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Optimum Design of the Battery Powered 6 Kwp Grid-Tie Photovoltaic System Under Kilis Conditions

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Abstract: ***The energy need is ever-increasing with the developing technology and increasing population. Fossil sources are widely being used in energy production since the past. Due to decline and even depletion of the fossil source reservoirs and the carbon dioxide emissions during their use, renewable energy sources are taking their place. In this study, electrical energy was produced from the renewable energy source, solar energy. The photovoltaic system is grid-tied and battery powered. When an electrical outage originating from the grid occurs, the battery steps in and provides the energy need of the system. The system was set in a Southeast Anatolia Region city of Turkey, Kilis. PV_Solar premium 2016 demo was used in system installment and analyses. In order for performance values of the program to reflect the real values, the region's geographical features, radiation, temperature, and insolation values are livingly defined. Photovoltaic system performance ratio, the amount of the energy that is given to the grid from the system, the amount of the energy that is stored within the battery from the system are obtained on a daily and a monthly basis in the system analyses. Existing conditions were accepted and the economic condition of the system in the following twenty-five years is examined.***

Keywords: Solar energy, photovoltaic, city of Kilis, system cost, battery powered systems

1. Introduction

One of the factors that determine the development levels of the countries is production and usage of clean energy. In this regard, recently clean and renewable energy sources started to take the place of fossil sources in the developed countries. Renewable energy sources are preferred due to their advantages such as being environment-friendly, sustainable, having low operation costs, reducing the country's dependence on foreign sources [1].

As a disadvantage, their initial installment costs are high [2]. However, when considered in the long term, the system pays off itself and makes a profit in short time. Countries follow various policies regarding the usage and improvement of renewable energy sources [3-5].

Researches regarding optimally benefitting from the renewable energy sources are being conducted. There are many studies about this topic in our country as well. Producing electrical energy from solar energy, which is a renewable energy, is one of the most important criteria regarding the country economy and development level.

Our country has enough potential regarding solar energy. Turkey's monthly average solar energy potential and Turkey's annual total solar energy potential distribution by regions are given respectively in Table 1 and Table 2.

Table 1: Turkey's monthly average solar energy potential [6]

Turkey's monthly average solar energy potential			
Months	Monthly Total Solar Energy		Hours of sunlight
	(Kcal/cm^2.month)	(kWh/m^2.month)	(hour/month)
January	4.45	51.75	103
February	5.44	63.27	115
March	8.31	96.65	165
April	10.51	122.23	197
May	13.23	153.86	273
June	14.51	168.75	325
July	15.08	175.38	365
August	13.62	158.4	343
September	10.6	123.28	280
October	7.73	89.9	214
November	5.23	60.82	157
December	4.03	46.87	103
Total	112.74	1311	2640
Average	308 cal/cm^2.day	3.6 kWh/m^2.day	7.2 hour/day

Table 2: Turkey's Annual Total Solar Energy Potential Distribution by Regions [6]

Solar Energy Potential Distribution by Regions		
Region	Solar Energy (kWh/m^2.year)	Sunlight (hour/year)
The Southeastern Anatolia	1460	2993
The Mediterranean	1390	2956
The Eastern Anatolia	1365	2664
The Central Anatolia	1314	2628
The Aegean	1304	2738
The Marmara	1168	2409
The Black Sea	1120	1971

As it can be seen from the tables, Turkey has an annual insolation capacity of 2640 hours, surpassing many countries in this regard. Our country also has an annual average radiation value of 1303 kWh/m2-year and daily 7.2 hours of insolation time. When considered on an annual basis, our country approximately has 110 days of daily insolation time. Under these conditions, our country is not using its solar energy enough for producing electrical energy [6]. Different policies are being developed to aid our country's development by making electrical energy production from solar energy more attractive [7].

2. Geographical Features of the Region

The study was conducted under the geographical conditions of Kilis, a Southeastern city of Turkey's. Kilis is located between 36o 42' 57" northern latitude and 37o 6' 54" eastern longitude. Average height is around 680m [8]. Annual temperature average is 16,9 oC. The region is one of the most ideal areas in Turkey regarding benefitting from solar energy due to its geographical conditions. According to the potential solar energy atlas (PSEA), total sun radiation values of the city of Kilis is given in Figure 1 [9].

