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Generation Management Analysis of a Stand-alone Photovoltaic System with Battery

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Abstract
The purpose of this research work is the supply of the electricity required by renewable energies. A photovoltaic (PV) cell is used is a type of crystal silicon PV cell. The software used in this work is Homer. It is capable of simulating renewable energies to monitor the demand for loads. Electricity is generated by the PV cells and the electricity produced is direct current, while the energy required alternates after a voltage converter is used for conversion. The storage will be used at times when no electricity is produced by the PV cell or the production of electricity is higher than demand. In this work, a battery is considered as a storage unit. The important results obtained from this work can be attributed to the production of 15339 kW electricity by the PV cell.

Keywords: *Renewable energy, photovoltaic cell, electricity demand, simulation.*

1. Introduction

Today, energy consumption has grown worldwide, especially the production of electricity from fossil fuels, which emit greenhouse gases into the atmosphere. These gases cause a lot of pollution and harmful effects on the environment [1-4]. One way to reduce fossil fuel consumption is to use renewable energies [5, 6]. Renewable energy is available everywhere, and is environmentally friendly [7-9]. However, it also has disadvantages, one of which is that it is not available during daylight and it has different values throughout the year. Thus to use this kind of energy, one needs to use a storage device that uses several types of renewable energy sources [10-13].

Iran is about 1,600,000 km^2, which is about 1101 × 1.6 m^2. The daily amount of solar radiation in Iran is 1.6 × 5.5 × 1012 kW, and the total amount of sunlight per day for Iran is approximately equal to 9 * 109 MW/h. If only 1% of Iran received solar energy and the efficiency of the energy supply system was only 10%, we could still receive 9 × 106 MW of energy per day from the sun. Among the solar technologies, a Photovoltaic (PV) cell is the most common and the cheapest technology. The PV cells are devices that convert solar radiation energy directly into electrical energy. The combination of renewable energies is network-independent and network-disconnected. The researchers who have worked on the grid-connected are Smida [15], Lingamuthu [16], Saad [17], and Konneh [18]. The researchers who have worked on the stand-alone were Saul [19], Das [20], and Ghenai [21]. Some other research works have also been done in this area. Halabi *et al*. [22] have carried out a research work, titled “flexible hybrid renewable energy system design for a typical remote village located in a tropical climate. Sawle *et al*. [23] have presented a social-techno-economic design of a hybrid renewable energy system using the optimization techniques. Khan *et al*. [24] have presented a hybrid renewable energy system as a potential energy source for water desalination using reverse osmosis. Ma *et al*. [25] have carried out a research work, titled “techno-economic evaluation of a hybrid renewable energy system: applications and merits”.

In the present work, the solar cell behavior was evaluated and the performance of the voltage converter was analyzed. Also for the design of a high-reliability system to supply the maximum load required, the storage system was evaluated.

2. Materials and method

2.1. City of Karaj

Karaj is one of the central and hilly cities in Iran, and it is known as the Iran's fourth most populous city. Karaj is situated 20 km (12 mi) west of Tehran at the foothills of the Alborz Mountains. The climate of Karaj is a bit cooler than Tehran, and it receives 260 mm of rain annually (and like Tehran, its precipitation pattern is similar to those of Mediterranean climates). The Köppen-Geiger climate classification system classifies the city's climate as cold semi-arid. The Karaj latitude and longitude are, respectively, 35° 49' 57.58" and 50° 59' 29.58" E. Figure 1 shows the location of the City of Karaj in Iran.

Figure 1. City of Karaj.

2.2. Solar radiation

In this work, we collected data for the years 2017-2018 from the meteorological wind Karaj Province.

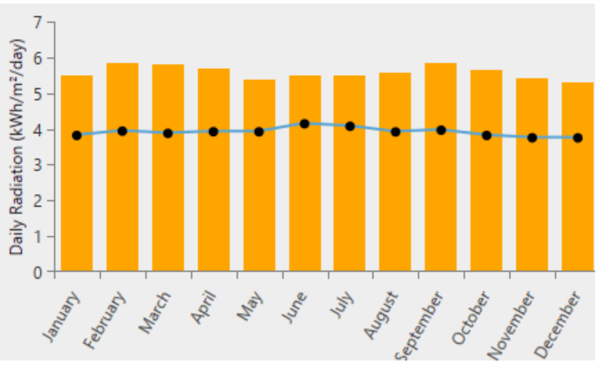

Figure 2. Graph of the solar radiation in the studied area.

