Solar energy efficiency in the city of Samawah and its speed in charging off-grid PV system batteries

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Abstract. The research shows a study of solar energy efficiency in the city of Samawah by using solar cells with some installations to generate electric energy and charge batteries for areas far from electric power plants and areas that are difficult to connect to the national electricity grid (off grid). Solar energy efficiency is calculated based on the average energy consumed within one home during 24 hours without interruption in those areas. Hence, this research focuses on designing a (photovoltaic system) to generate electrical energy consisting of solar cells with a charge regulator with a current inverter with rechargeable storage batteries. This system depends on the average amount of solar radiation falling in those areas and the high temperature of the sun, which is useful for charging and storing batteries faster.

Keywords: Solar energy efficiency, batteries, control charge, fast charge.

1. Introduction
The interest in renewable energies stems from being one of the available possibilities through improving and directing them for development purposes in the areas of providing the population with electric energy. In the recent period, there has been an increase in the trend towards searching for alternative energy sources because the current energy sources are exhausted and will not be sufficient to meet the needs, so thinking about solar energy sources to generate electrical energy, especially in remote areas, because of its distance from the processing centers as well as the effort, time and costs that you need, and because it is clean energy. And non-polluting to the environment and not depleted [1]. Diesel electric power generators need fuel and maintenance expenses, and the greater the load on the diesel, the higher the fuel and maintenance costs, as it can reach 60% of the cost of the total working life of the diesel system, unlike solar cell systems that do not require fuel and maintenance. Which makes it suitable for remote areas and it is clean and non-polluting to the environment and does not leave any waste and does not run out, which gives it a special place in this area. Paying attention to solar energy in several areas with the aim of reaching more rural development, whether in the old or newly reclaimed areas, with the aim of improving their social and economic conditions on the one
hand and limiting the aggravation of desertification on the other hand, and here the search for an alternative resource becomes rational, and this alternative can be energies Renewable, especially solar energy [2]. Solar cells can be used in many fields, as they are easy and available, including making a water purification system using solar cells, operating motors, heating water, operating steam coolers, and many other uses [3]. There are many designs by which batteries can be charged from solar cells, and from these methods (p & o) where the conduction current (IC) is controlled to obtain the largest power point from the voltage and power curve of the photovoltaic cell [4]. A study and analysis of the PV batteries used in residential units were also conducted to obtain the best types of batteries that are more economical and of high quality [5]. The cost of a photovoltaic system was designed and economically calculated for a typical off-grid home in Pakistan, as well as the amount of energy expended per house, with the result being adequate in terms of cost and quality of system operation [6]. It is possible to increase the self-consumption and store the energy generated in rechargeable batteries by converting solar energy into electrical energy through the charging regulator device, which regulates the process of charging the batteries from the solar cells and feeding the electrical loads from the energy at the same time [7]. The calculation of the self-consumption of solar energy and its impact on the distribution network has been revised. This effect increases the profits of manufacturers of solar cell systems and the expansion of research and design work to improve solar energy systems [8]. The solar energy system was analyzed off-grid, and the effect of temperature and dust on the production efficiency of the photovoltaic system was analyzed. These factors negatively affect the production of electrical energy [9]. Solar energy systems can be constructed from simple structures through which electrical energy is generated with constant current and voltage of 12 volts and converted into electrical energy with alternating current and "220 volts voltage at a frequency of 50 Hz" [10].

2. Energy requirement for one home

Table No. (1) shows the energy needs required for a residential house in the Salman district of the city of Samawah, which is one of the areas not connected to the national electricity grid, due to its distance from the city. This house is considered one of the country houses with low energy demand, which was chosen in our research to see the rate of energy expended during the whole day and the drawing of electrical current from the loads connected to the photovoltaic system, as well as the speed of charging the batteries to compensate for the energy consumed. The rate of use of electrical appliances is calculated according to the high and low temperatures during the year, as the temperature rises during the summer period and reaches (55) degrees Celsius and continues for six months, then the temperature begins gradually. It drops to 15 degrees Celsius in the winter and continues for two months. When the temperatures are high, the energy expenditure is more due to the evaporative cooling devices.

