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Comparative Analysis of SAM and PVsyst Simulations for a Rooftop Photovoltaic System

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ABSTRACT: Turkiye is a country rich in renewable energy resources, one of which is its tremendous potential, especially in solar energy. Investments in photovoltaic systems are increasing day by day in order to evaluate this potential The simulations of these systems, which will be established while making investment plans, are very important in terms of investment return times. In this study, information and data were obtained from a working rooftop photovoltaic system and simulations were carried out using PVsyst and system advisor model (SAM) software. The simulation data was compared with the power plant's electricity generation data using statistical analysis methods of deviation, Root Mean Square Error (RMSD), and Mean Absolute Deviation (MAD). When all these analysis methods were evaluated, it was seen that the error and deviation values of the SAM software were lower on an annual basis. On the other hand, it has been determined that the error and deviation values of the PVsyst software are lower on a monthly basis.

Keywords: Rooftop photovoltaic system, SAM, Pvsyst

1. INTRODUCTION

The need for energy has been increasing daily with the developments in industry and technology. An inclination toward non-renewable energy sources has been observed when responding to this increase. Due to this tendency, the problem of global warming has intensified. In order to prevent the global warming problem and to meet the ever-rising energy demand, a rapid trend towards renewable energy sources has been taking place, and the use of many sources, such as solar energy, wind energy, and geothermal energy, has become widespread.

The utilization of solar energy is being realized with both thermal systems and photovoltaic (PV) systems. Photovoltaic systems; Today, it is seen in many areas, from open lands to rural areas away from the grid. According to the International Energy Agency (IEA) December 2021 data, the installed power capacity of photovoltaic systems worldwide is 894.3 GW, and electrical energy production from photovoltaic systems is 994 TWh/Year. For Turkey, these values are 8 GW and 12.9 TWh/Year, respectively [1]. While 240107 MW of this 8 GW installed power belongs to the energy investments in 2020, this value has become 498050 MW for 2021 [2].

In the installation of photovoltaic systems, it is of great importance that the projecting phase is carried out in the most accurate way to ensure that the system's energy production is at the highest level. For this reason, many factors, such as the location of installation, the slope, power & orientation of the panels, and the power of the inverters, need to be analyzed. Many software with different tools has been developed to carry out these analyses, including different climate databases, shading analysis, and many other factors that would affect the quality of production result in the projection phase [3].

In a related study, simulation was done using PVSyst, SAM, and PVLib software for a 75 MWp plant in Kalkbult, Northern Cape Province of South Africa. The results obtained from all three software were compared with the production results of the facility in 2014. PVLib software was rated the best regarding modeling flexibility, followed closely by SAM software. However, when other general features and functions are considered, SAM would be the most suitable among these three software packages [4]. In another study, simulation and efficiency analysis were performed using PVsyst software for a grid-connected photovoltaic system with an annual energy production of 1109 MWh at Umm Al-Qura University. It has been verified by the PVsyst software that 1109 MWh of energy can be met by a 100 MW photovoltaic power plant [5].

In a study conducted for the International Solar Energy Institute in Tashkent, Uzbekistan, analyses of the 2.24 kW photovoltaic system connected to the grid were done using PVsyst simulation software for 2018. Eight modules with a power of 280 W and four micro-inverters with a power of 580 W were used in the system installed in the field. It was observed that the power plant produces 14.65 kW of power under the best conditions. The performance rate of the system was calculated as 79.7% in the PVsyst software, and the actual performance rate was calculated as 95.5% [6]. A study was conducted for the photovoltaic system planned to be installed in Borg El Arab, an industrial city in Egypt. The system is designed for a commercial building with a total power capacity of 1.47 MW DC. SAM and PVWatt software were used to simulate the system's electricity generation, which was created with 4608 modules and two inverters to form 18 serial modules and 256 parallel arrays [7]. Again, a PVsyst simulation study was conducted for India's Bikaner Engineering Faculty machinery department office. The annual energy demand for the Mechanical Engineering Department was determined to be 1086.24 kWh; It was calculated that the current produced energy with the solar panels is 1143.6 kWh, and the energy provided to the user due to different losses is 1068.12 kWh [8]. In another study, instead of analyzing the annual optimum inclination angle of the panels in the photovoltaic system, the monthly or seasonal optimum inclination angles were analyzed, and the effect of this scenario on energy efficiency was studied. For this, the geographical location of the University College of Science and Technology in Gaza Strip-Palestine was chosen. The System simulation was done using the Photovoltaic Geographical Information System (PVGIS) software. It was observed that the energy produced increased by 5.82% and 4.77%, respectively, when the monthly and seasonal optimum slope angles were used in the system. Results were then validated with SAM. The results obtained from the SAM were close to those obtained from the PVGIS software tool [9]. In another study, the design and performance analysis of the 700 kWp photovoltaic system connected to the grid in Daikundi city of Afghanistan was done using Pvsyst. As a result of the simulation, the system production was calculated to be 1266 MWh/year, the performance ratio as 0.797, and the system losses as 0.10 kWh/kWp/day. If the power factor is between (0.7–0.9), it is stated that the system works efficiently [10]. In another study for a photovoltaic system having different operating conditions, a grid-connected solar roof system was designed in Bhubaneswar, Odisha. With the help of SAM and Solar Edge software, various studies such as site selection, roof selection, panel layout, and array electrical design were carried out, so the roof of the building and the total efficiency loss was calculated with design and simulation [11]. In a study for photovoltaic solar energy planned on the roof of an agricultural farm in the city of Elazig, analyses and designs were done using PVsyst software. According to the analysis results, it was observed that the system would produce 1601 MWh of energy for 10 years, reducing approximately 164,547 tons of carbon emissions. The amortization period of the photovoltaic system was calculated to be 4.6 years [12]. In another study, a hybrid photovoltaic system of a 17-digit village in India with google coordinates of 14.13°N and 75.42°E was investigated using PVsyst software. The system was designed for 3 different applications: 13.84 kWh/daylighting, 30 m^3 water pumping, and a combination of both energy needs. After comparing the hybrid system with the individual systems, it was seen that a reduction of 1.32 kWp in photovoltaic capacity and a payback period of eight years resulted in a 21.87% savings in the total project cost [13].

