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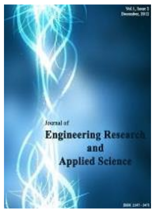

Software aided production value comparison of a solar power plant

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Abstract
In this study, electricity production values of a solar power plant belonging to Amasya University located in Amasya/Turkey were compared with the results of some solar energy calculation programs. When the comparison results are analysed, it can be seen that the production results of used calculation programs are less than the actual production of the plant. While the difference between actual production and HOMER calculation program is +6,69%, the difference between actual production and PVGIS stands out +10,62%. In consideration of these results, HOMER calculation program has been achieved closer results for facilities in Amasya region..

Keywords: fotovoltaic, HOMER design, PVGIS.

1. Introduction

Energy demand is increasing in over the world. The installed capacity reached to 95890,6 MW and consuming has been realized 310000 GWh in Turkey in the year 2020 [1]. In our country, in 2023, to upgrade our installed capacity to 110.000 MW and to make the rate of renewable energy facilities in installed capacity about 30% are among the other goals [2].

YEKDEM and YEKA support mechanisms for using domestic products made interest to investors drew on PV systems.

Engineering Design Companies are using computer software for all kinds of calculations such as the value of solar radiation in selected areas, the connection configuration of panels and inverters to be used, monthly and annual energy production, capacity ratios and financial cash flows.

Much software on the market are more effective on different issues so it is known that users use software according to their works.

In this work we aim to demonstrate the difference between the results of the simulation software PVGIS, HOMER and actual production results of a plant in-service in Amasya/Turkey for photovoltaic power plant investors who want to establish and design. Thus, feasibility studies may be prepared by considering this difference in new investments.

First, it will be beneficial to take a look to different worldwide research on applications and results of software programs.

Çubukçu and Colak (2013) were carried out a study in Gökçeada. A photovoltaic power system simulation independent from the network and the actual performance comparison examination was performed. In the PVGIS simulation program used in the study the system efficiency is calculated as 5% and 41% implementation rate and it was realized as 4% and 32% in physical measurement. It is observed that the study findings of PVGIS results appear very close to the actual results [3].

In the study made by Petrovic, Simic ve Vrazig (2013), the same data is given, and simulation results were investigated in HOMER, PVSYTS and PVGIS programs. When results are examined on a monthly basis, although the error percentages for each month are different, the program PVSYST has given the most accurate results on the basis of annual production [4].

In the study of Psomopoulos, Loannidis, Kaminaris, Mardikis and Katsikas (2015), PVGIS, PVWatts and RETScreen simulation programs have been compared. In the comparison of annual production

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with simulation results, PVGIS – 4%, PVWatts – 6,5%, RETScreen – 12,6 % difference has been found to occur [5].

In the study of Sharma, Verma ve Singh (2014), all commercially available photovoltaic solar simulation programs have been compared in detail in the category of accessibility, price, working platform, working capacity, output and update. As a result, all programs are more capable in different subjects so it would be useful to conduct the selection of program according to the work [7].

In the study conducted on the profitability of wind and solar energy use in cement sector by Araz and Çeliktaş, for determining the solar potential, PVGIS program data was used and in the designated area solar power plant recycling time was determined to be 11 years [8].

In the study of Karadoğan, Kılıçarslan and Çeliktaş (2014), In regions with high solar potential in Turkey, the production of ground and roof systems already installed and engaged in the production on grid was compared with PVsyst and PVGIS simulation programs results. As a result of comparison in different regions, actual energy production rose more than 5,54% and the largest difference was 11%, according to the software results [9].

Tomis and Pipa (2011) were conducted design and analysis of battery stores solar energy system to be presented for the use of the grid independent house in Slovakia by using the HOMER software. At the end of the study, the cost of energy production unit would be 0,8 €/kwh and when the cost of energy power line that must be made to draw the line to available network added, the resulting € 0.15 / kWh compared to the energy cost is estimated to be almost halved [10].

In the study of Al-Masri ve Amoura (2013) using the wind and hybrit potential of Jordan, production of electricity and review of the unit price of energy and the economy was determined. As a result of their analysis by means of the software MATLAB and HOMER the cost of energy production was calculated to be 0.049$/kwh in a hybrid system with a 20-year life expectations. [11].

Yerli, Özdemir, Kaymak ve Şahin carried out a feasibility and analysis study for establishment of a 500kwp PV Power facility in ITU Maslak campus. In this study, Homer and RETScreen software was used. As a result of the study total annual production would be 737,31 MWh and it has been calculated that it will pay off in 5 to 6 years. [12].

