Designing, Photovoltaic (PV) system for Household electrical Demand

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Abstract

Photovoltaic (PV) power systems convert sunlight directly into electricity. PV system can be contributed to energy generation in the electrical network to provide a sustainable access to electricity and to stimulate development. As result of that, solar system makes power supply more reliable and resilient. Due to weak grid and case of blackouts, PV system can be used as an effective solution to solve problem to provide electrical energy for house load. Furthermore, using solar system for electrical energy demand that cause improved living conditions and contributing to achieve environmental, economic and social objectives, as result of reduction of greenhouse gases and creation of local employment. A residential PV power system enables a homeowner to generate some or all of their daily electrical energy demand on their own roof. In this paper, designing (PV) system to provide all households electrical demand during all day with connection to grid as backup for the system with flexibility to switch the system between off grid and grid connection. Size of PV designed based on power consumption of Household Loads. In addition, the size of batteries charges and Inverter depends on power consumption. HOMER software is used to simulate and analyze the PV system. The analysis shows that the 15,342kWh/yr PV system can supply all electrical house demand and it saves around 14.099kg/yr of carbon dioxide emission

keyword: Photovoltaic**,** energy generation**,** house load**,** solar system**,** HOMER software**.**

الملخص

تعمل الخلايا الكهروضوئية (PV) على تحويل ضوء الشمس مباشرة إلى كهرباء. فيساعد النظام الكهروضوئي علي تعويض بعض النقص في الطاقة علي الشبكة الكهربائية العامة ويساعد على توفير وصول مستدام للكهرباء ونتيجة لذلك ، يعتبر النظام الشمسي مصدر طاقة أكثر موثوقية ومرونة. و نظرًا لضعف إمدادات الكهرباء في بعض الأماكن وحالة انقطاع التيار الكهربائي ، يمكن استخدام الخلايا الكهروضوئية كحل فعال لحل مشكلة توفير الطاقة الكهربائية للأحمال المنزلية. علاوة على ذلك ، فإن استخدام النظام الشمسي لتوفير الطاقة الكهربائية يؤدي إلى تحسين الظروف المعيشية والمساهمة في تحقيق الأهداف الاقتصادية والاجتماعية والبيئية نتيجة خفض إنبعاثات غازات الاحتباس الحراري وخلق فرص عمل محلية.

نظام الطاقة الكهروضوئية السكني يُمكِّن صاحب المنزل من توليد بعض أو كل احتياجاته اليومية من الطاقة الكهربائية على أسطحه الخاصة ، في هذه الورقة ،تم تصميم نظام توليد كهرباء بإستخدام الخلايا الكهروضوئية لتوفير احتياجات منزل من الكهرباء طول اليوم مع وجود اتصال بالشبكة الكهربائية كدعم احتياطي لنظام الخلايا الكهروضوئية واستمرار تزويد الأحمال الكهربائية المنزلية بالكهرباء.تم تصميم الخلايا الكهروضوئية علي أُساس كمية استهلاك الطاقة الكهربائية في المنزل وكذلك سِعت البطاريات والعاكس علي مقدار استهلاك الطاقة الكهربائية في المنزل والفترة الزمنية لاستخدام المعدات الكهربائية داخل المنزل . أستُخدم برنامج هومر لتحليل و محاكاة النظام الكهروضوئي خلال خمسة وعشرون سنه من العمر الافتراضي للخلايا الشمسية حيث وجدا انه ينتج سنويا 15,342 كيلو وات في في سنه من الطاقة الكهربائية ويقلل من إنبعاثات غاز ثاني أكسيد الكربون بحوالي 14.099 كيلوجرام في السنة وتوفير الطاقة اللازمة لتشغيل الأحمال الكهربائية في المنزل.