In this study, the electricity generation data for one year for the photovoltaic sourced Solar Power Plant (SPP), located on the roof of cold storage in Elmalı district in the province of Antalya, was taken from the power plant's remote monitoring system. The plant was simulated separately in PVsyst and SAM (System Advisor Model) software. By comparing the results of the simulations and the production data with each other, the similarity rates of the programs to the actual production data were calculated. Thus, in the preliminary estimation of electricity generation data for an SPP to be established in Elmalı, one of the two different software gave production results closer to the actual production data determined, in particular, the climate data package used in the study. A study has been carried out that will guide commercial investments and academic studies of power plants of similar capacities in the district.

2. MATERIAL AND METHOD

This study was carried out in Turkey, Antalya province, Elmalı district. The actual data of the power plant for 2021 were used for the Simulation. According to the General Directorate of Meteorology data, Elmalı district has a semi-arid-semi-humid second-degree mesothermal climate type. Winters are cool, and summers are hot. The highest temperature was measured as 45 ºC and the lowest temperature as -4.6 ºC between 1930-2021 for the province of Antalya, where Elmalı district is affiliated. The annual average temperature is 18.8 ºC, the annual highest and lowest temperatures are 24.2 ºC and 13.8 ºC, respectively, and the average number of rainy days is 83.5 days [14]. In Figure 1 and Figure 2, graphs showing the global radiation values and sunshine durations of the Elmalı district are given [15].

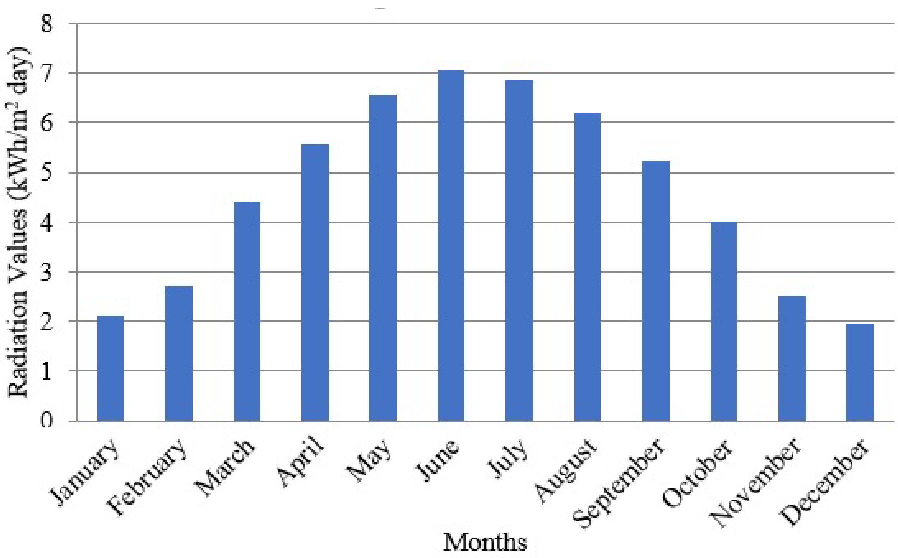

Figure 1. Global monthly radiation values graph of Elmalı district.

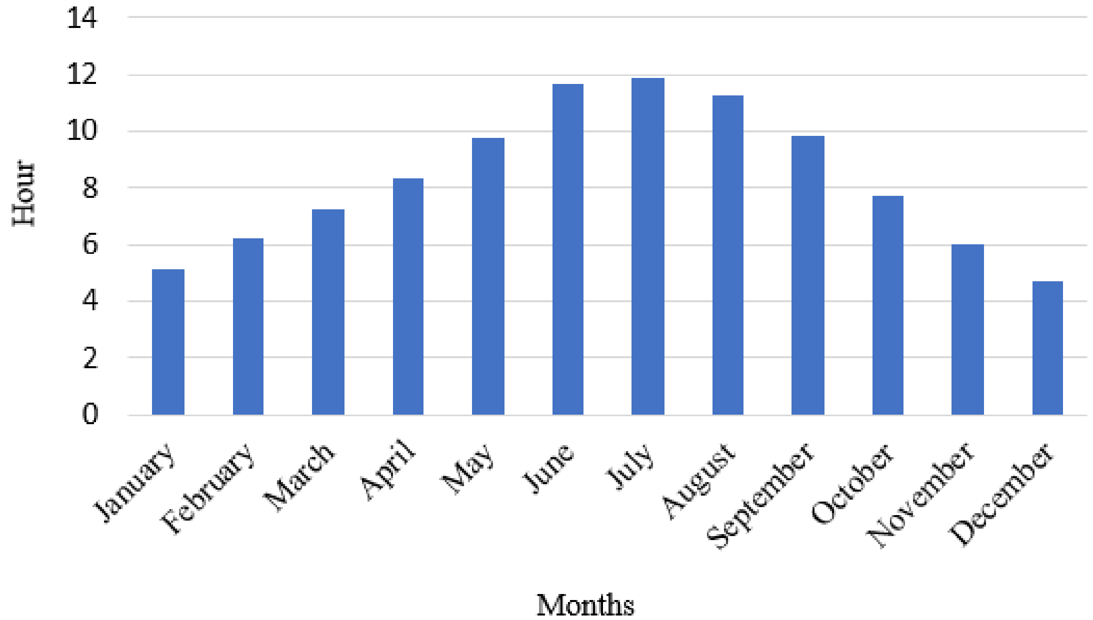

Figure 2. Sunshine duration of Elmalı district.

2.1 General Features Of The Powerplant

The study was carried out for the solar power plant installed on the roof of cold storage in the Elmalı district. The view of the power plant is presented in figure 3.


Figure 3. A picture of the power plant being studied.

The roof where the power plant is installed has 2 different orientations. Both of these orientations are inclined at 10 degrees. A total of 360 panels and 2 inverters were installed on the roof of the power plant. The characteristics of the panels and inverter are given in table 1 and table 2. The panels used in the power plant consist of 18 rows, and there are 20 panels in each row.

