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Examination of Web-Based PVGIS and SUNNY Design Web Photovoltaic System Simulation Programs and Assessment of Reliability of the Results

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ABSTRACT

Due to the polluting effect of fossil fuels on environment and their exhaustible nature, investments in renewable energy resources continue to increase. In order to benefit from solar energy which is one of these energy resources, 50 GW of new power plants were installed only in 2015. Following the "regulation on unlicensed electricity generation" issued to benefit from the renewable energy potential available in Turkey, the installation of systems that generate electricity from solar energy via photovoltaic power is rapidly increasing. The use of simulation software is very important in the design and analysis of photovoltaic solar power plants. In this way, it is possible to obtain production data and conduct investment analyses before the power plant is established. Some of the simulation programs are web-based. In this study, web-based solar energy simulation programs PVGIS and Sunny Design Web were investigated and the proximity of simulation results to the actual results was studied. Dicle University Solar Power Plant was selected as the study field in order to compare the simulation results of the software. Dicle University Solar Power Plant is a photovoltaic solar power plant established and operated within the Engineering Faculty of Dicle University for introduction, education, production and analysis purposes. In the study, simulation of the 250 kWp solar power plant established in Dicle University was performed with PVGIS and Sunny Design Web software by using installation parameters and thus, one-year production values were obtained. The results of both web-based programs are compared with each other and with the actual production values from the plant.

1. Introduction

Especially in 2015, the countries attending the Paris Climate Change Conference signed an agreement in which they agree and undertake that they will exercise effort to keep the temperature increase between 1.5-2 ^{o}C by diminishing the use of fossil fuels and thus reducing the greenhouse gas emissions [1-2]. Following this agreement, transition to renewable energy has started to gain momentum. Turkey also has rich renewable energy resources. In particular, utilizable solar energy potential is available. According to the study performed by EIE (General Directorate of Renewable Energy) using the sunshine duration and radiation intensity data available in General Directorate of Meteorology (DMI) measured in 1966-1982, average daily total sunshine duration and daily total radiation intensity are 7.2 hours and 3.6 kWh/m² respectively in Turkey [3-5]. While Turkey usually benefits from solar energy for water heating purposes in recent years, solar power plants make up a large proportion of the production plants installed after one of the statutory regulations “Regulation on Unlicensed Electricity Generation in Electricity Market” came into effect in 2013. 86% of the unlicensed plants installed are solar power plants. According to 2016 July data from EPDK (Energy Market Regulatory Board), installed capacity of temporarily accepted solar power plants has reached 582.04 MW.

Increasing studies on the installation of solar power plants in Turkey and in the world required the performance of feasibility studies such as cost analysis, compatibility and efficiency of these plants. Calculations must be made through simulation programs, because such calculations are dependent on many variables such as global solar radiation values and sunshine hours. Therefore, many programs have been released for the simulation of photovoltaic solar power plants or systems [6-11]. Some of these programs are web-based service providers. The web-based simulation programs PVGIS and Sunny Design Web are addressed in this study. By simulating an installed and operated power plant with these programs, it is aimed to compare the results with each other and with the actual production values of the plant. 250 kWp plant established in Dicle University has been selected as the installed and operated power plant.

2. Materials and Methods

PVGIS is a free online tool used to estimate the solar power of a photovoltaic (PV) system (Figure 2). It calculates the annual output energy of the panels. PVGIS is a project conducted by JRC (Joint Research Center) from the European Commission’s science services center. A free web-based simulation program was prepared as part of this project. This application shows the average daily and monthly electrical energy production as well as the global irradiation on the plant location per square meter in the form of graphs and tables. The system also provides the tables of estimated losses due to temperature and low irradiation by using local ambient temperature, estimated losses due to optical reflection effects, cable losses, inverter losses and combined PV system losses. It is possible to import horizontal-axis, tilted-axis and dual-axis results with the tracking options.