I. Introduction

Electrical Energy is an important type of energy in human life. Most of the electrical energy around the world is generated from un-renewable sources such as, natural gases and fossil fuel. All of these resources have a limited lifetime and cause pollution problems, in addition, an increasing global warming [1]. Libya is one of the countries that mainly depend on fossil fuel to generate electrical energy [2, 3]. All of electrical energy in Libya provided by Gas-turbine, steam –turbine and combined cycle power plants. In addition, the electrical energy consumption per capita in Libya has increased from 2.794 KWh in 2009 to 3.13 KWh in 2015. The national electric network is available to 99% of the population [4]. Furthermore, the electrical energy demand in Libya is growing rapidly around 6%-8% annually, which affects the national electrical network output production capacity [5]. Moreover, Libya has issues with the electricity shortages and power cuts during these years (since2015 until the time of writing this paper). As result of the damage and destruction incurred during the civil war on transmission and distribution network particularly in western, eastern and south Libya as well as damage in some power plants. All development and maintenance projects in the electrical network suffer from a lack of financial support. Power demand in grid network are increasing and power generation in power plants decreasing that causes an interruption in the electricity supply and an increase in the hours of interruption for consumers. Most Libyans are left without electrical power for a few hours a day. And for this, some homeowners, businesses, and health centers are using diesel generators as an alternative power source [6].

However, Libya is located in North Africa between 10°E and 25°E longitude and latitude between 20°N and 32°N. Most of Libya land is located in North Africa desert [7], each1km2 from North Africa desert land receives solar energy equivalent to 1.5 million barrels of crude oil. That solar energy can generate around 250GWH of electrical energy each year [4]. If the potential of solar energy of Libya is utilized efficiently this will provide the electrical energy demand of Libya and it can also contribute to provide electrical energy for world demand by exporting electrical energy [8]. Solar system can contribute to energy generation in the electrical network to provide a sustainable access to electricity and to stimulate development. As result of that, solar system makes power supply more reliable and resilient. Due to weak grid and repeated cases of blackouts, PV system can be used as an effective solution to solve problems of providing electrical energy for house load. Furthermore, using solar system for electrical energy demand, that results in improved living conditions and contributing to achieving environmental, economic and social objectives [9]. The paper highlights the benefits using solar Energy to generate electrical energy, in addition in this work particular attention is paid to the design, simulation and analysis of photovoltaic system for house electrical demand, the research considers energy consumption of household and proposes small – scale solar power generation for its daily domestic energy demand . The HOMER software is employed in examining the feasibility of the project and analyzing the size and cost of solar PV system for the load under consideration.

II. Design and Simulation

PV system is simulated by HOMER software which is developed in The US by NREL [10]. To simulate this PV system, there are several data that are required, which are energy sources, economic input, system component types, loads each hour during the day, constraints, cost, connection type (homer). In this paper, PV system with flexibility to switch the system between (grid and off –grid) are considered, which gives home owner stability and continuity to supply household load. The objective of the design is to ensure continue supply of electrical energy to household load during blackouts and scheduled shutdowns. The HOMER is used in calculating the optimum component sizes and cost of the power generation and used as the basis for proposing solar power generation for the household demeaned in our community. The schematic diagram of PV system model is illustrated in figure 1

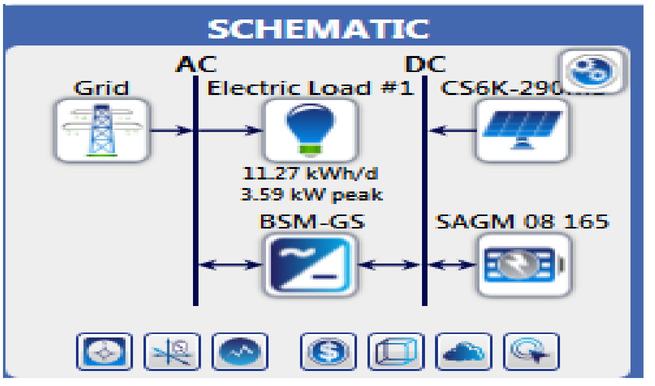


Figure 1. The schematic diagram of PV system model

A. Electric load

Consider a typical household which has 4 lamps LED (light–emitting diodes), washing machine, vacuum cleaner, phone charger, laptop computer, Iron, refrigerator, TV receiver and television. Operation time and power consumer are shown in Table 1.