Table 1. Technical and mechanical properties of the panels used in the power plant

Technical Properties of the Panels	
Number of Strings in the System	18
Number of Panels in the System	20
Total Number of Panels	360
Panel Type	Monocrystal Panel
Panel Angle	East-West 10°
Maximum Power	325 Wp
Maximum Voltage Vmpp	33.68 V
Maximum Current Impp	9.65 A
Open-Circuit Voltage Voc	40.55 V
Short-Circuit Voltage Isc	10.26 A
Mechanical Properties of the Panels	
Panel dimensions	1670mm x 1000mm x 35mm
Cell	Monocrystalline
Cell number	60
Weight	18kg ± 1kg
Front Glass	3.2mm, tempered glass with high transmittance and low iron content
Back Protection	Polyester PET Film
Frame	Anodized Aluminium
Junction Box	3 Bypass Diode
Connector	MC4 Compatible

Table 2. Technical specifications of the inverter used in the plant

Technical Properties of the Inverter Used in Elmali Power Plant	
Number of Inverters Used	2
Number of Series per Inverter	9
Rated Power of Inverter	50 kW
Maximum Input Voltage DC	1000 V
Starting Voltage DC	420 V
MPTT Starting Voltage Range DC	480-800 V
MPTT Number	3
Maximum Input Current	108 A
Maximum Short Circuit current	165 A
Nominal Output Power AC	50 kW
Maximum Output Power AC	55 kW
AC Voltage	400 / 230 V
Maximum Current Flow AC	80 A
Frequency	50Hz/ 60Hz

In the study, the power plant project was examined, and simulations were carried out using PVsyst and SAM programs in accordance with reality. In the simulation studies, the climatic data package of the NSRDB resource in the climate interface of the SAM program was used. Some data on climatic characteristics are given in Table 3.

Table 3. Climatic data sourced from NSRDB

	Global Radiation (kWh/m^2)	Diffuse Radiation (kWh/m^2)	Average Temp (°C)	Wind Speed (m/s)
January	65.9	26.97	1.51	1.8
February	100.3	33.36	4.38	1.5
March	137.9	46.23	7.74	1.8
April	181.4	57.69	11.14	1.6
May	196.2	75.21	15.68	1.6
June	224.2	59.36	21.95	1.5
July	254.8	49.22	26.7	1.8
August	199.8	57.09	25.36	1.5
September	187.3	39.96	23.1	1.6
October	136.3	30.25	14.66	1.6
November	88.3	26.55	9.04	1.4
December	61.6	23.27	6.78	1.6
Total	1833.9	525.16	14.06	1.6

The panels in the power plant have 2 different azimuth angles since the roof has two different orientations. The azimuth values are 53° and -127° for the PVsyst program, 53° and 307° for the SAM program, and the panel slope is 10°, the same as the roof slope. The numbers and total powers of the panel group with each azimuth angle in the power plant are equal to each other. Panel groups with different orientations in this power plant are connected to different inverters. By comparing the simulation results with the plant data, deviation rates from the plant data were calculated. Simulation steps are presented under separate headings for the software used.

2.2 Procedure of Simulation

In this study, PVsyst software version 7.2.12 was used. PVsyst is a computer software package for inspecting, sizing, and data analysis of PV systems. It deals with grid-connected, off-grid, photovoltaic systems involving the use of pumps. In the analyses done, it includes a very comprehensive background on meteorological data and photovoltaic system component data. This software is very useful in both industry and education. The interface of the software is presented in Figure 4 [16].

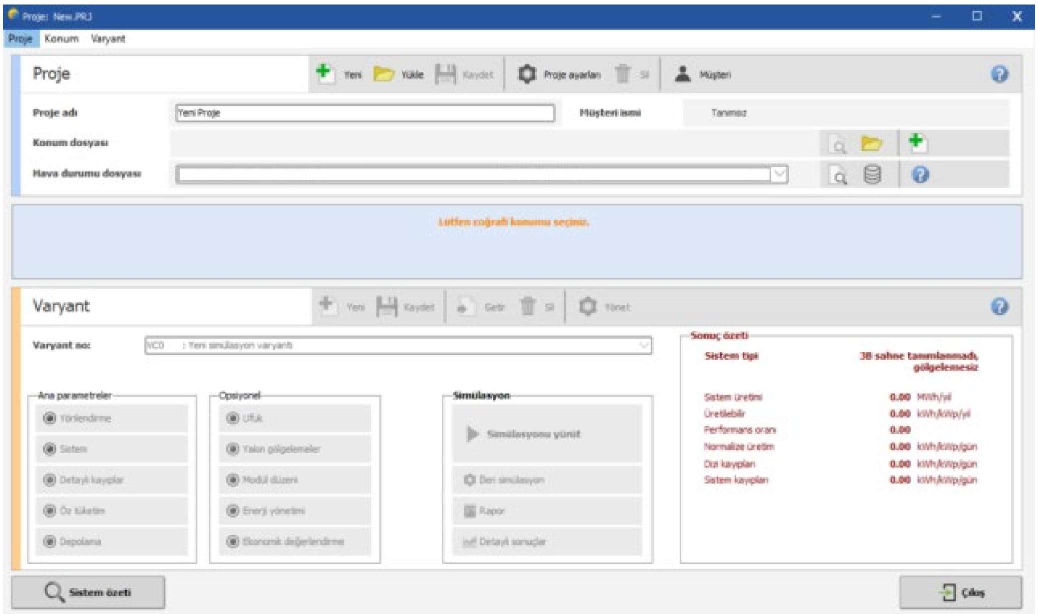

Figure 4. The interface of PVsyst software

Since the power plant where the study was carried out is a system connected to the grid, the "Grid-Connected" system option and then the location of the power plant were selected in the "Project design and simulation" section. Since the same climate data should be used for both software after location selection, the climate data selection process was performed using the import option in PVsyst software of NRSDB climate data from the SAM software repository. In the software, the azimuth angle Azimuth values and the current inclination angle of the panel are entered under the orientation button, and the panel orientation number is defined as two. Then, by entering the system button interface, the panel and inverter options used in the switchboard were selected from the system database, and the serial and parallel connection numbers and shapes of the panels in the power plant were defined here, and the simulation was completed. The process flow chart for this study is presented in Figure 5.

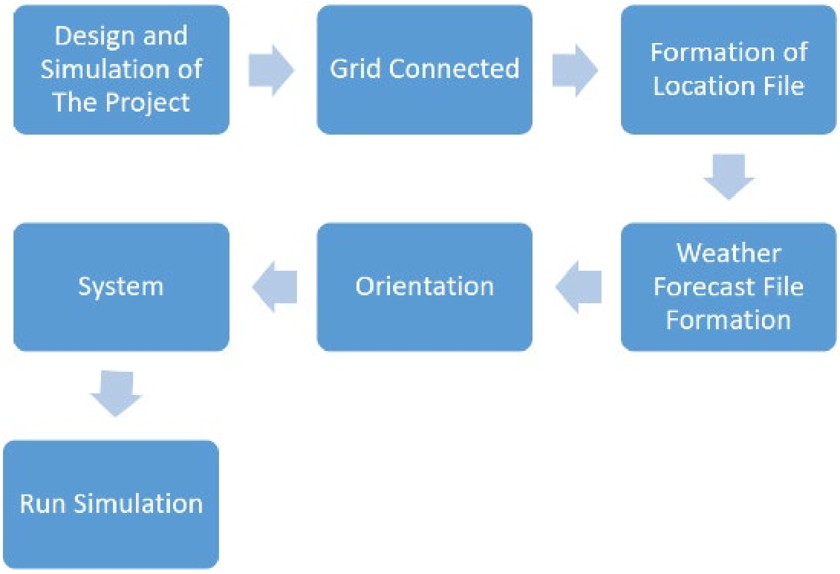

Figure 5. Process flow chart of PVsyst software.

