AN EMPIRICAL STUDY OF DESIGNING AND SIZING OF A GRID CONNECTED SOLAR PV SYSTEM FOR A HOUSE IN MISRATA CITY

Abdusalam M. Ben-Naser
Faculty of Eng. Mech Eng. Dep. Misurata University Email : abennaser@yahoo.com

Abstract

Solar photovoltaic system is one of renewable energy system which uses PV modules to produce electricity. utilization of the solar energy to power electric appliances starts by converting the energy coming from the sun to electricity. Photovoltaic systems can be used to power in almost all kinds of applications such as residence, industry, agriculture, livestock, etc. Solar energy can be used to operate most if not all the appliances available in homes. The electricity generated can be stored or used directly, fed back into grid line or combined with one or more other electricity generators or more renewable energy sources. Employing renewable energy technologies like solar power seems to be a good option, especially for third world countries which receive huge amounts of solar radiation around the year. Designing on grid PV system depends on a variety of factors such as geographical location, solar irradiation, and load requirements. The current paper presents studying and designing a common on Grid PV system configuration and how to optimize the results in order to build the best cost efficient technology. The paper illustrates the components required for the design of an on grid photovoltaic system that will power all electric appliances at a medium-energy-consumption residence in Misrata City. The system required 12 modules with total area of 19.2 m^2, and two inverters of 1.8 KW each.

Key worlds: Photovoltaic, standalone Photovoltaic system, off grid system, Maximum Power point tracking, Inverter, Solar PV panel, Solar batteries.

Nomenclature

kWh/d	kilo-watt-hour per day
AH	ampere-hour
T amb	Ambient temperature
GlobHor	Horizontal global irradiation
DiffHor	Horizontal diffuse irradiation
Isc	Short-circuit current
Voc	Open-circuit voltage
GCPV	Grid connected photovoltaic

1 INTRODUCTION

Solar energy is clean, free available, environment friendly and secure energy source. Conventional methods of generating electricity can produce pollutants such as carbon dioxide which is considered as the main gas responsible for global warming. A look at the world map of mean solar radiations reveal that, Africa as a continent receives the highest amounts of solar radiation between 300 and 350 W/m^2 annual. This makes the African continent of which Libya is a part, exceptionally suitable for solar energy projects. In spite of this huge potential, Africa still trails the rest of the world in terms of solar energy applications and energy services in general [1].

Electricity is one of the driving forces for economic development. The challenge to meet the growing demand is difficult for both developed and developing countries alike. For people in rural areas the cost of electricity is often high and inaccessible due to the high cost of energy infrastructure[2]. A decentralized power system can function either in the presence of grid, where the extra electricity can sold to the grid that reduces the system running cost, or as a stand-alone isolated system exclusively meeting the local demands of remote locations, eliminating the need of batteries for storage [3].

The central component of any photovoltaic power system is the solar cell. It is the transducer that directly converts the sun's radiant energy into electricity. The only resource needed to power a solar cell is sunlight; through the photovoltaic effect, the energy contained in the sun light can be converted directly to electrical energy. Photovoltaic systems represent a silent, safe, not pollutant and renewable source of electrical energy [4].

The time line of solar cells began in the 19th century when it is observed that the sunlight striking certain materials generates detectable electric current. Historically they have been used in situations where electrical power from the grid was unavailable. The price of the PV modules were in the past the major contribution to the cost of these systems. A downward tendency is now seen in the price for the PV modules due to a massive increase in the production capacity of PV modules. For example, the price per watt for a PV module was between 4.4 -7.9 USD in 1992 and has now decreased to 2.6-3.5 USD [5].

Libya is blessed with enough sun shine which can meet our energy demand without any compromise and it is also pollution free.

In the present paper sizing and calculation of output power of grid connected photovoltaic system is done for a typical residential house in Misrata (Libya). In this analysis PVsyst 6.41 software is used. The system is designing to provide the electricity to the house for all over year and excess electricity will be provided to the grid.

For development of the grid connected photovoltaic system, it is very important to collect important data that effects performance of the system. There are two data set that are effect the system parameter one is geographical data and another is load data [6].