In Homer, according to the load consumption, there is assumption that off peak time Refrigerator and therefore the load consumption is almost constant and low during these hours, while the peak time is from 10 am to 12pm. the load variation for a day for different months as shown in figure 2

Table 1.Average load consumption

Loads	Power Rating(W)	Time hours(h)	Energy (W.h)
32 Inch LED TV	60	8	480
Refrigerator	200	8	1600
Receiver TV	12	8	96
Iron	1000	0.15	150
Lap top Computer	100	2	200
Phone Charger	4	0.3	1.2
Vacuum cleaner	450	0.2	90
Washing Machine	500	1	500
Lamps LED 15w*4	60	6	360

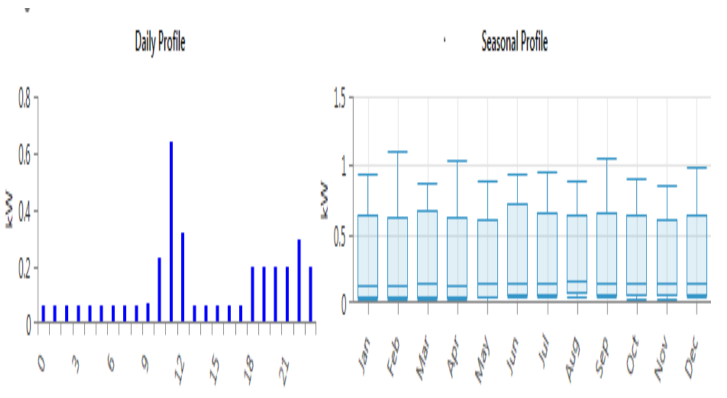


Figure2. Daily load Profile and Seasonal load Profile

B. PV size

The size of the photovoltaic array is the main factor to provide electrical power for the designed system. To calculate the PV size using HOMER, several parameters required are efficiency and operation temperature. In this design, the lifetime of 25 years for PV (Canadian solar CS6k-290MS) with no tracking system is selected, the cost per watt-peak of PV modules is $1.6, the replacement and maintenance costs are tacked as $5per panel.

C. Battery Size

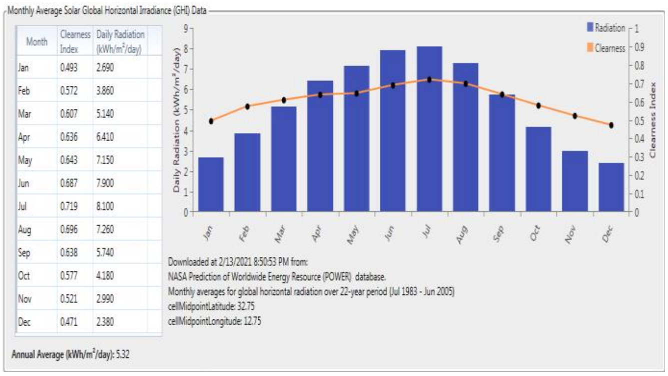
Battery is used to supply energy to house electrical load during night time and day when is no sunlight. Trojan SAGM08165 battery is selected in software which has following details 8 V 165 Ah. The capital, replacement and operation with maintenance costs are taken $413, $10 and $2 also 1 to 4 numbers of batteries are input to the software, battery lifetime 8 years.

D. Inverter

Inverter is applied to convert DC power to AC power. In this study, BLUESN 5Kav pure sine wave is used in software, this inverter can be used as grid tide mode and off – grid, and it has following details size 5kw, lifetime15 years and efficiency 97%. The capital, replacement and operation with maintenance costs are taken \$331, \$50 and \$2.In addition, it has protection for over load and short circuit and solar charger controller

III. Solar Radiation data of the site

The location data of the site, which are latitude 32.75N and longitude 12.75 E, are used for calculation of solar radiation and temperature. Data was gathered from NAS production of Worldwide Energy Resource and scaled annual average radiation of the site is 5.32Kwh/m^2/day [10] as shown in Figure3