2.3. Simulation Procedure in SAM

SAM software has a wide range of educational and sectoral uses by offering different renewable energy systems simulations and energy storage simulations. This study was carried out using SAM version 2021.12.2. The software interface is presented in figure 6 [17].

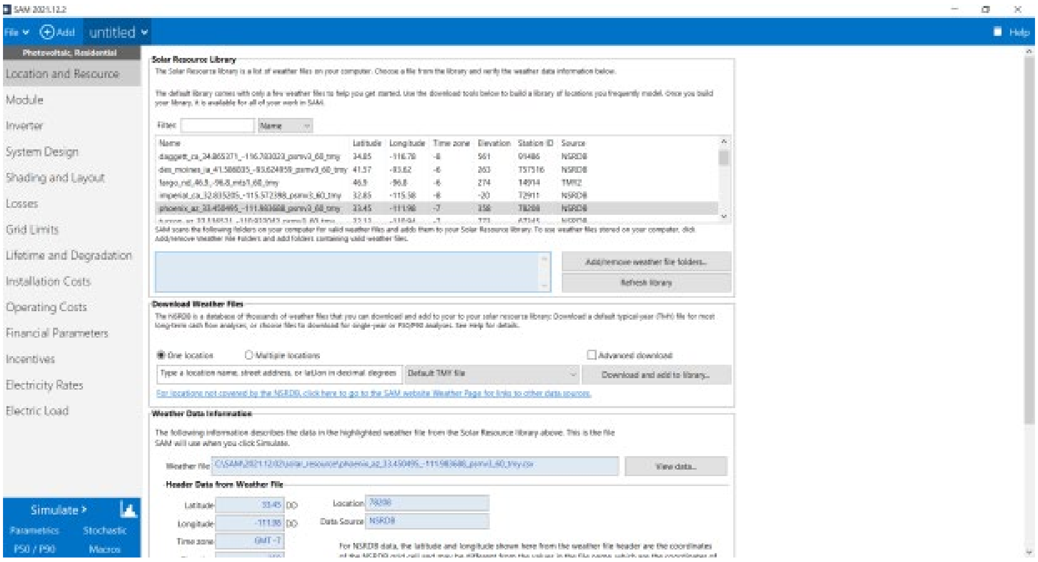

Figure 6. SAM software interface

After selecting the file button in the software interface, the new project option was selected, and then the photovoltaic section was entered. A detailed PV model option was selected under the Photovoltaic option, and a grid-connected option was selected since the current plant is a grid-connected system. The project interface was switched over to the individual user interface. The location determination process, the first step of project simulation, was carried out by entering the coordinates of the power plant into the system. The data from the NSRDB climate data catalog were drawn and defined in the system for simulation. After this stage, the panel and inverter data used in the power plant are entered into the program, and the panel and inverter steps are completed. Under the system design button, 2 different orientations were selected, and azimuth angles, panel angles, and the number of inverters were processed. Features such as the number of panels in an array and the number of arrays were entered into the software. The simulation is completed by performing all these operations. The process flow chart of the simulation is presented in Figure 7.

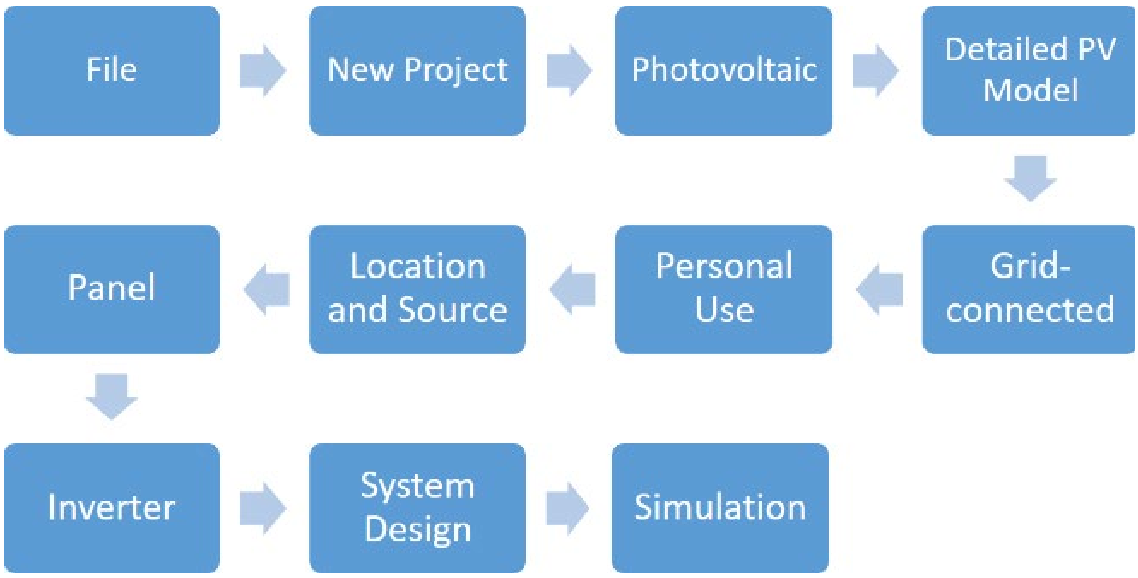

Figure 7. SAM software process flow chart.