Hossain, Chowdhury, Longo, and Yaïci (2019) designed an off-grid rooftop solar system for conventional consumption of domestic electricity use in residential units in Bangladesh. They showed at HOMER a comparison of using a traditional grid connection and a standalone photovoltaic (PV) system. This system, in which 10% daily load variation is taken into account in HOMER, is designed for a peak load of 602 W, which is much higher than the daily load consumption, and the recommended daily energy consumption is accepted as 6 kWh. Since the cost per unit is approximately 0.211 $ (16.88 Tk) with this system, it has been observed that the total energy cost will decrease and there will be no additional fuel costs for energy consumption gradually. [13].

Fantidis, Bandekas, Potolias ve Vordos (2013) researched the unit price of energy in 20 kW PV system in Greece by using HOMER software, according to the placement of the installation area the unit price was determined to be between 0,122$/kWh to 0,152/kWh [14].

Alzyoud (2014) has used HOMER and ETAP software programs in the study of solar PV system integration into the electricity grid of Jordan. Besides daily and annual PV energy production, he has studied the flow of produced load in the grid bus and line losses [15].

2.General information

In this study, We used HOMER and PVGIS software programs that were frequently used in the literature.

HOMER (Hybrid Optimization Model for Electric Renewables) software is a computer-based program to design and analyze the combination of traditional energy supplies, generators and load with renewable energy sources. After the system you want to set up or analyse added to the program step by step, the data related to renewable energy sources are defined and the software is provided to make electrical and economic analysis. It is a useful program especially in the operation of the hybrid system to make a separate analysis of each system in terms of delivering economic and production details to the user.

In this study, rather than economic analysis of PV system, it was intended to make a comparison with annual production value, monthly and yearly energy output data of the software has brought to the force.
PVGIS (Photovoltaic Geographical Information System) is a map-based free software program used to estimate the production of solar power plants to be established in in Europe, Asia, Middle East and Africa. It is easy to use because it runs through the Google Map application. It has more than 10 years database from Europe-wide deployed 566 radiation measurement points. Taking into account the local temperature in the calculation and taking into account in calculating the efficiency losses in PV panels.

Figure 1 shows a general wiring diagram of the on-grid PV systems. In the 10-30 kW power inverters, designed for the roof, home and small applications, sizes become increasingly small, wall-mounted easy models becomes apparent. In future, inverters equipped with built-in protection equipment seem to minimize the external protection requirements.

For large-scale solar fields, power inverters from 100 kW up to 1500 kW are available to customers. Maximum of 98,6% efficiency resulting inverters have superior features such as easy to carry, easy installation, fast commissioning and internal grid protection. They support almost any kind of communication protocol and infrastructure is presented internally to the customer for remote monitoring [16].

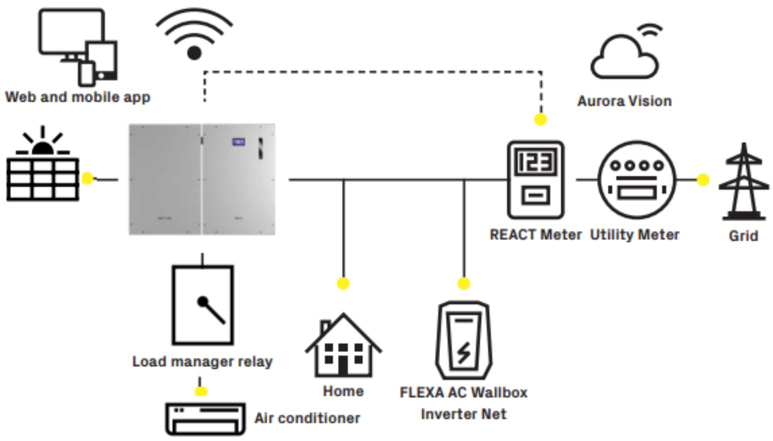

Figure 1. General connection diagram of the PV system [16]

Developments in the PV solar panels continue as well. On the market in terms of price/performance the most preferably and with most product types of panel technology is polycrystalline silicon technology. Increasing efficiency of the panels is now available in the market at higher power and efficiency and their productivity began to rise to 18%. Products of different countries are accessible in a lot of points across the globe and they possess relatively cheap tags. Temperature rise affects the panel output has declined to 0.48% / C° level with the existing panel technology [17].