2 GEOGRAPHICAL DATA

The building is located in Misrata city at latitude 32.19 degrees north and Longitude 15.03 degrees east, , 4 meters above sea level. It has an average ambient temperature 21.1 ºC and wind speed about 3.8 m/s. The total area of the building is 120 m^2. Global irradiance is maximum on the May (246.2 kW/m^2/month) and minimum on December (94.4 kW/m^2/month). Total global irradiance in the whole year is 2052.9 kW/ m^2 as shown in Table 1.

Figure (1) shows sun path for the building location. From the figure it is shown that sun shine is higher in the summer session whereas sun shine is lower during the winter session. Hence solar radiation is highly available in summer session in the site location.

3 LOAD DATA

To design SAPV system, the energy demand must be determined to avoid oversizing the power system which can be led to additional cost. The energy demand consumption is determined based on the daily power used and its operating time. The daily load energy consumption for the house is shown in table 2.

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Table 1: Global and diffuse radiation for Misrata city

Month	GlobHor kWh/m²	DiffHor kWh/m² °C	T Amb °C
January	102.7	34.23	12.23
February	117.6	41.33	12.81
March	172.2	53.46	16.52
April	200.9	63.88	19.56
May	233.5	70.06	24.02
June	234.9	66.1	26.6
July	246.2	57.05	29.16
August	223.1	60.46	29.46
September	175.7	59.69	26.87
October	141.3	51.51	23.84
November	110.2	32.3	17.83
December	94.4	32.26	13.54
Year	2052.9	622.33	21.09

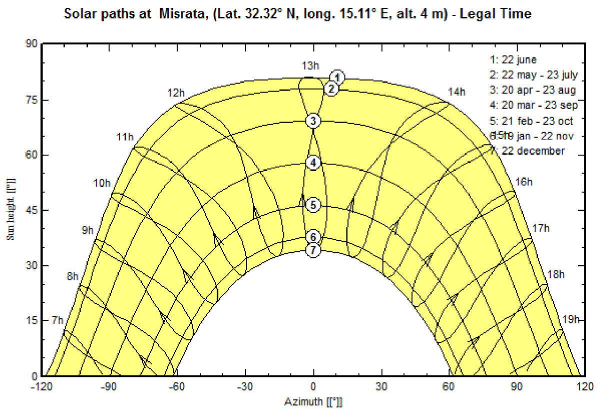

Figure 1: Sun path for the site

Table 2: House hold appliances and lighting load

Load type	No of unit	Rated power(W)	Hours used/day	KWh/day
Energy saving lamps	10	15	5	0.75
TV set	1	100	7	0.7
Computer	1	90	5	0.45
Refrigerator	1	60	10	0.6
Iron	1	800	0.5	0.4
Air conditioning	2	1200	4	9.6
Washing machine	1	1200	0.5	0.6
Total				13.1

4 TYPES OF SOLAR PHOTOVOLTAIC POWER SYSTEM

The PV systems are designed to provide power to electrical loads. The load may be of DC or AC type and depending on the application, the load may require power during the daytime only or during the night time only or even for 24 hours a day. Since a PV panel generates power only during sunshine hours, some energy storage arrangement is required to power the load during the non-sunshine hours. This energy storage is usually accomplished through batteries. During the non-shine hours the load may also be powered by auxiliary power sources such as diesel generator, wind generator or by connecting the PV system to the grid or some combination of these auxiliary sources. In the present study, the grid connected solar PV system is used only. PV systems can be broadly divided into three categories as shown in figure (2) [7].

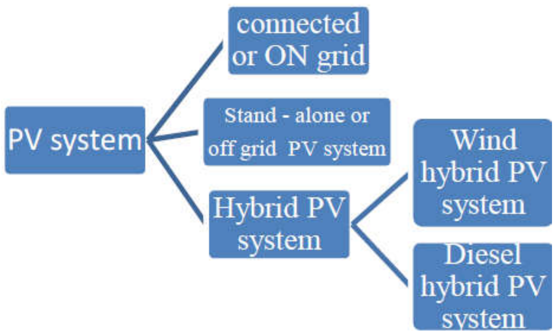

Fig. 2: Calcifications of PV systems

A grid-connected PV system consists of solar panels, one or several inverters, a power conditioning unit and grid connection equipment. They range from small residential and commercial rooftop systems to large utility-scale solar power stations . Unlike off grid power systems a grid-connected system rarely includes an integrated batteries, as they are still very expensive. the grid-connected PV system supplies the excess power, beyond consumption by the connected load, to the utility grid [8].Figure (3) shows a grid type connected.