2.4. Statistical Analysis

As a result of the simulation studies, one-year data was taken, and these data were compared with the real data and with each other on a monthly and annual basis. Several comparison parameters are used to facilitate the calculation of the deviation between each software and to obtain a reliable comparison. Using Equation 1, monthly and annual deviation rates were calculated. In addition to the annual deviation between the software, the RMSD (Root Mean Square Error) given in equation 2 and the MAD (mean absolute deviation) analysis methods given in equation 3 were also used.

$$\%\ DEVIATION = \frac{D_g - D_s}{D_g} \times 100 \qquad (1)$$

In Equation 1, D_g represents the actual value for the corresponding month. The D_s value represents the value of the same month for one of the simulation programs used.

$$RMSD = \sqrt{\frac{1}{n}\sum_{t=1} (G_t - S_t)} \qquad (2)$$

$$\text{MAD} = \frac{1}{n}\sum_{t=1} |G_t - S_t| \qquad (3)$$

In Equations 2 and 3, the "n" value represents the total number of months in a year, and "G_t" and "S_t" represent the actual production value of the month for which the calculation is made and the value belonging to the simulation, respectively. In this study, the most commonly used analysis methods in the literature were preferred.

3. RESEARCH FINDINGS AND DISCUSSION

The monthly and annual electricity production values obtained from the simulations using the PVsyst and SAM program were compared with the actual values taken from the power plant on a monthly and annual basis. The comparison of PVsyst, SAM, and power plant electricity generation data is presented graphically in Figure 8. It has been calculated that October is the month in which the PVsyst data and the power plant data are closest to each other, and there is an electricity generation difference of approximately 73 kWh between the two data. The month in which the largest difference between the two data was observed was June. This month's difference between the two data was calculated as 3630 kWh. It was calculated that the plant data is closest to each other with the generation data obtained from the SAM software and that there is an electricity generation value difference of approximately 947 kWh between the two data. It was calculated that the most significant difference between the data occurred in June, and the difference between the two data in this month was 4530 kWh. When examined in general, it has been calculated that the electricity generation values obtained from the PVsyst and SAM software in April are very close to each other. There is an electricity generation difference of 79 kWh. In July and November, it was calculated that the electricity generation difference between the software was the highest, and this difference was obtained as 1180 kWh.

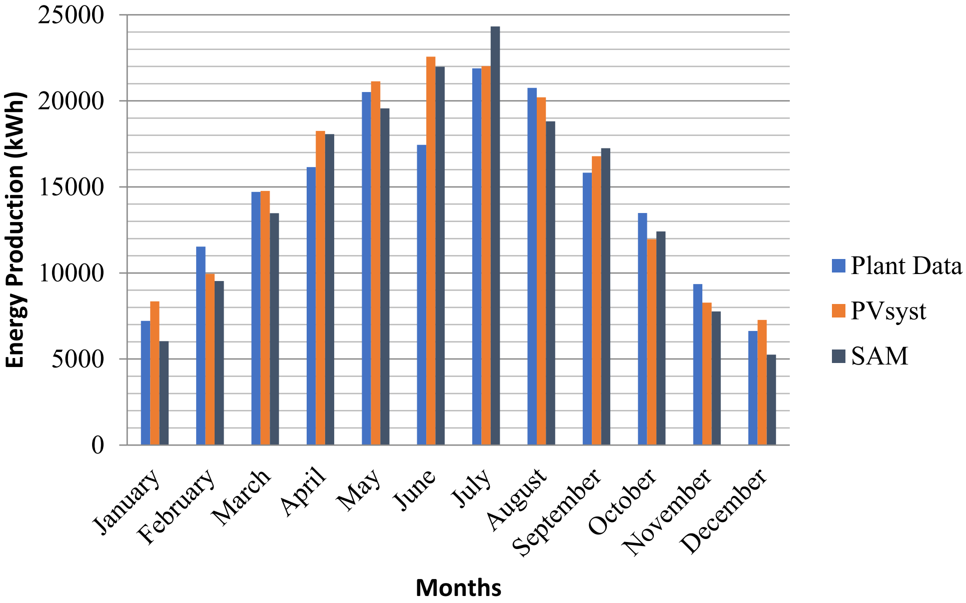

Figure 8. Monthly PVsyst-SAM and power plant data graph

The annual total electricity production values of the software and the total annual electricity production of the plant are presented in Figure 9. The annual total electricity production of the power plant was 175515 kWh. As a result of the simulation made with the SAM software, the electricity production was 174481 kWh, and as a result of the PVsyst simulation, the electricity production was 177750 kWh.

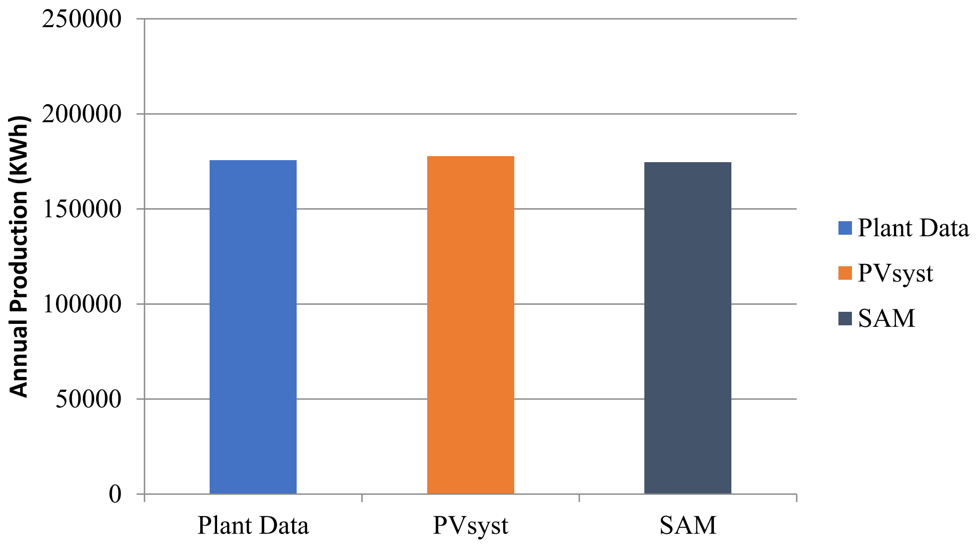

Figure 9. Annual production values of PVsyst, SAM, and plant data.

When the data obtained from the PVsyst software are evaluated, the monthly deviation rates from the plant values are given in Figure 10. When the rates are evaluated, the deviation rates are approximately 4% in January, March, and November, 6% in May, July, and December, 9% in February, 11% in August and September, 12% in April, 21% in June and 0.5% for October.