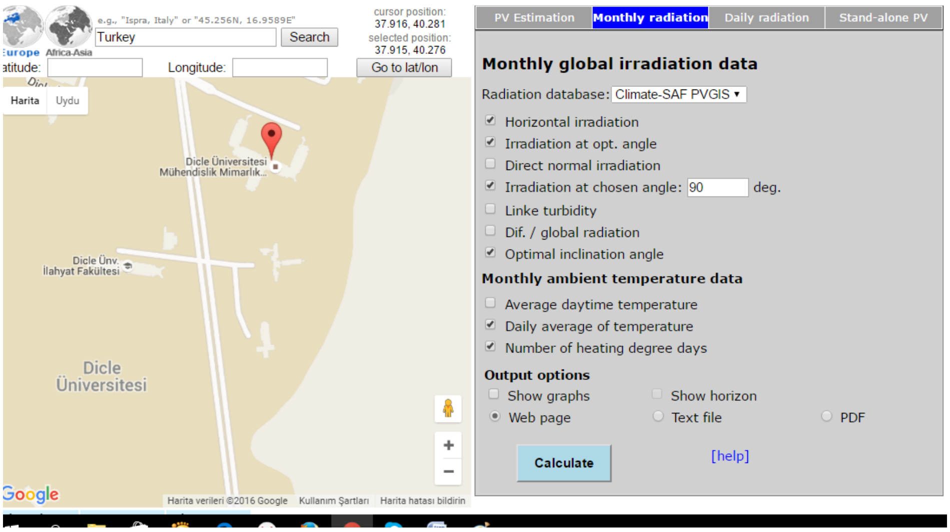

Figure 1. An example of interface appearance of the PVGIS software

Sunny Design Web is a web-based program with Turkish language option, developed by SMA Solar Technology for the design of renewable energy plants online. As shown in Figure 3, irradiation settings for configuration of the PV system can be both automatically retrieved from the database and customized by the user. The system also provides the opportunity to prepare self-consumption or non-self-consumption, non-connected and Hybrid PV projects. This program contains inverter and panel data of various firms, thereby allowing the design of solar power plants with the desired power and characteristics.

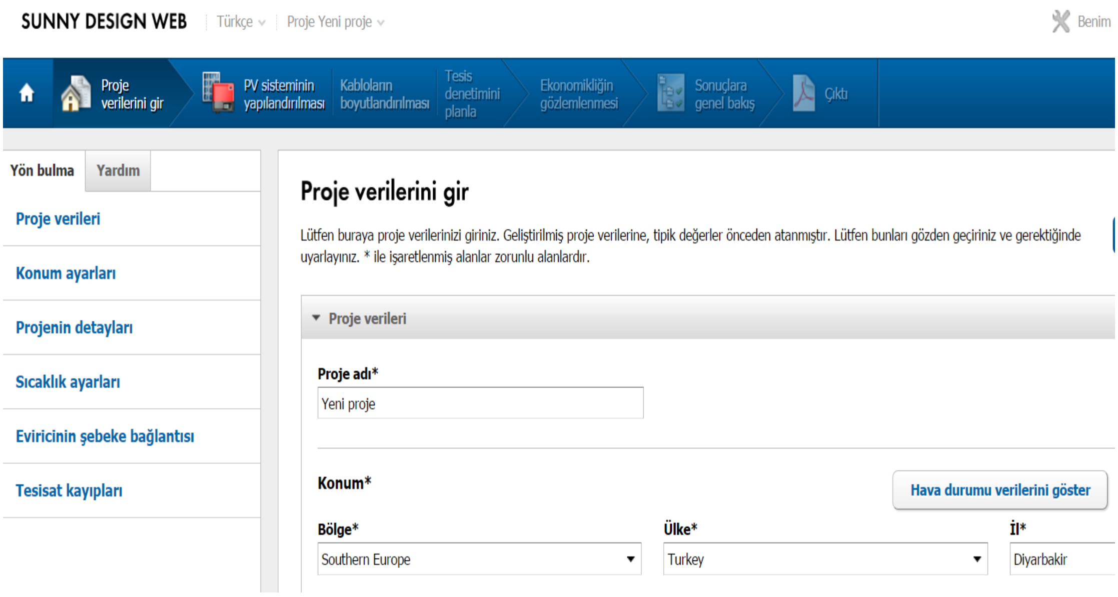

Figure 2. An appearance of Sunny design Web program interface

As an application example, 250 kWp solar power plant built in Dicle University Engineering Faculty was selected for the study [12]. By using installation parameters of this functioning plant, it was analyzed in two different web-based simulation programs.

Dicle University Solar Power Plant was built in the geographical characteristics of 40° 16'E longitude and 37° 54'N latitude. Its plant power is 250 kWp. Average ambient air temperature of the solar power plant ranges between 31.1 °C and 1.7 °C all year round [13].

Viessmann Vitovolt 300 P250 polycrystal modules were used in the plant. In this system, 1000 panes with 250 Wp power were placed with a 30° tilt angle and 0°' azimuth angle facing the south. Furthermore, 60 solar panels are present in each module. Characteristics of the panel used are given in Table 1. [14].