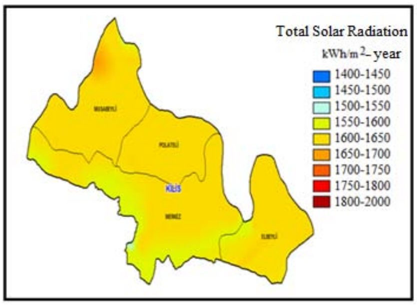

Figure 1: Total sun radiation values for the city of Kilis [9]

As it can be seen from Figure 1., the regions of the city of Kilis which are painted over with tones of yellow have more global radiation values. When considered generally, it can be seen that the radiation value of the city is higher than average radiation value. Insolation times of city of Kilis are given hourly on a monthly basis in Figure 2.

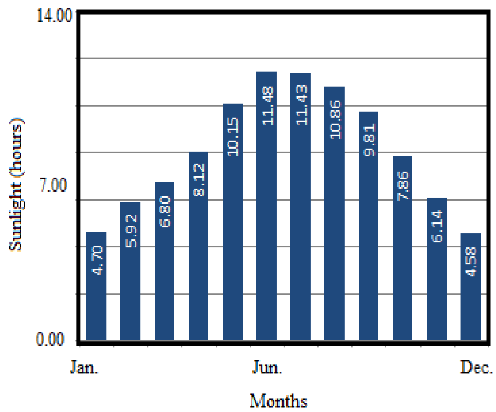

Figure 2: Monthly insolation times (hours) of the city of Kilis [9]

As it can be seen from Figure 2, when considered on an annual basis, June is the leading month in insolation time with 11.48 hour day. While the average insolation time is 11.25 hour-day in summer months, it is the lowest by 5.06 hour-day in the winter months. Total average insolation time is 8.15 hour-day on a monthly basis. The city has a higher insolation time compared to the average of Turkey.

3. Material and Method

6kWp grid-tie battery powered photovoltaic system design was made in this study. Demo version of PV solar-premium program was used for the design [10]. When the photovoltaic system is tied to the grid or a battery, it is possible to produce energy continuously. Battery systems step in when grid cannot provide the necessary energy, and supply the required uninterrupted energy. The system being perpetual is an important factor in many areas. Schematic for the designed system is displayed in Figure 3.

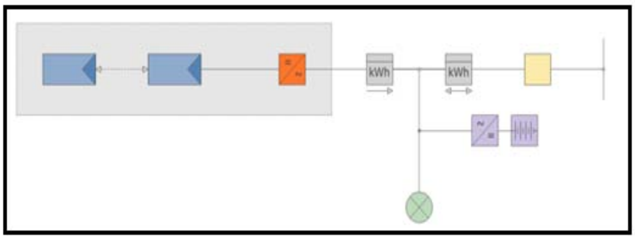

Figure 3: System schematic display

The system produces its energy by photovoltaic panels, and DC current is converted into AC current by the translator. This converted energy is transferred to the grid. Having a battery connection, the system charges the battery and gets supplied by it when the grid connection is severed. As the system's photovoltaic module, Solar Turk Energy company's module, which is connected parallelly to a 30o sloping roof, was preferred [11]. 24 modules were used in total. SMA Solar Technology AG company's MPP 1:1x11 and MPP 2: 1x11 featured types were used as a transformer. As a battery system, SunDepot 48-210 company's 165.0 A capable 5kW battery was used. Consists of 24 modules, the photovoltaic system has a surface area of 40 m2. The roof where the system is placed and layout of the panels are shown in Figure 4.