The operating rate of the electrical appliances shown in the above table ranges in the summer season approximately (95%), taking into account the difference in the power draw at night and day, hopefully in the winter season, the operating rate will be approximately (70%), as shown in the chart below.

| Equipment        | No. | Watt | Total Watt |
|------------------|-----|------|------------|
| Lamps            | 5   | 40   | 200        |
| TV               | 1   | 100  | 100        |
| Refrigerator     | 1   | 200  | 200        |
| Fans             | 2   | 75   | 150        |
| Water Pump       | 1   | 150  | 150        |
| evaporative cooling | 1   | 200  | 200        |
| Total wattage, (W)|     |      | 1000       |
3. Off-grid solar PV system components
When we talk about solar energy in homes, this means all the methods that convert solar energy into any form of energy that we need to meet our daily needs inside the home, and these applications may either be solar photovoltaic systems or solar heaters for heating water or even cooling systems. Or solar heating and more. The basic parts for the work of the solar energy system in the home are the solar panels, which are semiconducting electronic elements that convert light energy into electrical energy. This framework is considered very important, as it determines the size of the solar panel and also determines the angle of inclination and direction of the plate. As for the second part in the solar energy system, it is the charging regulator that maintains the capacity of the solar panel and the amount of voltage when the sun is low, as well as charging the batteries, that is, through the sun regulator, the charging can be regulated if it is high or low, it will adjust it and give only 12 volts. As for the third part, it is the batteries, and they differ from the batteries in cars. These batteries are for solar energy, and they are known to withstand the sun for long periods and for long periods of discharge. The benefit of these batteries is to give electrical energy at times when the sun is not present, for example at night. As for the last part, which is the current transformer (inverter), which converts DC into alternating current to operate AC devices such as computer, television, refrigerator, lighting and other devices, as shown in the figure below.
4. Design and calculation of an off-grid solar photovoltaic system

The solar energy system is calculated and designed depending on the electrical load rate to be fed from the photovoltaic system, the number of operating hours, as well as the location of the system installation, according to the climate and geographical location, to obtain an integrated and highly efficient photovoltaic system.

4.1. The size of the solar PV system

They are semiconducting elements that convert the energy of sunlight into electrical energy. Solar cells consist of electronic elements in which materials are collected that are based on absorbing the incident photons from the sun's rays and converting them into a direct electric current (DC). One of the most important elements that have this property is silicon (Si), with some impurities added to it to give it some electrical properties. Phosphorous element (P) is added to it, and this gives it the property of pumping electrons when photons of light collide with it, and this layer is called the (N) layer, while the boron element (B) is added to the bottom layer and gives it the electron absorption property, and this layer is called the (P) layer. The sun on the top layer gives electrons kinetic energy that makes them move between the two layers, generating an electric current.

Solar panels are the main component in solar energy systems and constitute about (80%) of the cost of the system and their size directly depends on the size of the load to be operated and the available solar radiation at the site of the site, as they are in the form of a group of cells connected to each other in one frame and connected with each other. Either parallel or successive. But if a group of solar panels are assembled in a larger frame, then in this case it is called the solar panel array [1].

The solar cells that were used in this project are monocrystalline silicon cells, and this type is characterized by high efficiency, but its price is very high because it is made of high-purity monocrystalline silicon, where the manufacturing method is very expensive and requires skilled workers.

The “size of the PV array can be calculated using Eq”. (1) [6].

\[
A_{PV} = \frac{L_{el}}{H_{avg} \eta_{PV} \eta_{B} \eta_{I} \tau_{CF}}
\]

where;

- \(A_{PV}\) = required region of “PV array in m².
- \(L_{el}\) = required electric load “through Kw h d⁻¹.
- \(H_{avg}\) is the usual irradiation available per day in kWh m⁻² d⁻¹.
- \(\eta_{PV}\) is the efficiency of PV panel in %.
- \(\eta_{B}\) is the battery efficiency in %.
- \(\eta_{I}\) is inverter efficiency in %.
- \(\tau_{CF}\) is the temperature correction factor normally taken as -0.4 to -0.5% per °C for crystalline silicon [6]. The battery and inverter efficiency is generally taken to be 85% and 90%, respectively. The peak PV power (\(P_{p(PV)}\)) can be calculated using Eq. (2) [6]

\[
P_{p(PV)} = A_{PV} I_{p} \eta_{PV}
\]

where; \(I_{p}\) is the peak solar irradiance taken as 1000 Wm⁻².