Umar, Bora, Banarjee and Panwar (2018) aimed to reduce the cost by analyzing the degradation, performance and optimization of PV power plants through simulations in their study based on a 1 MW grid-integrated photovoltaic solar power plant. They compared the performance of ten different simulation programs such as Homer, SAM, RETScreen, and PVsyst. By comparing the simulation results with the actual data of the power plant, it enabled the selection of suitable programs for the researchers. In the study, the annual average performance rate was found to be 0.7737%, and the capacity utilization factor to be 14.57% [18].

3.Materials and methods

Solar power plant we have analyzed the results is connected directly to the network and running on-grid design. Power value is 200 kWp and the panels were placed on a stable system design and they do not follow the sun.

The region where the plant is established has gently sloping structure and short herbaceous plants are grown on this region. Because of soil structure, which is suitable for piling, the basic structure has been created in the piling construction method widely used in power plants and on aluminium profile construction that we have seen frequently in practice.

At the examination of the panel assembly, the inclination angle to the horizontal plane has found to vary from 29º to 33º. Because with the angle of the panels where they are mounted will directly affect production, to be mounted at the optimal degree determined with the simulation programs that we use could allow the capture of the results for most suitable production. The azimuth angle of the panels has been mounted to be 0º.

Connectors used in the wiring of the panel cables are moved up to the inverter in cable trays. Inverters are mounted under panels.

Figure 2 shows the used PV panels label values. Panels are Renesola Jiangsu LTD brand, JC250M-24/Bb, 250Wp model and produced by Poly-Si cell technology. Figure 3 shows the used inverters label values. Inverters was selected as Renesola Replus 20000 TL3B model.

Figure 2. Solar Panel Label

Figure 3. The used inverters label

The cables of the inverter are directly connected into the AC distribution board, from there they are connected to the ends of the LV of 1250 kVA transformers. In the HV side of the 31,5 / 0,4 kV transformer protective gear are provided by using breakers and disconnectors. And measuring board namely billing basis counter is also on the HV side of the transformer.

HOMER and PVGIS software which are widely used worldwide and made plenty of academic studies and research on are used to compare the actual production of existing solar power plant.

3.1. PVGIS

This software may be used directly through the online internet page without installing on the computer. By using the search boxes that you come across on the main page the desired region to build a power plant can be selected and in that area if you will build the plant under a 20 kWp power with solar tracking system or fixed system panels you may see what will be the results of annual production of plant.

It is not able to directly enter the PVGIS calculation screen because production plant examined in this study has 200kWp power PV panels. For this reason, production for the 1 kWp panel at selected coordinates has been found by PVGIS calculation and calculation of the production of examined plant have been made by multiplying monthly production result by 200. Figure 4 shows the selection of production plant in the main screen of PVGIS.

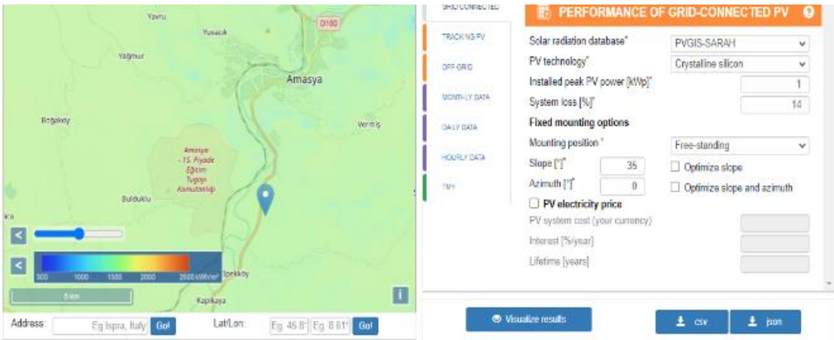

Figure 4. Main screen of HOMER

Table 1. PVGIS calculation result

Monthly PV energy and solar irradiation

Month	E_m	H(i)_m	SD_m
January	59.5	71.0	14.4
February	75.4	90.9	12.4
March	104.4	128.8	6.8
April	126.4	161.2	13.3
May	138.1	182.1	16.3
June	145.7	194.9	9.7
July	155.5	208.5	8.6
August	156.7	209.5	15.2
September	136.1	177.6	15.0
October	102.8	131.2	17.5
November	83.0	101.7	13.1
December	62.3	74.5	13.5

After selecting the desired area on the map on this screen, system power to be installed was selected as 1kWp. System efficiency was selected as 14%. As there is no solar tracking system, tracking checkboxes is not marked. Crystalline silicon was selected as PV technology and PVGIS was desired to use its own data for climatic calculations. Table 1. shows the reached calculations in PVGIS.