Fig 3 Components of grid connected PV system [9]

5 PERFORMANCE RATIO

The performance ratio (PR) is used to access the installation quality . The PR provides a normalized basis so comparison of different types and sizes of PV systems can be undertaken. The performance ratio is a reflection of the system losses [10].

$$PR= E_{sys} / E_{ideal}$$

Where:
E_{sys} = actual yearly energy yield from the system.
E_{ideal} = the ideal energy output of the array.

$$E_{ideal} = P_{array\cdot stc} \times H_{tilt}$$

Where:
H_{tilt} = yearly average daily irradiation, in kWh/m^2 for the specified tilt angle.

Parray.stc = rated output power of the array under standard test conditions, in Watt.

6 ORIENTATION OF SOLAR PANNELS

The potential energy yield depends heavily on the angle of incidence of the incoming radiation, the season and local weather conditions. It is easier to mount the solar panels at a fixed tilt and just leave them. But because the sun is higher in the summer and lower in the winter, then more energy can be captured by adjusting the tilt of the panels according to the season. It is also possible to use solar tracking devices that changes the azimuth and tilt angle throughout the year, but such systems are more costly and vulnerable to faults. Another option is to manually change the panels tilt angle seasonally.

As a rule of thumb, for a fixed PV array, typically the array needs to be oriented to face south in the Northern hemisphere. Optimum PV array output can be achieved using tilt angle approximately equal to the site's latitude. The simulations in the present is performed with a fixed panel [14]. Figure (4) illustrates the optimum panel azimuth and tilt angle all over the year in case of using fixed angle

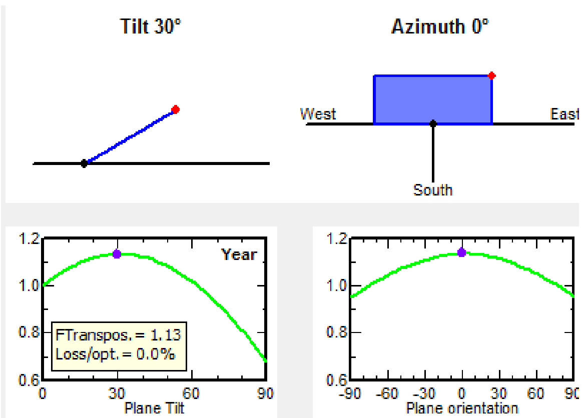

Fig. 4 Optimum Azimuth and tilt angled for the panel used in this study

7 SYSTEM CONFIGURATION

It is very important to select the best components in the system to achieve a cost-effective and reliable system [6]. All the components of the system are selected on the bases of their parameters and characteristics.

1- PV Panel:

Photovoltaic panel is the most important component of the grid connected PV system, as PV change the solar radiation energy into electrical energy. Solar panel is formed by putting together several PV cells. Putting together several PV cells forms a PV module; several modules form arrays and several arrays form panels see Figure 5. Solar cells are usually made of semiconductor materials such as silicon, gallium arsenide, cadmium telluride or copper indium diselenide [11].

PV array must be properly sized to supply the load throughout the year. In our study 310 W Sun Power PV module is selected, parameters of proposed module is given in table 3. Figure 6 shows the block diagram of the grid connected PV system in which the inverter supplies the user with the required energy, and exceeded power delivered to the utility grid. However in case the PV array does not produce enough energy, then the user takes the required energy from the utility grid.