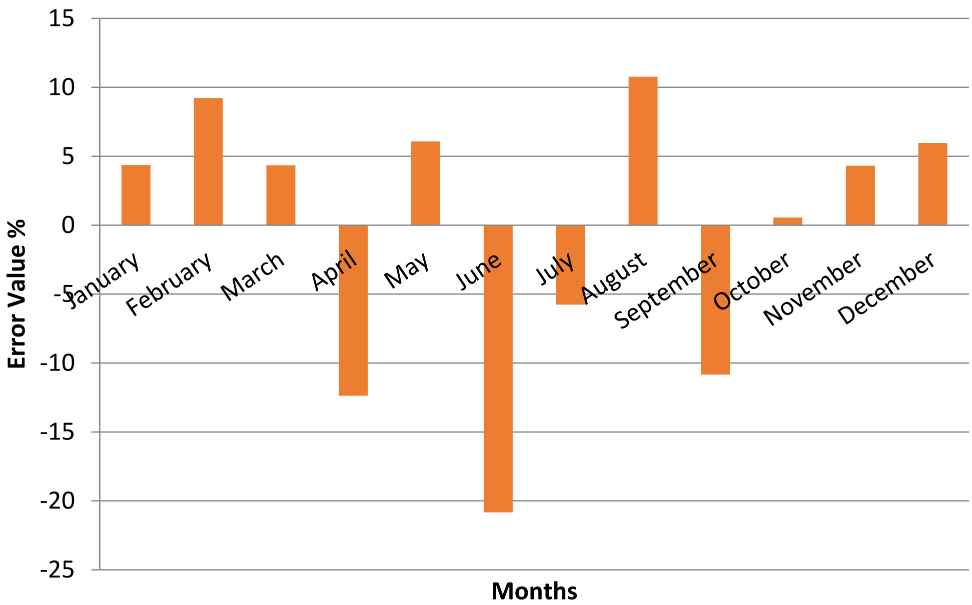

Figure 10. Monthly deviation rate of PVsyst software according to plant values.

When the data obtained from SAM is evaluated, monthly deviation rates from the central values are given in figure 11. When the rates are evaluated, the deviation rates are approximately 4% in May, 8% in March and October, 9% in August and September, 11.5% in April and July, 16.5% in January and November, 17.5% in February, 21% for December and 26% for June.

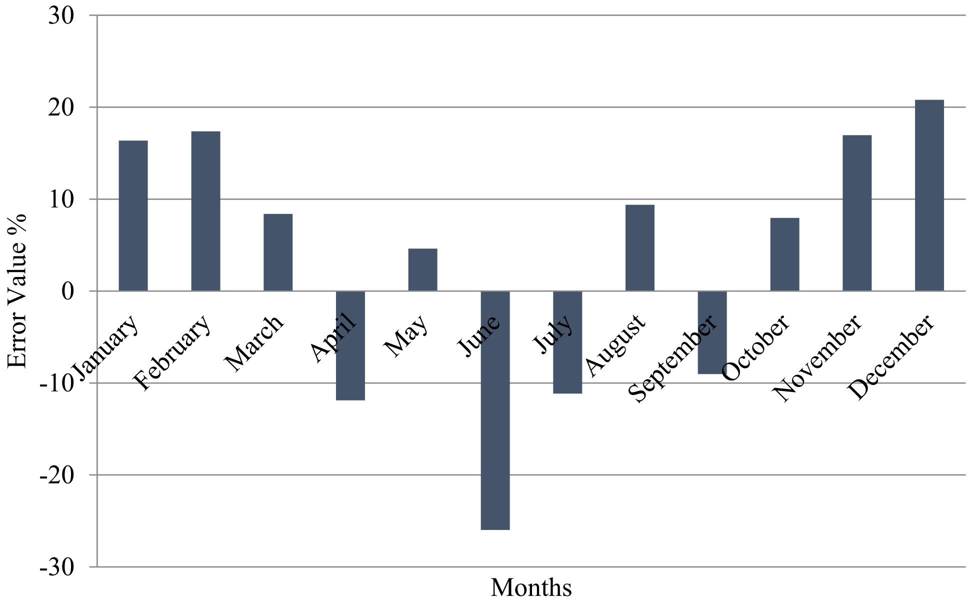

Figure 11. Monthly deviation rate of SAM software according to central values.

The loss diagram of the simulation performed in the PVsyst software is presented in Figure 12. Here, it is seen that the losses occur primarily at the nominal string energy and the total loss rate is approximately 20%. When the losses are subtracted, it is calculated that the net energy value produced is approximately 177.7 MWh.

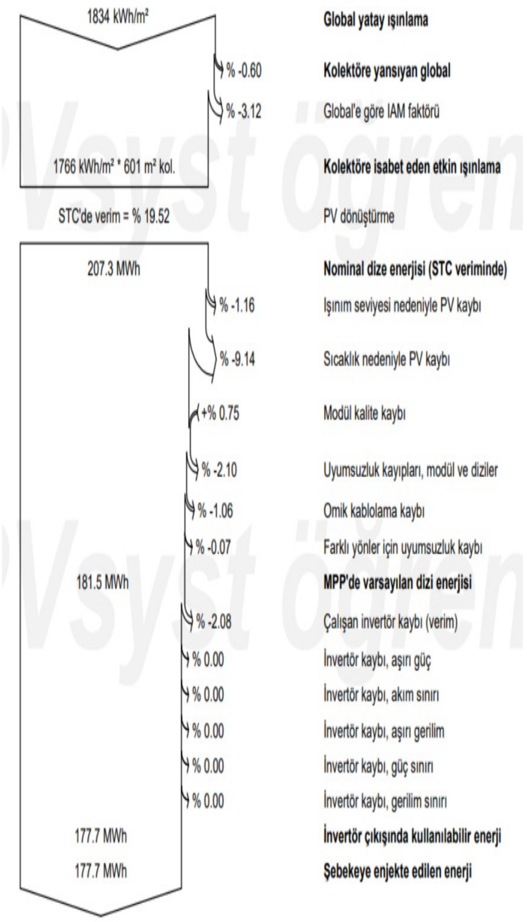

Figure 12. Loss diagram for PVsyst software

The loss diagram of the simulation performed in the SAM software is presented in Figure 13. It is seen that the total loss rate is approximately 15%, the electrical energy value given to the grid is calculated as 174.5 MWh and there are losses especially in the nominal radiation value coming to the panel surface.

