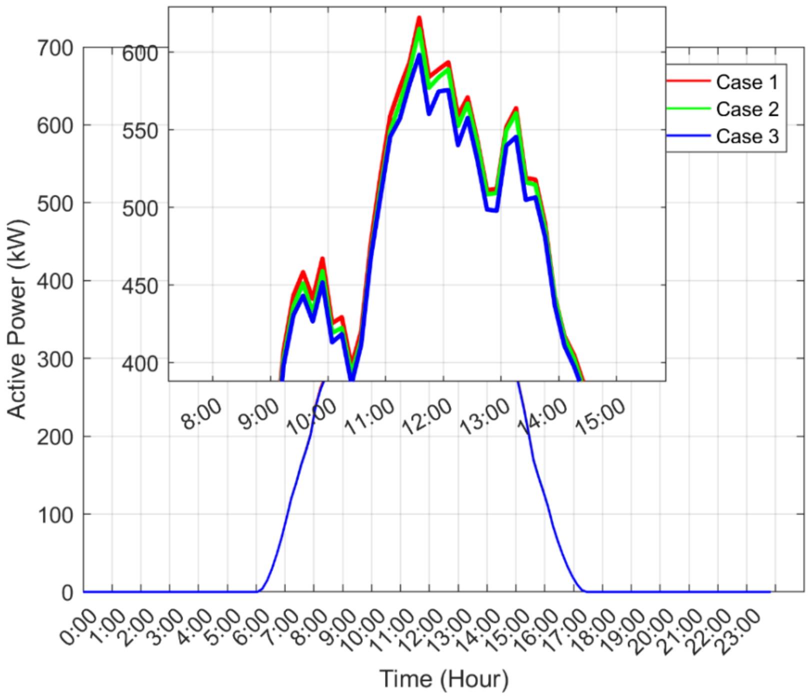

Figure 6. The 24-h PV panel output for Case A, Case B, and Case C.

JSR A
Journal of Scientific Reports

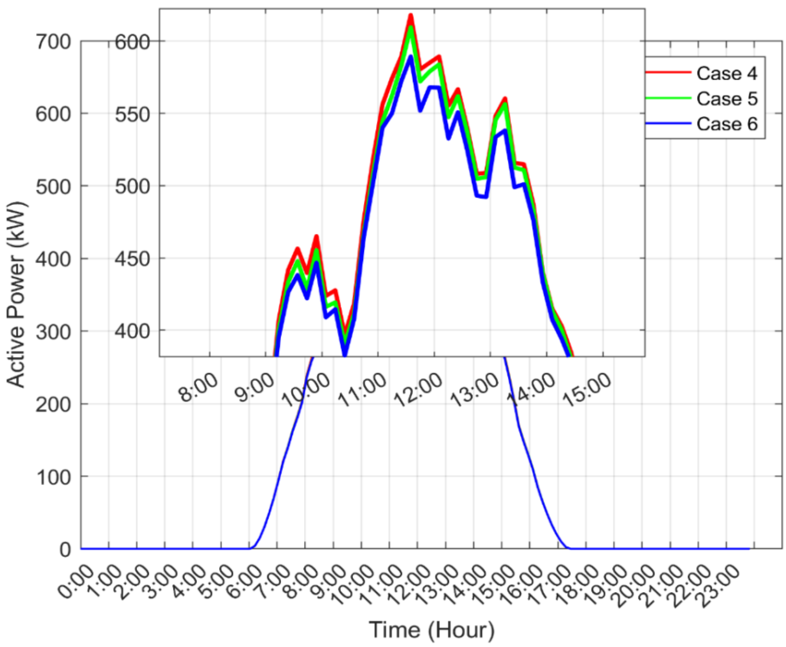

Figure 7. The 24-h PV panel output for Case D, Case E, and Case F.