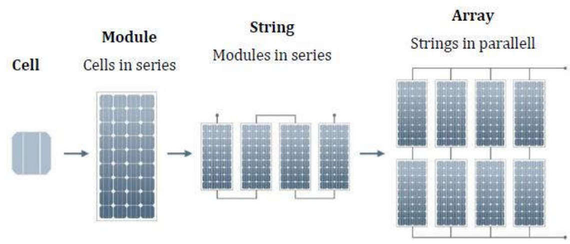

Fig. 5: structure of PV array [12]

Figure 7 illustrates the relation between the current and the voltage of the PV module. From this figure, it can be seen that, the irradiance level directly influences the output of the solar cell. The lower the irradiance level (compared to STC), the lower the efficiency of the system.

Table 3: PV module specifications

Specification	Parameter
Type of PV module	Sun Power_ SPR-E19-310-COM
Array global power KWp	3.72
Short-circuit current (Isc) A	6.05

Open-circuit voltage (Voc) V	64.4
Maximum current (Impp) A	5.67
Maximum voltage (Vmpp) V	54.7

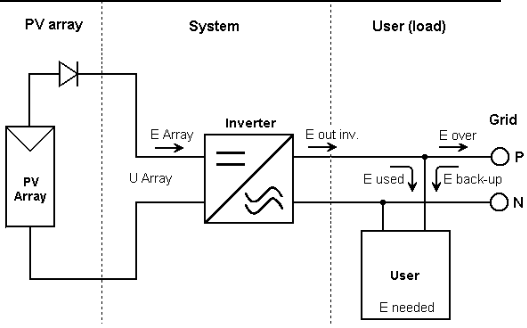

Fig. 6 Diagram of the grid connected PV system

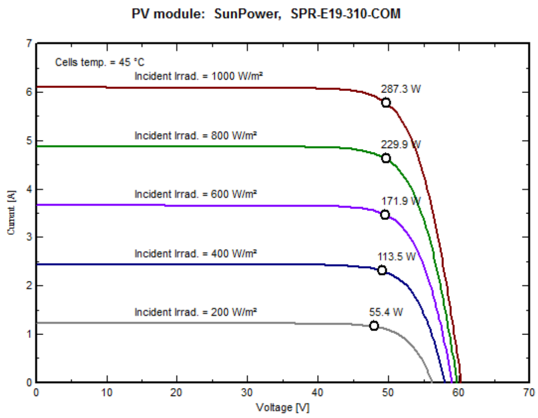

Fig 7: The relation between the current and the voltage of the PV module

2-Inverter:

A solar inverter, or PV inverter is the most critical component in a photovoltaic system. Most of the applications in a residential building generally use AC current, whereas PV module is a power source of DC current. The job of the Inverter is to converts DC power generated by the photovoltaic cells into AC power [13] allowing the use of ordinary commercial appliances. To rum the system properly, it is very important to match the inverter and the PV specification. Two inverters are used which manufactured by GESolar, the specification of the inverter is shown in table 4, and it has a maximum efficiency of 98.7%.The inverter efficiency curve as a function of the output is shown in Figure 8.

Table 4 Inverter specification

Pacification	Parameter
Model	GESolar+_ GES2-2KTL
Operating Voltage	80-400 V
Nominal AC Power	1.80 kWac
Grid Voltage	230 V
Maximum efficiency	96%
Nominal AC current	7.82 A
Maximum MPP Voltage	400 V
Maximum AC Power	2 KW

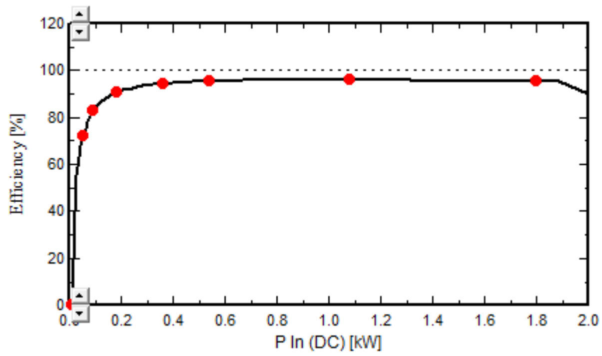

Fig.8: Efficiency curve of the 1.8 KW GESolar inverter

8 RESULTS AND DISCUSIONS

A pvsyst software was used as a simulaton tool. this software contains both meteoro-logical data and the possibility to select system components from various manufa-cturers. pvsyst can provide almost everything that needs to design a pv home system. it illustrates the number of pv module, battery, inverter size, pv module loss factor, energy calculation, hourly profile, p-v curve, maximum power point and more.