Table 1: Viessman vitovolt P250 module characteristics

	Measured Values	Rated Values
Nominal Power	253.1438 W	250 W
Maximum power voltage	30.3639 V	30.38 V
Maximum current	8.337 A	8.29 A
Open circuit voltage	37.1664 V	37.12 V
Short circuit current	8.796 A	8.76 A
Maximum system voltage	-	1000 V

The plant is comprised of eight 30 kW string and nine 10 kW strings. Catalogue information of the inverters is given in the Table 2 below. In the plant, one 10 kW ABB PVI-10-TL-OUTD and eight 30 kW ABB TRIO-27.6 TL-OUTD outdoor type inverters were used for the strings. Inverters have two MPPT inputs. There are 6 arrays in 30 kW inverters. Each three arrays are connected to one MPPT input of 30 kW inverters. 2 arrays are present in the 10 kW string. Each of these arrays is connected to different MPPT inputs of 10 kW inverters. 20 photovoltaic module series were connected in each array.

Table 2. ABB inverter characteristics

		ABB PVI-20.0-27.6 TL- OUTD	ABB PVI-10.0-12.5 TL- OUTD
Maximum Input Power	-	28600 W	12800 W
Maximum Input Voltage	$U_{INV-Max.Input}$	1000 V	900 V
Minimum Input Voltage	$U_{INV-Min..Input}$	500 V	360V
Maximum Input Current	I_{MPPT-1}	64 A	18 A
Maximum Output Current	-	46 A	22 A
Maximum Output Power	-	27600 W	12500 W

Dicle University Solar Power Plant is connected to the network via a 34.5 kV line. Network contact is provided by the conversion of low voltage at the inverter outputs to high voltage by a three-phase 0.4/34.5 kV 50 Hz, 630 KVA dry-type transformer. General wiring configuration of the Dicle University Solar Power Plant is shown in Figure 4.

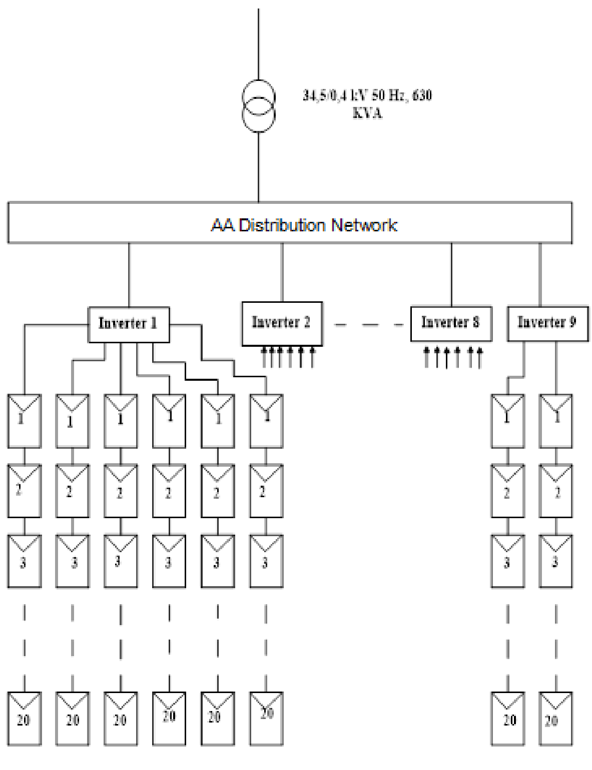

Figure 3: General wiring configuration of Dicle University solar power plant system

10 different parameters - PV power, energy, power produced, energy produced, DC power, DC voltage, current, voltage, output frequency, inverter temperature of the 250 kWp power plant can be measured and recorded in this power plant system by using ABB PVI-AEO-EVO data-logger. Immediate data were recorded in the data-logger in 5-minute intervals. Moreover, the data-logger has 12 digital inputs/outputs, 6 analogue inputs and 2 RS 485 series transmission ports. Recorded data can be remotely monitored by using Aurora Vision program.

3. Findings

All components used in the construction of the Solar Power Plant of Dicle University were modelled and simulated in PVGIS and Sunny Design Web programs. According to the simulation results from PVGIS, Table 3 demonstrates the average daily global irradiation amount on the horizontal surface by months. These values cannot be obtained in the Sunny Web Design program. The highest global irradiation value is observed in July.