From equations (1) and (2), we conclude that the size of the solar cells to be installed to feed any electrical load depends on the size and type of the load to be fed, the amount of solar radiation falling on the solar cells, as well as the efficiency of the whole system.

4.2. Sizing of the battery storage

A battery is a device that converts chemical energy directly into electrical energy that consists of one or more voltage cells. Each voltaic cell consists of two cells, the first half of the cell is the anode, and
the other is the negative electrode. In our project we use a secondary type battery (Deep Cycle), which is the rechargeable type that stores chemical energy and makes it available as an electric current, and there are two types of batteries, primary (disposable) and secondary (rechargeable), both of which are capable of converting chemical energy into electric power. Moreover, primary batteries can only be used once because they use chemicals in an irreversible reaction. The battery is recharged by connecting it with a charge regulator device that is attached to the solar cell, but in the opposite direction of the current discharge.

Battery Storage Capacity (BSC) can be calculated based on the number of operating hours at night, battery efficiency, depth of battery discharge, inverter efficiency, amount of load operated at night, and as shown in the following equation (3) [6].

$$B_{SC} = \frac{N_{CCD} \cdot L_d}{P_{in}\cdot \eta \cdot \eta}$$  \hspace{1cm} (3)

where; N_{CCD} is the largest number of continuous cloudy days and D_d is maximum permissible depth of discharge of the battery.

The PV battery system can be evaluated in terms of the self-attained consumption rate, which is calculated by the ratio between the PV energy used directly for E_{DU} or used to charge the E_{BC} battery and the total photovoltaic power produced E_{PV} as shown by the equation (4)[5].

$$S = \frac{E_{DU} + E_{BC}}{E_{PV}}$$  \hspace{1cm} (4)

4.3. Charge controller required

The charge regulator (solar charge controller) is an electronic device that regulates the electrical voltage coming from the solar cells before it passes to the batteries, the primary goal of the charging regulators is the process of regulating the charging of batteries in the sense of allowing the batteries to be fully charged without reaching the state of overcharging, as well as preventing regulators Charging The return of current from the batteries to the solar cells in the evening (where in the dark the solar cell is considered as an energy consuming load). In the event that a solar system connected to the batteries is used without protection against overcharging, it will be exposed to danger and may reduce its life significantly. It protects the system from excessive, deficient or volatile electrical currents because it contains (FUSE) and special circuits for that, and also works as a control system By means of the standards used in it so that it can give an alarm light when working irregular situations. There are types of shipping regulators, but there are two main types of regulators, (PWM) and (MPPT), and in this project we use the (MPPT) charging regulator. One of the best methods for obtaining maximum power from solar cells (mppt) is to use (P&O) design, when the temperature rises and changes unevenly, the P&O method is followed continuously, and the operating point is calculated when the battery is able to delay its maximum capacity [11].

4.4. Inverter off-grid

Solar inverter, or photoelectric inverter, is a device consisting of electronic circuits whose function is to convert the direct current (DC) from solar panels (PV) and batteries into alternating current (AC) to operate alternating loads. There are three types of solar inverters (grid-connected, off-grid, and hybrid inverter) and all of these types work with solar energy systems. In our research, an inverter that is not connected to the grid was used. This system works in the absence of electricity completely. It can be used with satellite and solar systems installed in remote areas. Solar inverters have special functions for use with photovoltaic, including maximum power point tracking and anti-high current protection [10]. When choosing an inverter for a solar photovoltaic system, it should be higher than the proposed
load for the house to be equipped with electrical power and at a rate of not less than 20% higher than the total power value required for AC transformers [6].