Month	Clearness Index	Daily Radiation (kWh/m²/day)
Jan	0.493	2.690
Feb	0.572	3.860
Mar	0.607	5.140
Apr	0.636	6.410
May	0.643	7.150
Jun	0.687	7.900
Jul	0.719	8.100
Aug	0.696	7.260
Sep	0.638	5.740
Oct	0.577	4.180
Nov	0.521	2.990
Dec	0.471	2.380

Figure 3.solar resources

IV. Results and discussion

The household electrical load is supplied by PV array and batteries. It will be installed in the rooftop of household. There is a grid connection in the system to give the homeowner more flexibility to feed house load when grid are having poor supply. The solar system is modeled in HOMER by selecting grid connection. The modeled system is shown in figure 1. Homer simulates the data and generates optimized results of the solar power system for the household. It gives the best PV panel, inverter and battery sizes for the electrical load size based on the lowest net percent cost. The software has select 8.78kw solar panel, 4 units of 165Ah battery and 5kw an inverter. Figure4 shows the cost summary of the system based on the net present costs which are as following, the initial cost is $12,409.94, the total replacement cost is $174, and the total operating cost is $2,395 .The analysis has been done for project life of 25 years.

Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
BLUESUN 5 kva pure sine wave inverter With MPPT Controller (4.87 kW)	$322.23	$20.65	$25.17	$0.00	($3.89)	$364.17
CanadianSolar All-Black CS6K-290MS	$5,479.71	$0.00	$1,956.72	$0.00	$0.00	$7,436.42
Trojan SAGM 08 165	$6,608.00	$153.44	$413.68	$0.00	($7.93)	$7,167.19
System	$12,409.94	$174.09	$2,395.57	$0.00	($11.82)	$14,967.78

Figure 4.cost summary

Figure5 shows monthly average electrical power from PV array for the household load. The load is powered by 8.78kW PV panel. The power generated by PV panel during the year is 15,342kWh/yr. From figure5 it can be seen that, PV panel has highest power generation between March and October, while other months witnessed low production with assumption, that the household load during the year is constant.

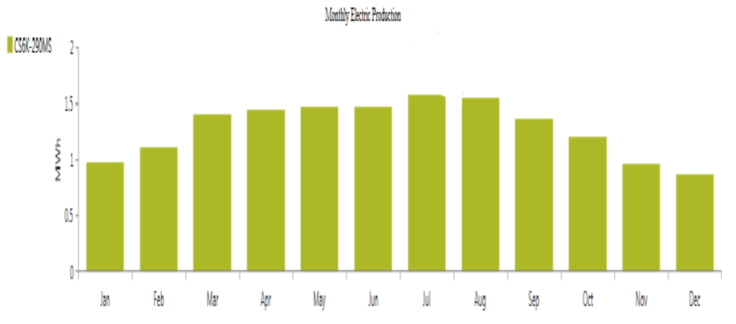


Figure5. Monthly PV average power generation for household electrical Demand

V.Environmental Impacts

Based on [11], for 1kWh of electric energy produced from a conventional electrical system in Libya 0.919Kg of CO_2 is released to the atmosphere from that, the value of CO_2 reduction by a PV system which is generating 15,342kWh/yr is about 14,099.3Kg/yr is calculated. Therefore, the carbon dioxide emission reduction is one benefit of solar system. Using PV system can reduce the demand of energy from the grid as result decreasing carbon dioxide emission. Also it has benefit for communities, governments who are able to reduce carbon dioxide emission by using solar system which is a pathway to sustainable development.

VI. Conclusions

As result of the potential of solar energy in Libya, the paper highlights the benefits of using PV system as an alternative to utility grid to provide all electrical house demand as result of instability and inerrability of Libya utility grid and cut offs of electrical power for long hours during a day. Environment benefits, including reducing carbon dioxide emission, reducing noise caused by the use of standby generators in residential areas were achieved. In addition, community benefits providing all electrical house demand and it can contribute to increasing capacity of grid network, solar system provides job opportunities in installation and design.

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