As shown in figure 2, the maximum solar radiation of September and the lowest for the month of May have the values 5.7 kWh/m^2/d and 5.1 kWh/m^2/d, respectively.

2.3. Electric load

The load consumption of a building is calculated according to the following steps: 1-Determination of the electrical equipment. 2- Extracting the amount of electrical power required by different equipment. 3- Determination of the coefficient of coherence between equipment. 4-Determination of the load consumption diagram for the hours of the day. Therefore, according to the above, the rate of electric charge for a typical building in Karaj for a day and night is shown in figure 3.

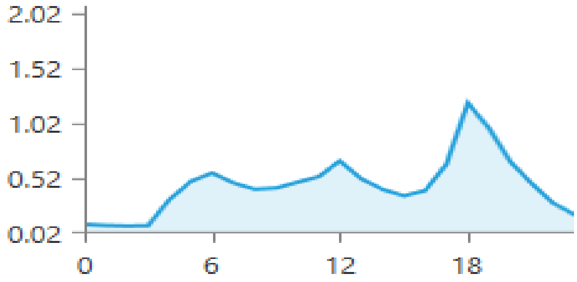

Figure 3. The electric load for a residential unit.

As it can be seen in this figure, the peak load is about 18 o'clock with a value of 1.23 kW.

2.4. Necessary equipment

The target hybrid system consists of devices including a PV cell, a DC/AC converter, and a battery storage. All explanations and details about the hybrid system are given below.

Photovoltaic (PV) cell

Using a PV cell, one can convert the sun's radiant energy directly into the electrical energy; this is due to the use of semi-conductors for cell construction. One of the most common semi-conductors is crystal silicon, which is available all over the world. Table 1 shows the properties of the PV cell.

Table 1. Crystal silicon solar cell. characteristics.

Type	Tracking system	Nominal cell temperature (^{0}C)	Derating factor%	Life time
Flat plate	No tracking	47	80	25

Converter

The converter indeed converts the power from direct current (DC) to alternating current (AC) or vice versa. An inverter converts a DC voltage from solar modules into an AC voltage. In the current production systems in which the demand is different from the power electronics, the converters can be used to establish production and demand. Table 2 shows the properties of such a convertor.

Table 2. Convertor characteristics.

Invertor input		Rectifier input	
Efficiency (%)	95	Efficiency (%)	90
Life time (yr)	15	Relative capacity	100

Battery

A battery is used to store the excess energy. In its design, a lithium ion battery is used; its full profile and details can be seen in the figure below. Table 3 shows the properties of this lithium battery.

Table 3. Technical specifications of lithium battery.

Nominal voltage	12 V
Nominal capacity	1 Kwh
Maximum capacity	83.4 Ah
Capacity ratio	0.403
Efficiency	80%
Maximum charge current	16.7 A
Maximum discharge current	24.3 A
Life time	12 years

2.5. Simulation

In this study, the PV cells are used to supply the required electrical charge but since these cells produce DC power while the demanded load is of AC type, it is used after current converters. Also because the intensity of the radiation is not uniform throughout the day and there is no radiation at night, the battery is used to increase the reliability of the system. Figure 4 shows this configuration.

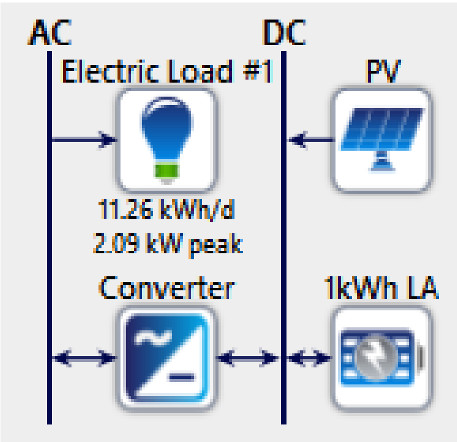

Figure 4. Solar system design with Homer software.

3. Results

According to the simulation, we can see the whole electrical energy produced by the PV cell in figure 5.