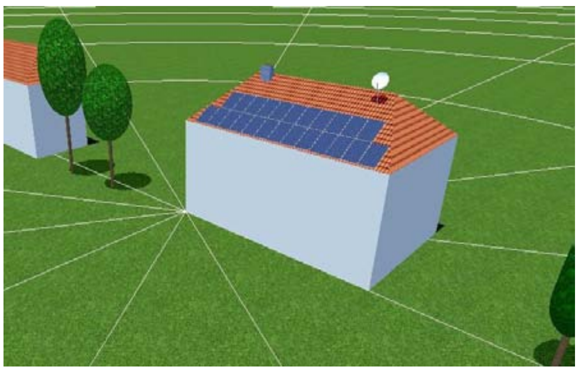

Figure 4: Layout of the set panels

The panel was planned to have a shade effect value under than 1% in its settlement. Shade effect percentage values on the panels are shown in Figure 5.

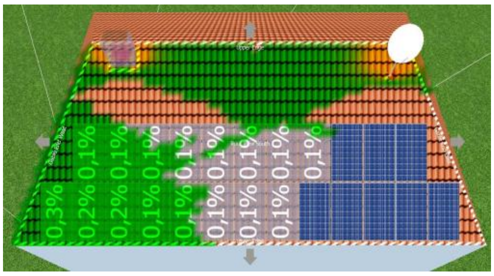

Figure 5: Shade effect on panels

4. Findings

Monthly measurements were taken in order to evaluate on an annual basis after the system is designed. Changes in energy amount produced by the photovoltaic system, energy amount stored in the battery and the situations where the battery feeds the system are shown in Figure 6.

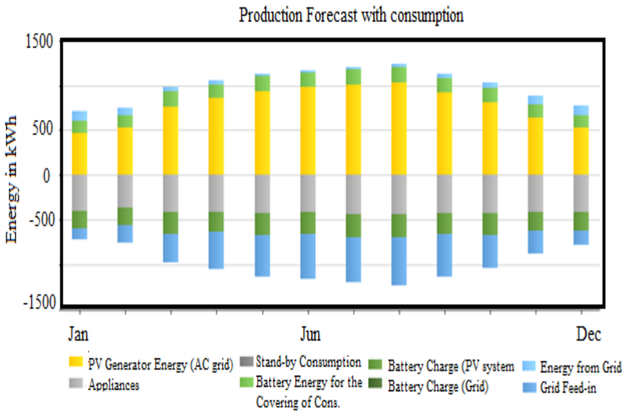

Figure 6: System energy data

As it can be seen from the figure, the most electrical energy is produced in summer months where radiation is the highest. Stable spent energy amount of the system is 500 kWh per month. The battery system is charged to be full at all months. Also, it can be seen that no energy was used in summer months. Due to regional features, outdoor temperature and radiation impact the performance of photovoltaic system [12,13]. Monthly outdoor temperature and radiation changes are respectively shown in Figure 7 and Figure 8.

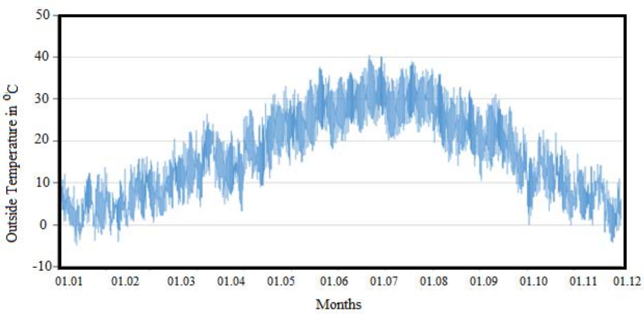

Figure 7: Monthly outdoors temperature change

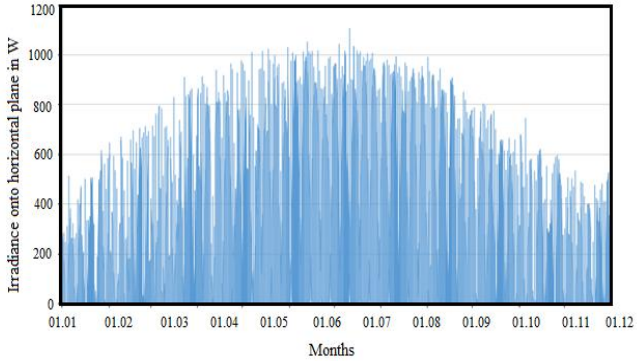

Figure 8: Monthly horizontal radiation value changes

During the periods where temperature values are high, radiation falls onto the parallel surface at steeper angles and increasing energy production. Considered on a general basis, radiation values are higher than normal values and production of electrical energy at desired levels. Monthly energy amount given by the photovoltaic panel to the grid as kWh is shown in Figure 9.