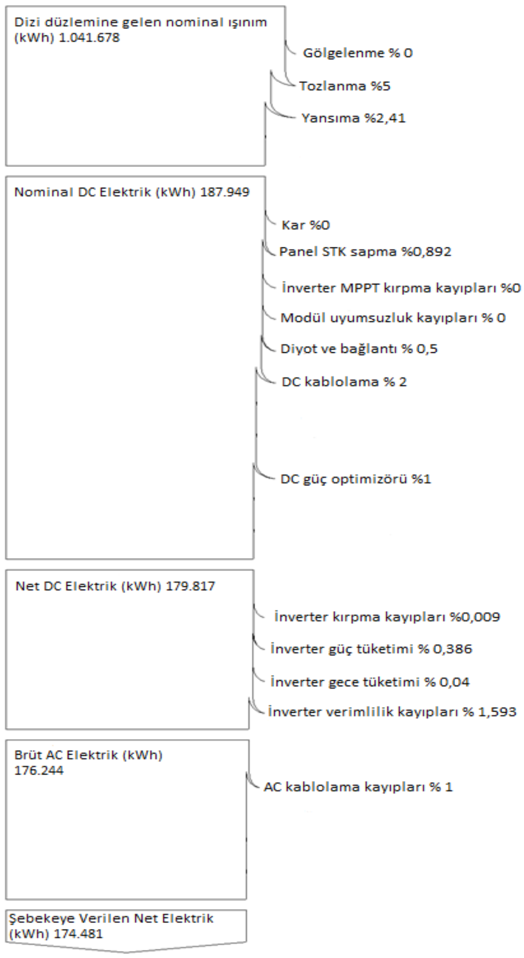

Figure 13. Loss diagram for SAM software

Figure 14 shows the data of the RMSD analysis method of the PVsyst and SAM. Here, it is seen from the plant data that the error values are lower for the SAM in April, May, and August, and the PVsyst has fewer error values in all other months. The annual deviation value was calculated as 298.69 for SAM and 644.94 for PVsyst.

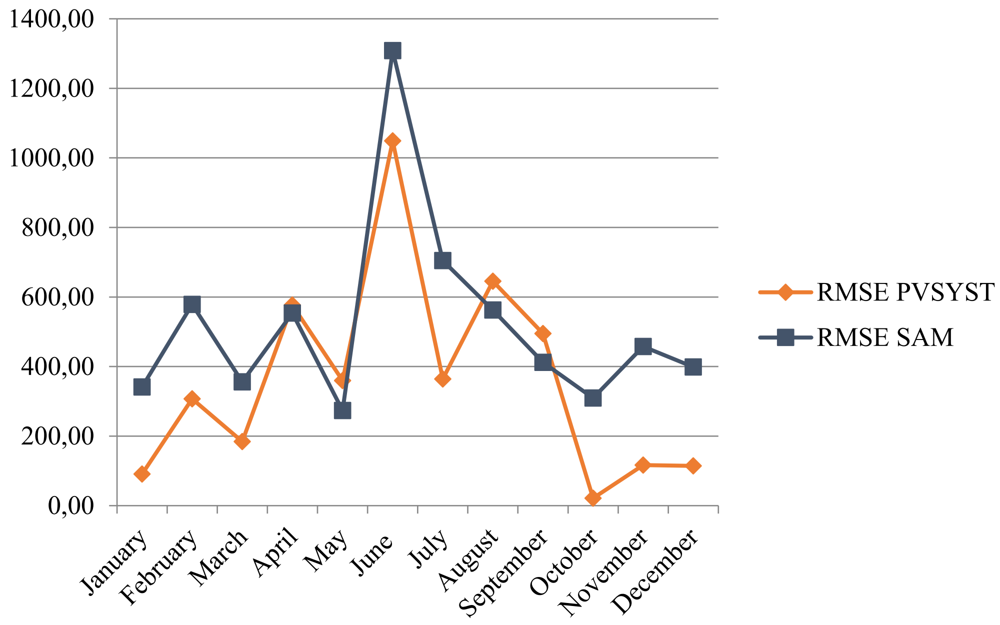

Figure 14. RSME results against actual production values for PVsyst and SAM simulations.

Figure 15 shows the data of the MAD analysis method of SAM and PVsyst. Here, it is seen that the deviation values from the plant data are lower for the SAM software in April, May, August, and September, and the PVsyst has fewer deviation values in all other months. The annual deviation value was calculated as 86.23 for SAM and 186.18 for PVsyst.

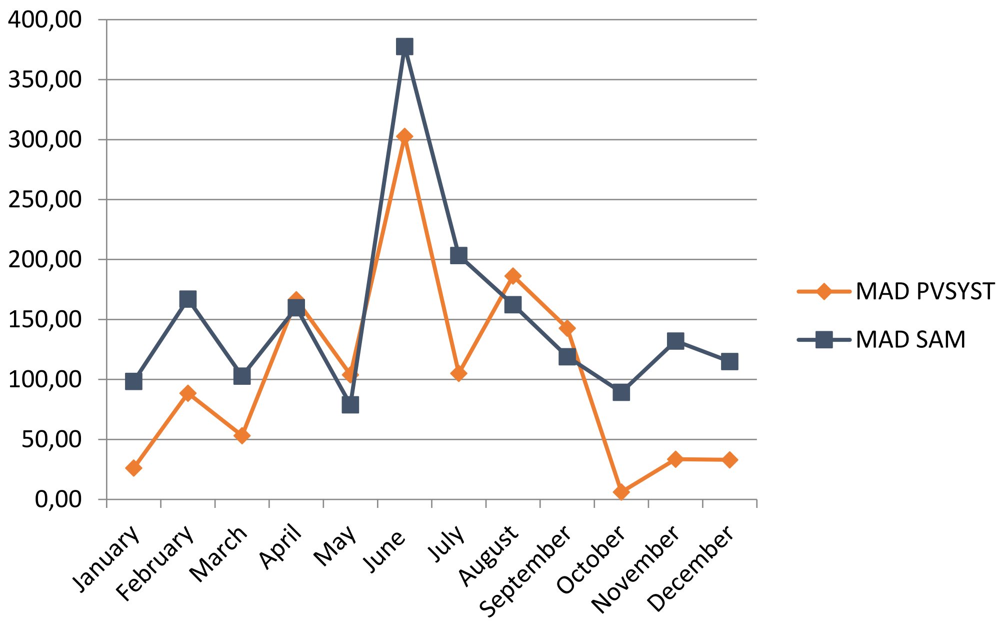

Figure 15. OMS(MAD) results against actual production values for PVsyst and SAM simulations