4. CONCLUSION

This paper has investigated the effects of wind speed and mounting type on the output performance of photovoltaic modules in an unbalanced distribution network. The analyses of the PV system was conducted on the unbalanced IEEE 34 node feeder. No load consists entirely of constant power, constant impedance, or constant current. Therefore, in order to represent the actual system loads, the loads in the IEEE 34 distribution test system are modeled as ZIP load model, which is a voltage dependent load model. In addition, a residential ZIP coefficient and residential load curve were used. For the three-phase unbalanced power flow solution, the OpenDSS software, which is open source, was used. The PV conversion process is strongly influenced by the operating temperature, which affects the PV power output and the efficiency in a nearly linear way, making them decrease with it. A simple equation (Eq. (3)) that uses three environmental variables (solar irradiance, wind speed, and ambient temperature) and a dimensionless mounting parameter that indicates the integration level of a specific installation was applied to estimate the PV operating temperature. Two mounting configurations (free standing and flat roof) and three wind speed data namely, high, moderate, and low have been used in the present study. To assess the effect of the wind speed alone on PV power output, the same ambient temperature and irradiance have been used for each case study. The simulated scenarios show that the substation demand and network losses decreased when the PV was integrated into the distribution network. The highest loss reduction was achieved by 12.66% in the free standing high wind speed scenario (Case A). The results also indicate that module temperature was influenced by wind speed. The PV output power was higher for high wind speed cases than for low wind speed for both mounting types. In the case study simulated with the high wind speed data set (Case 1), the PV panel generated 2.21% more power than in the scenario simulated with the low wind speed data set (Case C). This is because the wind cools the cell temperature and consequently reduces the PV power loss due to temperature. Moreover, the present study also assessed the impact of PV mounting configuration on PV performance. Under high, medium, and low wind speed conditions, the PV module generated 0.47%, 0.64%, and 0.9% more energy in free standing mounting than in flat roof mounting, respectively. The accurate selection of mounting type for solar system projects is crucial for the overall production, efficiency, and lifespan of solar panels. Since it is a costly investment, the selection of mounting systems should not be overlooked as a minor consideration. It is concluded that it would be useful to take wind speed into account when assessing PV energy production, particularly in the areas with higher wind speeds.

ACKNOWLEDGEMENT

This research has received no external funding.

REFERENCE

[1] Petroleum, B. (2022). BP Statistical Review of World Energy, (71), 60.

[2] Victoria, M., Haegel, N., Peters, I. M., Sinton, R., Jäger-Waldau, A., del Canizo, C., Breyer, C., Stocks, M., Blakers, A., Kaizuka, I., Komoto, K. (2021). Solar photovoltaics is ready to power a sustainable future. Joule, 5(5), 1041-1056.

[3] Dash, P. K., Gupta, N. C. (2015). Effect of temperature on power output from different commercially available photovoltaic modules. International Journal of Engineering Research and Applications, 5(1), 148-151.

[4] Dubey, S., Sarvaiya, J. N., Seshadri, B. (2013). Temperature dependent photovoltaic (PV) efficiency and its effect on PV production in the world–a review. Energy procedia, 33, 311-321.

[5] Rahman, M. M., Hasanuzzaman, M., Rahim, N. A. (2015). Effects of various parameters on PV-module power and efficiency. Energy Conversion and Management, 103, 348-358.

[6] Kawajiri, K., Oozeki, T., Genchi, Y. (2011). Effect of temperature on PV potential in the world. Environmental Science & Technology, 45(20), 9030-9035.

[7] Skoplaki, E., Boudouvis, A. G., Palyvos, J. A. (2008). A simple correlation for the operating temperature of photovoltaic modules of arbitrary mounting. Solar energy materials and solar cells, 92(11), 1393-1402.

[8] Griffith, J. S., Rathod, M. S., Paslaski, J. (1981). Some tests of flat plate photovoltaic module cell temperatures in simulated field conditions. In 15th Photovoltaic Specialists Conference, 822-830.

[9] Al–Bashir, A., Al-Dweri, M., Al–Ghandoor, A., Hammad, B., Al–Kouz, W. (2019). Analysis of effects of solar irradiance, cell temperature and wind speed on photovoltaic systems performance.

[10] Goverde, H., Goossens, D., Govaerts, J., Dubey, V., Catthoor, F., Baert, K., Poortmans, J. Driesen, J., (2015). Spatial and temporal analysis of wind effects on PV module temperature and performance. Sustainable Energy Technologies and Assessments, 11, 36-41.

[11] Tahir, Z.R., Kanwal, A., Asim, M., Bilal, M., Abdullah, M., Saleem, S., Mujtaba, M.A., Veza, I., Mousa, M. Kalam, M.A., (2022). Effect of Temperature and Wind Speed on Efficiency of Five Photovoltaic Module Technologies for Different Climatic Zones. Sustainability, 14(23), 15810.

[12] Gökmen, N., Hu, W., Hou, P., Chen, Z., Sera, D., Spataru, S. (2016). Investigation of wind speed cooling effect on PV panels in windy locations. Renewable Energy, 90, 283-290.