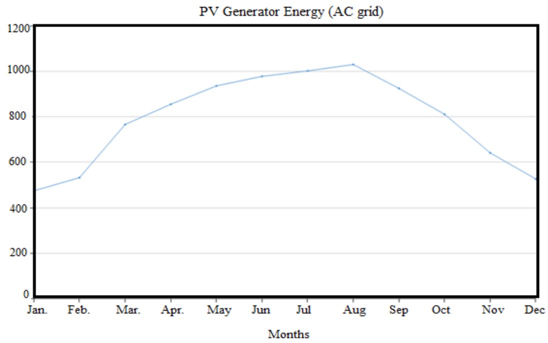

Figure 9: Monthly amount of energy given by the photovoltaic panel to the grid

System's electrical energy production data depending on the daily changes of temperature is also evaluated daily. Data regarding these changes are shown in Figure 10.

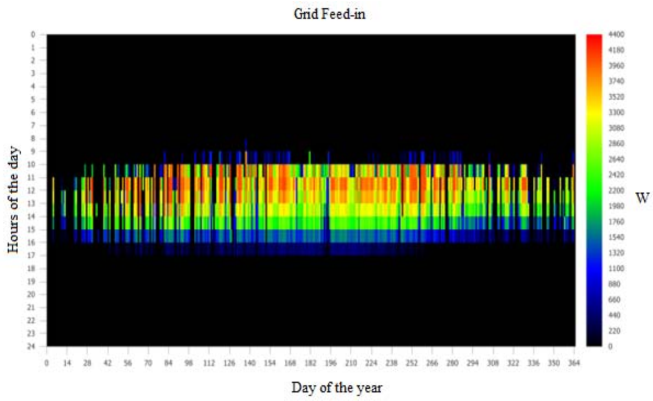

Figure 10: Daily energy given to the grid (W)

As it can be seen from the figure, energy production is at the maximum level in red painted regions. As we approach blue from red, energy production, depending on the incidence of sun rays, is decreased. Changes in the amount of electrical energy given to the grid are shown in Figure 11 on a daily basis. Due to lack of radiation, the system cannot make production in night hours.

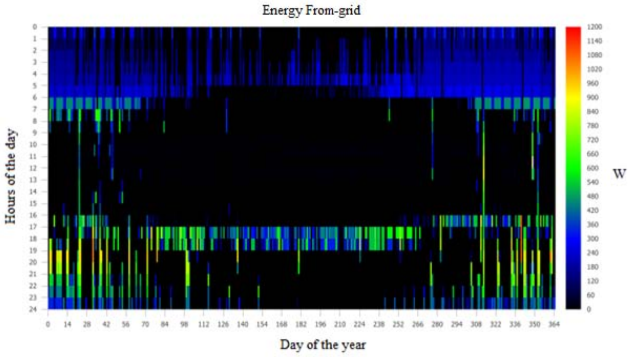

Figure 11: Changes in the energy given to the system from the grid on a daily basis

As it can be seen from Figure 11, the system never used energy from the grid in summer months. Electricity was taken in winter, especially around the hours of 16:00-24:00. Aside from that, when considered on a general basis, electrical energy need from the grid is low. When there is almost no need for energy in the noon, there is a need for energy during night hours. The battery system is also charged quickly when there is excess energy in the system. Changes regarding battery system being supplied by the photovoltaic system are shown in Figure 12 on a daily basis.