4. CONCLUSIONS AND RECOMMENDATIONS

In recent years, there has been a great increase in energy demand, and the incapacity to respond to this surge in demand has caused a large supply deficit. Thus, there has been a significant increase in energy prices globally. At this point, foreign energy-dependent countries such as Turkey are more affected by energy price hikes. This increase becomes much more noticeable with the fluctuations in foreign exchange rates. In terms of climate change and the use of domestic resources, the trend towards electricity generation has gained momentum in recent years, especially by the discovery of renewable energy sources in our country. Solar energy, one of the renewable energy sources, is more favored in terms of investment, especially since its maintenance costs are not high and the initial investment costs are low compared to other renewable energy systems. It is very important to estimate the electricity production values in solar power plants since the return rates of the investments are a very important part of the investments made. In this study, SAM and PVsyst, which are software with a very common usage area in academia and commercial, were used especially in simulations of electricity generation in solar power plants. At the point of electricity generation from solar energy of these two software, error and deviation rates were calculated by using statistical analysis methods. Thus, if the related climate data package is used, a prediction about electricity production estimation for the investments to be made at the specified location and nearby installed powers is provided. Which one of the two software could have the lower error and deviation rates from the actual production on an annual or monthly basis was determined as they were compared with each other. As a result of the comparison, it was calculated that the deviation rate of the SAM software data is 0.59%, and the deviation rate of the PVsyst software data is 1.27% annually. When the analysis using the RMSD method was examined, it was seen that the annual error value was 298.69 for the SAM software and 644.94 for the PVsyst software, and the SAM software reached higher error values in all months except 3 months. In the MAD analysis, it was determined that the annual deviation values were 86.23 for the SAM software and 186.18 for the PVsyst software, and the deviation value of the SAM software was lower in only 4 months of the year. Evaluating the deviation rates on an annual basis and using the specified climate data showed that the deviation and error values of the SAM software were lower on an annual basis compared to all the analysis methods given in the study. When evaluated monthly, it was determined that the deviation and error rates of the electricity generation data of the PVsyst software were lower than all analysis methods. In addition, when losses were evaluated, it was determined that the loss rates for the two software were different. In light of all these data and the results that will be taken into account during the simulations of the power plants to be established, it is recommended to use the SAM software in annual evaluations since it gives results closer to the real electricity production when evaluated on an annual basis, and PVsyst software in monthly evaluations, since it gives more accurate results monthly. The location of the region which could produce the highest amount of electricity & the lowest return of investment periods for the power plant, which is planned due to the low deviation in the region, can now be calculated thanks to the study which was carried out with the software specified above. Similar simulations for solar power plants installed in other regions of our country can be carried out with the help of different software and by determining the deviation rates in the simulations, which gives more accurate results in which region can be determined.

5. ACKNOWLEDGEMENTS

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Conflict of Interest

No conflict of interest was declared by the authors.

REFERENCES

[1] IEA, International Energy Agency. (2021). "Renewable Electricity". https://www.iea.org/reports/renewables-2021/renewable-electricity. [Access Date: 04.03.2021].
[2] EIGM, General Directorate of Energy Affairs. (2022). Turkish Electricity Investments January 2022 Summary Report. https://enerji.gov.tr/eigm-raporlari [Access Date: 20.02.2022].
[3] Silva, J. L. D. S., Costa, T. S., Melo, K. B., Sako, E. Y., Moreira H. S., Villalva, M. G. (2020). A Comparative Performance of PV Power Simulation Software with an Installed PV Plant. IEEE International Conference on Industrial Technology (ICIT).
[4] Gurupira T., Rix, A. J., (2017). PV Simulation Software Comparisons: PVsyst, NREL SAM and PVlib. Southern African Universities Power Engineering Conference (SAUPEC).
[5] Alnoosani, A., Oreijah, M., Alhazmi, M. W., Samkari, Y. (2019). Design of 100MW Solar PV on-Grid Connected Power Plant Using (PVsyst) in Umm Al-Qura University. International Journal of Science and Research, 8, 356-363.
[6] Matchanov, N. A., Seok, K. O., Mirzaev, A. A., Malikov M. A., Saidov, D. S. (2020). Study of Energy Yield on Grid Connected Micro-Inverter Type 2.24 kW PV System Using PVsyst Simulation Software. Applied Solar Energy, 56, 263-269.
[7] Darwish, M. A. A. (2021). Design of a photovoltaic system using SAM and ETAP software. 2021 International Conference on Green Energy, Computing and Sustainable Technology (GECOST).
[8] Kumar, R., Rajoria, C. S., Sharma A., Suhag, S. (2021). Design and simulation of standalone solar PV system using PVsyst Software: A case study. Materials Today: Proceedings, 46, 5322-5328.
[9] Dabbousa, T. A., Al-Reqeb, I., Mansour S., Zainuri, M. A. A. M. (2021). The Effect of Tilting a PV Array by Monthly or Seasonal Optimal Tilt Angles on Energy Yield of a Solar PV System. International Conference on Electric Power Engineering.
[10] Baqir, M., Channi, H. K. (2022). Analysis and design of solar PV system using Pvsyst software. Materials Today: Procedings, 48, 1332-1338.
[11] Rout, K. C., Kulkarni, P. S. (2021). Design and Analysis of Grid-Tied Rooftop Solar PV System at Bhubaneswar, Odisha Using SAM. International Conference on Intelligent Technologies.
[12] Doğan Y., Korkmaz, M. (2021). Application And Economic Contribution Of The Solar Energy System In Agricultural Plants: Usıng PVsyst Software. Engineering Sciences, 16, 89-96.
[13] Muralidhar, K., Rajasekar, N. (2021). Soiling and Shading Analysis of Hybrid PV System for Rural Application using PVsyst Software. 2021 Innovations in Power and Advanced Computing Technologies (i-PACT).
[14] MGM, Republic of Turkey General Directorate of Meteorology. (2022). Climate Data.

https://www.mgm.gov.tr/iklim/iklim-siniflandirmalari [Access Date: 24.03.2022].
[15] Republic of Turkey Ministry of Energy and Natural Resources General Directorate of Energy Affairs. (2020). Turkey Solar Energy Potential Antalya Data. https://gepa.enerji.gov.tr/MyCalculator/pages/7.aspx [Access Date: 24.03.2020].
[16] PVsyst. (2022). Programme Interface. https://www.pvsyst.com/. [Access Date: 31.03.2022].
[17] SAM, System Advisor Model. (2022). Programme Interface. https://sam.nrel.gov/. [Access Date: 31.03.2022].