5. Methodology of work

The solar energy system consists of several parts as previously mentioned (solar cells, charging regulator, batteries and inverter) and each part has its own function, the system is fully linked with the loads in the house to be fed with electric current, where the solar cells work at sunrise and until sunset An average of 14 hours in the summer and 10 hours in the winter season, as the solar cells work to prepare the full load with electric current and charge the batteries at the same time, but in the evening the solar cells do not work and the amount of voltage produced by the cells is equal to zero, and here comes the role of the batteries to work To feed the load completely through the energy stored by the batteries and convert it into electrical energy that is converted from direct current to alternating current via the solar inverter. The maximum operating period for electrical loads from batteries depends on the amount of loads that are operated, so the smaller the loads, the longer the operating period.

6. Actual calculate for the PV system

Before starting the process of calculating the required system, it is necessary to know the factors that affect the efficiency of the system work, and the most important of these factors are the cleanliness of the solar cell, the electrical losses of the wires, the ambient temperature and other harsh weather conditions that can affect the efficiency of the work of the solar cells. The intensity of lighting and the temperature emanating from the sun are the main source of solar cells, so the more intense the lighting and the lower the temperature, the more efficient the work of the solar cells.

**Pc:** Power required= 1000W…. from table (1)

\[ P_c = 1000 \text{W} \]

Where:

\[ N_{BATT} = \frac{1.3 \times P_t \times H_{OP}}{V_{BATT} \times B_{CAP}} \]  

1.3: Discharging factor.

\[ H_{OP} \]: Number of operating hours=14 h.

\[ V_{BATT} \]: Battery voltage =12 V.

\[ B_{CAP} \]: Battery capacity =150 Ampere.

\[ N_{BATT} = \frac{1.3 \times 1000 \times 14}{12 \times 150} = 10 \]

\[ E_{BCH} = N_{BATT} \times B_{CAP} \times V_{BATT} \]

\[ E_{BCH} = 10 \times 150 \times 12 = 18000 \text{W/H} \]

**E_{BCH/W}:** Battery charging power W/H

\[ E_{BCH/W} = \frac{E_{BCH}}{H_{OP}} \]

\[ E_{BCH/W} = \frac{18000}{14} = 1286 \text{W} \]
\[ E_T = E_{RCH} + p_r \]  \hspace{1cm} (8)

\[ E_T = 1286 + 1000 = 2286 \text{ W} \]

\[ N_{pp} = \frac{E_T}{5pp} \]  \hspace{1cm} (9)

\[ N_{pp}: \text{Number of panel Photoelectric.} \]
\[ S_{pp}: \text{Size of panel Photoelectric.} \]

\[ N_{pp} = \frac{2286}{130} = 18 \] \hspace{1cm} or
\[ N_{pp} = \frac{2286}{250} = 9 \]

7. Energy efficiency gained

The highest gains from solar energy can be converted into electrical energy and used to accelerate the charging of batteries during loading in the area where the PV system must be constructed. The standard degree was adopted as a statistical method to indicate the energy difference that reaches the surface of the solar cell panels in the event that the solar cell panels are fixed according to the azimuth angles of the head and the angle of the horizontal dimension, and a database was built for the period between (8 am - 12.30 pm) and for each season. The angles for the position of the sun's disk in the city of Samawah were determined according to its astronomical position using the "3D Energy Program".

The intensity of direct and diffuse solar radiation was measured using (SPM-1116 SD Solar Meter). A site for field solar radiation monitoring on the roof of the house has been approved to avoid the impact of neighboring buildings on the intensity of the received radiation. Figure (3) shows the amount of radiation intensity (watt/m²/hour) reaching the surface of the solar cell different in the amount of angles (azimuth, and the horizontal dimension) throughout the year in the city of Samawah, the district of Salman. From the chart above, we note that there is a marked contrast between the recorded daily readings in the winter months, but for the readings recorded daily in the summer months, relatively little variation it has.