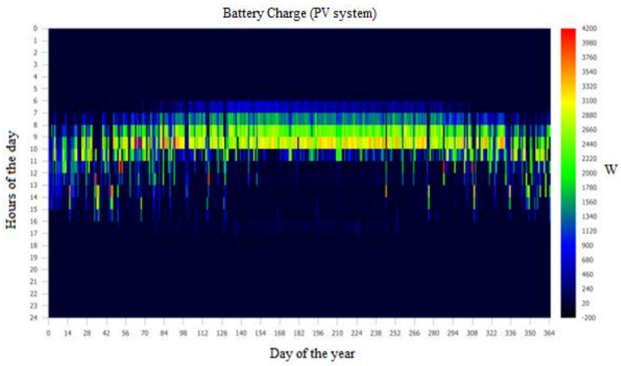

Figure 12: Supply of the battery system on a daily basis

As it can be seen from the figure, the battery finishes charging between the hours of 06:00-16:00. The most energy transfer occurs at noon hours. Maximum energy transfer occurs during summer months. The system was supplied from the battery system when it is not supplied by the grid. This happens at a low ratio. Daily energy consumption values regarding system being supplied by the battery are shown in Figure 13.

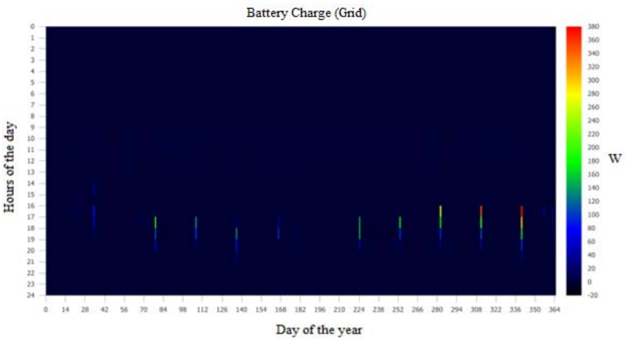

Figure 13: Energy data regarding the system being supplied by the battery on a daily basis

The system is supplied by the battery system for a short amount. This only occurs during the night when there is no radiation and when electrical energy cannot be taken from the grid. 730kWh/year worth of energy was taken from the grid, on the other hand, 4304 kWh/year worth of energy was given to the grid. The system is financially evaluated on a twenty-five-year period [14]. According to this, data of the financial values of the produced energy and system installment cost are shown in Figure 14.

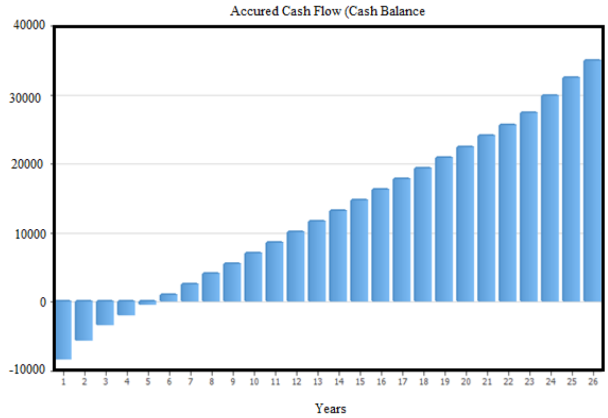

Figure 14: System costs analysis

When the system's financial analysis was made, it was seen that its active yield was 18.26%. It provides 2668,6 TL/year worth of savings annually. The system covered the initial installment cost in the first five years and started making a profit after year six. Profit increased in the following years.

5. Conclusions

Desired energy production values were obtained after the installment of the system since the city of Kilis is rich with the potential for solar energy. Yearly energy production and consumption values of the designed system were examined. Data was taken into account by considering climactic and geographic conditions. Equipment used in the system installment is accessible and affordable equipment around the country. Therefore, a system which has 24 photovoltaic modules, produced 9488,3 kWh/year worth of energy for the grid. 2436 kWh/year of this energy was used by the system. 4304 kWh/year of the energy was transferred to the grid. 2748 kWh/year of the energy was used to charge the battery. Due to being a source of green energy, system prevented the use of fossil energy sources and approximately prevented 5145 kg/year worth of CO_2 emission. System's annual yield is 1581,4 kWh/kwp. Performance ratio of the system is 79,4%. The system started making a profit after 5 years of its installment.

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