Table 3. Change of global irradiation amounts by months according to PVGIS simulation program

Months	Average Daily Global Irradiation [kWh/m²]	Average Monthly Global Irradiation [kWh/m²]
January	3.3	96.9
February	3.9	109
March	5.33	165
April	5.7	171
May	6.58	204
June	7.56	227
July	7.66	237
August	7.58	235
September	7.05	212
October	5.83	181
November	4.42	132
December	3.17	98.4
Yearly	**5.67**	**172.36**

Comparison of the first-year actual production values and simulation results of the electrical energy produced by the Dicle University Solar Power Plant is presented in the Figure 5 below.

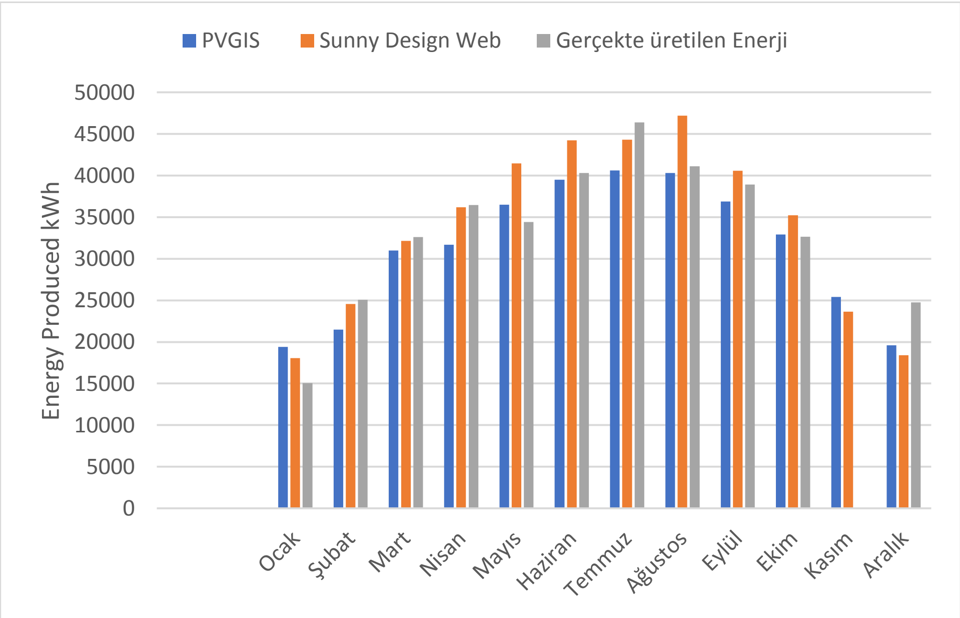

Figure 4. PVGIS - Sunny design Web simulation results

In this study, both simulation programs predicted less energy production than the actual energy production in December. Considering the actual production values of the plant, 20.8% and 25.64%

more energy was produced according to PVGIS and Sunny Design Web simulation programs respectively in December. The exact opposite was observed in January. The actual energy production by the system in January was 19.92% lower according to Sunny Designer Web simulation program and 28.97% lower according to PVGIS simulation program. In other months, simulation results and actual production values are more close to each other.

4. Results and Discussion

In this study, the solar power plant which was built in Engineering Faculty of Dicle University and has been analyzed for production values since December 2015 was simulated using the PVGIS and Sunny Design simulation programs in accordance with its actual values.

Analyzed results showed that 375.3 MWh annual energy production was predicted by the PVGIS simulation program and 406.23 MWh energy production was predicted by the Sunny Designer Web program. According to the Sunny Designer Web program, actual production values can be reached in April at the earliest. Sunny Designer Web simulation program predicted the actual energy production with an error of 0.83% for April. While an energy production of 36.474 MWh was observed in the system in April, PVGIS simulation program and Sunny Designer Web simulation program predicted 31.7 MWh and 36.172 MWh energy production respectively. PVGIS simulation program reaches the actual production values with the least error in October. The actual production values were predicted with an error of 0.82% for October. Actual production predictions for October were 35.224 MWh in PVGIS simulation program and 32.9 MWh in Sunny Designer Web simulation program. Actual energy production was 32.631 MWh in October. Considering the actual production values of the total energy produced during 12 months (excluding November) as shown in Figure 5, PVGIS simulation program predicted 4.85% less energy production than the actual production values while Sunny Designer Web simulation program predicted 3.9% more energy production than the actual production values. In the light of one-year performance, Sunny Designer Web simulation program was observed to produce closer results to the actual production values.

Plant assessment and performance analysis using simulation programs are not common in Turkey. However, obtaining performance parameters by simulating the solar power plant with simulation programs is important for the assessment of the plant. Thus, data offering insight into performance enhancing studies are acquired.

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