3.2. HOMER

In our study, only PV modules and the network is selected as the generator because calculation of energy will be produced using only the PV modules rather than the different generator sources. PV modules can be selected as internal inverter connected to the AC bar and also selected as connected to the DC bar. Figure 5 shows the main screen of HOMER

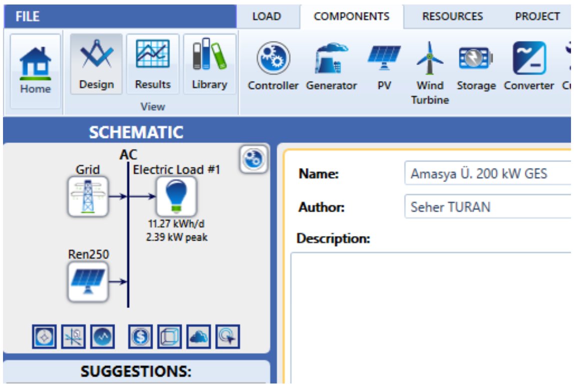

Figure 5. Main screen of HOMER

In the screen seen in Figure 5, the name of the production plant and project organizer's names are entered in boxes and the establishment region of production plant is selected on the map. After that, PV modules to be used in the facility are selected and added to the system as shown in Figure 6.

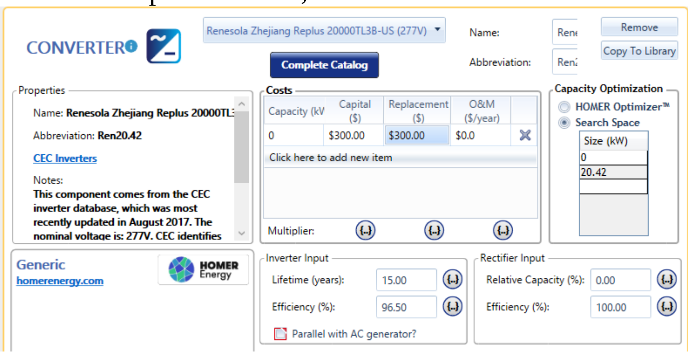

Figure 6. Adding options of HOMER panel

Since exactly the same inverters and network was not in program data similar inverters have been selected. The system was completed by network also added to the system.

After completing the system design, it has been given decision of reflection of solar radiation and climatic conditions are used in panels' efficiency calculations such as the number of cloudy days, year-round average temperature to be taken from which databank and loaded on the internet as shown in Figure 7. In this study, NASA data was used in calculations in HOMER program.

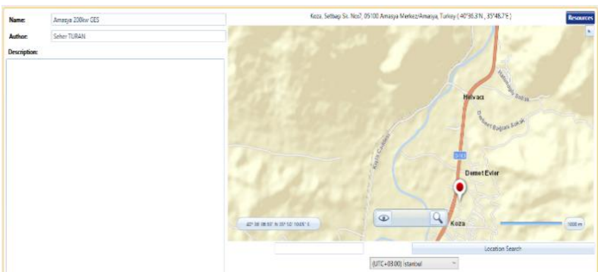
Figure 7. The selection of the climatic resources

After the design of the system and GHI (Global horizontal irradiance) value for a specified position on the map loaded from internet, it has been reached the result screen by pressing calculation button in HOMER program as shown in Figure 8.

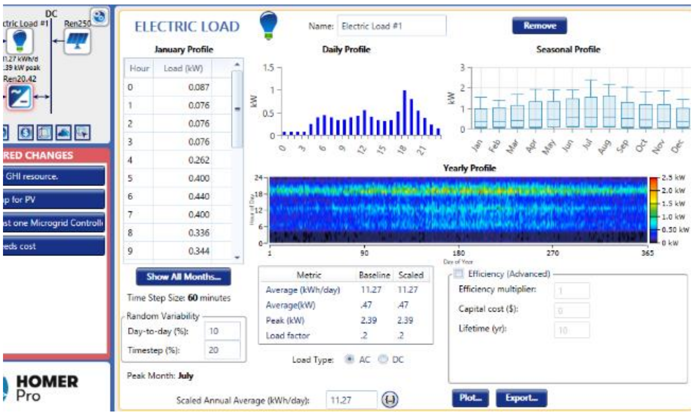

Figure 8 . HOMER calculation results

Calculation results on Figure 8 show that the total annual production of 200 KW panel will be 447.400,66 kWh. Again, the same results screen shows in the region seen as colored graphics at which times in the days of year PV system will produce how much power very clearly.