[13] Schwingshackl, C., Petitta, M., Wagner, J.E., Belluardo, G., Moser, D., Castelli, M., Zebisch, M. Tetzlaff, A. (2013). Wind effect on PV module temperature: Analysis of different techniques for an accurate estimation. Energy Procedia, 40, 77-86.

[14] Kaplani, E., Kaplanis, S. (2014). Thermal modelling and experimental assessment of the dependence of PV module temperature on wind velocity and direction, module orientation and inclination. Solar Energy, 107, 443-460.

[15] Said, S. A., Al-Aqeeli, N., Walwil, H. M. (2015). The potential of using textured and anti-reflective coated glasses in minimizing dust fouling. Solar Energy, 113, 295-302.

[16] Hasan, K., Yousuf, S. B., Tushar, M. S. H. K., Das, B. K., Das, P., Islam, M. S. (2022). Effects of different environmental and operational factors on the PV performance: A comprehensive review. Energy Science & Engineering, 10(2), 656-675.

[17] Koehl, M., Heck, M., Wiesmeier, S., Wirth, J. (2011). Modeling of the nominal operating cell temperature based on outdoor weathering. Solar Energy Materials and Solar Cells, 95(7), 1638-1646.

[18] Mattei, M., Notton, G., Cristofari, C., Muselli, M., Poggi, P. (2006). Calculation of the polycrystalline PV module temperature using a simple method of energy balance. Renewable energy, 31(4), 553-567.

[19] Kurtz, S., Whitfield, K., TamizhMani, G., Koehl, M., Miller, D., Joyce, J., Wohlgemuth, J., Bosco, N., Kempe, M. Zgonena, T. (2011). Evaluation of high‐ temperature exposure of photovoltaic modules. Progress in photovoltaics: Research and applications, 19(8), 954-965.

[20] Kaplanis, S., Kaplani, E., Kaldellis, J. K. (2022). PV temperature and performance prediction in free-standing, BIPV and BAPV incorporating the effect of temperature and inclination on the heat transfer coefficients and the impact of wind, efficiency and ageing. Renewable Energy, 181,

235-249.

[21] Wijeratne, W. P. U., Yang, R. J., Too, E., Wakefield, R. (2019). Design and development of distributed solar PV systems: Do the current tools work?. Sustainable cities and society, 45, 553-578.

[22] Stapleton, G., Neill, S. (2012). Grid-connected solar electric systems: the earthscan expert handbook for planning, design and installation. Routledge..

[23] Awan, A. B., Alghassab, M., Zubair, M., Bhatti, A. R., Uzair, M., Abbas, G. (2020). Comparative analysis of ground-mounted vs. rooftop photovoltaic systems optimized for interrow distance between parallel arrays. Energies, 13(14), 3639.

[24] Cura, D., Yilmaz, M., Koten, H., Senthilraja, S., Awad, M. M. (2022). Evaluation of the technical and economic aspects of solar photovoltaic plants under different climate conditions and feed-in tariff. Sustainable Cities and Society, 80, 103804.

[25] Tamoor, M., Habib, S., Bhatti, A. R., Butt, A. D., Awan, A. B., Ahmed, E. M. (2022). Designing and energy estimation of photovoltaic energy generation system and prediction of plant performance with the variation of tilt angle and interrow spacing. Sustainability, 14(2), 627.

[26] Kazim, W. (2015). Performance of PV Panel Mounting Structure for Flat Surface and Roof-Top in UAE Climatic Conditions. Int. J. of Sustainable Water & Environmental Systems, 7(1), 37-40.

[27] Dugan, R. C., McDermott, T. E. (2011). An open source platform for collaborating on smart grid research. 2011 IEEE power and energy society general meeting, 1-7.

[28] World Bank. World Bank via ENERGYDATA.info under a project funded by the Energy Sector Management Assistance Program (ESMAP). Retrieved march 9, 2023, from https://energydata.info/dataset/pakistan-solar-radiation-measurement-data.

[29] Kerting, W. H. (1991). Radial distribution test feeders IEEE distribution planning working group report. IEEE Trans. Power Syst, 6(3), 975-985.

[30] Diaz-Aguiló, M., Sandraz, J., Macwan, R., De Leon, F., Czarkowski, D., Comack, C., Wang, D. (2013). Field-validated load model for the analysis of CVR in distribution secondary networks: Energy conservation. IEEE Transactions on Power Delivery, 28(4), 2428-2436.

[31] Emiroglu, S., Uyaroglu, Y., Ozdemir, G. (2017). Distributed Reactive Power Control based Conservation Voltage Reduction in Active Distribution Systems. Advances in Electrical & Computer Engineering, 17(4), 99-106.