![Figure 3. The amount of solar radiation during the year.](image-url)
Table 2. Schedule of recorded readings for one day in the summer.

| PV power | Load power | Batt. capp | Batt. voltage | PV Char. | Time hour |
|----------|-----------|-----------|---------------|----------|-----------|
| 90%      | 90%       | 86%       | 12            | 89%      | 8.00 am   |
| 96%      | 90%       | 93%       | 12            | 96%      | 10.00 am  |
| 91%      | 90%       | 96%       | 12            | 98%      | 12.30 pm  |
| 80%      | 95%       | 96%       | 12            | 86%      | 6.00 pm   |
| 00%      | 95%       | 82%       | 12            | 60%      | 10.00 pm  |
| 00%      | 95%       | 64%       | 10            | 60%      | 12.00 am  |
| 00%      | 80%       | 45%       | 9             | 00%      | 6.00 am   |
| 80%      | 90%       | 90%       | 12            | 80%      | 8.00 pm   |

From the readings that were recorded on a day of the week in the summer and shown in the table above, we note the efficiency of solar cells in converting the sun’s energy into electrical energy, as well as their speed in charging batteries.

8. Resolute and discussion

Satisfactory results have been achieved from this research, and it is possible to design a photovoltaic solar cell system that converts solar energy into electrical energy that can be used to feed homes in remote rural areas in addition to the national electricity supply networks, in addition to that, the climatic conditions in the area discussed are good for these systems and help encourage the work of wider solar energy systems and stations that can be used in many areas, such as solar systems for pumping water, solar systems for outdoor cooling and lighting, etc., far from the national electricity grid.

Generating electric energy using solar energy is economically feasible compared to conventional energy in remote areas, and it does not result in any waste that leads to environmental pollution affecting human, animal and plant health, as in diesel generators, and the system's life is also long and does not require maintenance except to clean it from dust. To increase their efficiency, the use of solar energy is feasible for sites that are 60 kilometers or more from transmission lines.

The cost of the solar cell system to be installed in areas not connected to the national electricity grid can be reduced by using DC electrical loads, as well as making use of systems that mainly operate with solar cells, such as solar coolers, pumps, heating, heaters and other devices that work with solar energy systems.

Solar radiation is the main source of energy in the atmosphere, as it contributes more than 99.97% of the energy used in the atmosphere and in the surface of the earth. As for the other sources, namely the Earth's interior, the energy of the stars, and the phenomenon of tides, they contribute only a small amount, not more than 0.03%. As for solar energy, it is responsible for all processes that occur in the atmosphere, such as air turbulence, clouds, rain, winds, lightning, thunder and others. The main reason for the constant movement of the atmosphere and the variability and change of weather is the existing differences from place to place in the abundance of solar energy.

9. Conclusion

Although a solar cell system is expensive to implement, the energy from the sun provides a clean and renewable energy source that nothing else on Earth can provide. The world is moving slowly, but it is definitely turning away from fossil fuels and looking for more sustainable energy sources for its daily
needs. This means that more and more people will be choosing products that can be exposed to the free energy source, sunlight.

The issue of electricity shortages in Iraq is hampering the country's economy and threatening its fragile political system, and this matter will get worse unless immediate and effective measures are taken to address it. And the time has come for oil companies to help in Iraq by developing renewable energy as a new way of investing to obtain relatively high returns and to improve the company's image as a friend of the environment. Iraq needs a fast-growing and sustainable economy to improve the quality of public life for people. Despite all the promises of change, the country still suffers from many obstacles, including: mismanagement, corruption, and the absence of correct policies. In order to use renewable energy sources, it must adopt correct policies to encourage the participation of foreign direct investment in the future. The current approach to generating electricity - which is currently dependent on conventional thermal power plants and little hydroelectric power - requires the addition of various generation sources of renewable energies such as solar and wind energy. For Iraq to rely on renewable energy, the government needs to reform the electricity sector and open the market for public-private partnerships in generating and distributing electricity. The renewable energy compensation program is an appropriate program; To give it sufficient capacity for oil companies and the government alike to invest and strengthen renewable energy in Iraq, the public-private partnership has been successfully implemented in many regions - developed and developing countries alike - including the Middle East region; This will help Iraq gradually reduce support for electricity and invest in reforming the sector. The renewable energy compensation program may be the most appropriate type of partnership mechanism between the public and private sectors to accelerate the development of renewable energy sources, and the ultimate goal of the renewable energy compensation program is to have a framework for revitalizing the electricity sector in accordance with recommendations of international institutions. And Iraq must adopt integrated policies to encourage other sources of energy - other than oil and gas - if it wants to catch up with the rest of the region.

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