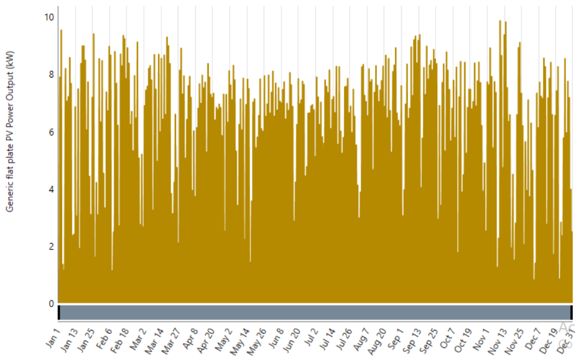

Figure 5. Electrical energy produced by PV cell.

As it can be seen in figure 5, the total amount of electricity produced in a year is 15339 kW, which is the highest and lowest power generation for the months of August and December, respectively. It consists of an average electrical output PV cell of 1.5 kWh/h and 42 kWh per day.

Figures 6 and 7 can be seen in the utilization rate of the currency converter.

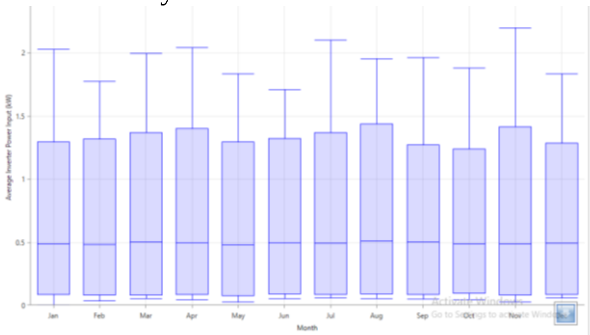

Figure 6. Inverter power input.

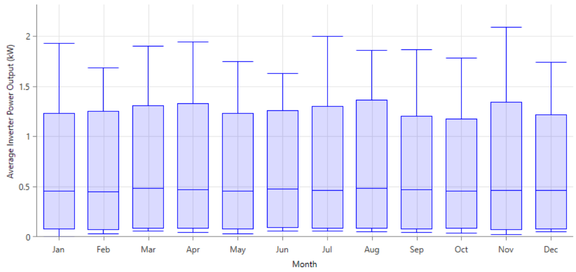

Figure 7. Inverter power output.

As it can be seen in figures 6 and 7, the mean output energy of the converter is 0.469 kWh, and the total energy input and output in a year is 4323 kW and 4107 kW, respectively, with a maximum output of 2.09 kW.

The amount of battery used as a storage system and power supply system can be seen in figures 8 and 9.

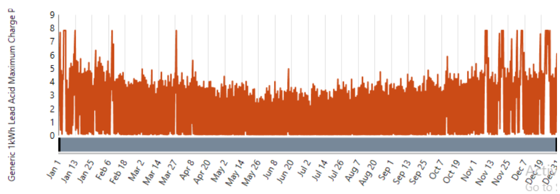

Figure 8. Battery maximum charge power.

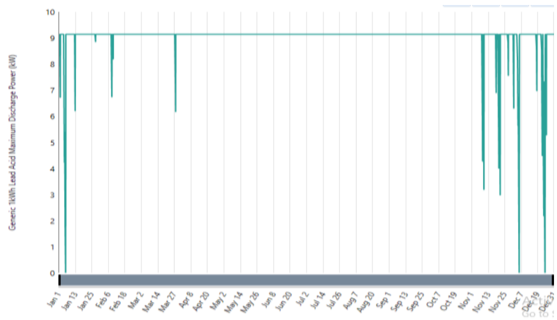

Figure 9. Battery maximum discharge power.

As it can be seen in figures 8 and 9, the battery is used when the sun's radiation is unavailable. The battery is mostly utilized in winter because of the short solar hours. The total energy input and output in a year is 2673 kW and 2146 kW, respectively.

4. Conclusion

Due to the increasing human need for energy and the lack of fossil fuels, the use of renewable energies such as solar energy has become more and more popular. In this research work, solar energy was used to supply electricity to a building. It was observed that this energy could supply all the energy consumed regardless of the cost involved. Even on some days, the amount of power produced by the cell was higher than demand. The highest amount of electrical energy produced by the cell was when the most radiation was available. Most utilization of a battery was in winter because of the short solar hours.

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