To provide a comparison of PVGIS, HOMER software and actual production on a monthly basis, results were arranged in Table 2, collected in monthly basis and converted the format as shown in the results section.

4.Results

PVGIS and HOMER software results were compared by selecting coordinates of solar power plant and similar PV panels and inverters. From the date of commissioning of plant, 20-month data was added to the comparison.

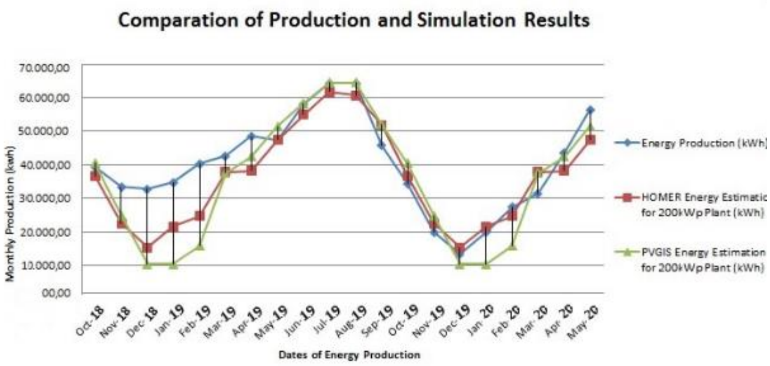

Figure **9.** Comparison of production and simulation results

Table 2. Actual production and software results comparison chart

Date	Produced Energy (kWh)	HOMER 200kWp Facility Production Estimate (kWh)	PVGIS Month Average (kwh/kwp)	PVGIS 200kWp Facility Production Estimate (kWh)
Oct. 18	23.761,46	22.680,548	120,6	24.120,00
Nov.18	21.353,976	17.012,232	85,9	17.180,00
Dec.18	21.150,628	14.123,916	60,8	12.160,00
Jan.19	21.902,00	16.662,32	59,5	11.900,00
Feb.19	24.153,824	17.913,36	75,4	15.080,00
March 19	25.093,908	23.145,6	100,4	20.088,00
April 19	27.431,084	23.278,12	126,4	25.280,00
May 19	26.963,876	27.001,66	138,1	27.620,00
June 19	31.226,96	30.014,576	145,7	29.140,00
July 19	33.765,984	32.740,368	155,5	31.100,00

Aug. 19	33.783,752	32.280,528	156,7	31.340,00
Sept. 19	26.298,4	28.729,676	136,1	27.220,00
Oct. 19	21.762,744	22.680,548	121	24.200,00
Nov. 19	15.969,216	17.012,232	83	16.600,00
Dec. 19	13.334,576	14.123,916	62,3	12.460,00
Jan. 20	15.948,728	16.662,32	60,7	12.140,00
Feb. 20	18.960,48	17.913,36	72,1	14.320,00
March 20	20.571,88	23.145,6	115	23.000,00
April 20	25.498,36	23.278,12	125	25.000,00
May 20	30.573,04	27.001,66	143	28.600,00
Total	479.504,88	447.400,66		428.548,00

In the comparison of production and estimated production shown in Table 2, total plant results were estimated by the monthly kWh / kWp power output value obtained from PVGIS results multiplied 200 as plant power. In HOMER software, the results indicate the direct result of production of 200 kWp PV panels. Actual production and simulation values are compared in Figure 9.

5.Conclusions

When the production comparisons were examined in figure 8, the results of both of the production simulation program is very close to the actual production results in the months of highest production and it is observed that in November, December and January months there is an amount difference between simulation and actual production.

It is observed that during the final months of 2018 very dry and cloudless year an increase occurred in actual production but during the end of 2019 closer to seasonal averages the difference between the production and estimated results were decreased.

As a result, actual production of plant and software results are very close to each other especially in high production months. The actual production seems to be a little more than estimates made by using the PVGIS and HOMER software for PV panel solar power plant to be made in Amasya region. This difference will function as a safety factor and it is seen as an amount more production than the production calculation in the forecast of the feasibility of investments helping in fastening the feasibility calculations.

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