8.1 Balances and main results

The output of the pv system depends upon the received solar radiation and temperature. figure 8 shows the voltage-current diagram of the photovoltaic module. at the 60°c temperature maximum power point voltage will be 279 v whereas at the 20°c temperature maximum point voltage will be 329 v, and open circuit voltage is 428 v at -10 °c

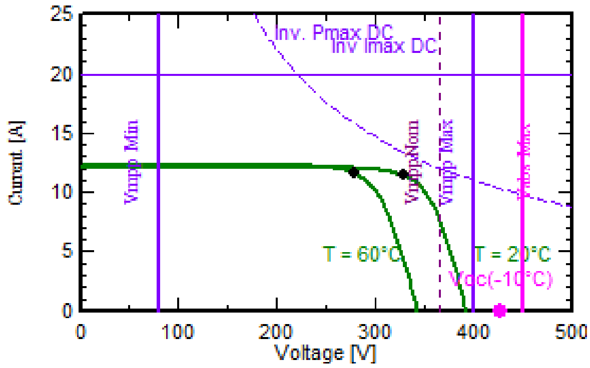

Fig. 8 PV Array Voltage-Current Characteristics

Figure 9 shows the monthly averaged total in-plane insolation together with the monthly ambient temperature averaged over the daytime hours. The highest value was in July with 246.2 kWh/m^2 and the lowest in December was 94.4 kW h/m^2. While the annual solar energy received by the PV array is 2311.1kWh/m^2, and the mean ambient temperature was 21.09 C.

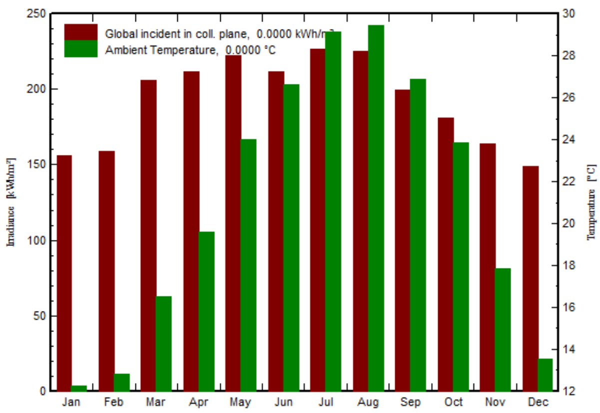

Fig 9 Monthly averaged total irradiation and ambient temperature

8.2 Performance ratio

The performance ratio (PR) is the final yield divided by the reference yield (YF/YR). Performance ratio for the simulated photovoltaic system is 81.2 %, which is the annual average PR value. There is small variation in PR value on monthly basis, which can be seen in Figure 10.

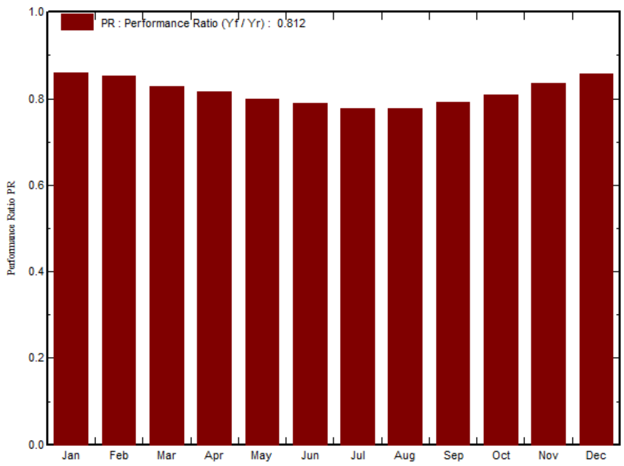

Fig. 10 Performance ratio

8.3 System Losses

PV system is not able to convert the total energy that received from the solar radiation as a result of various losses. Figure 11 shows detailed losses occur in the proposed grid connected PV system. Firstly about 2053 kWh/m^2 radiation is incident on the solar panels and the biggest losses are achieved during PV array electric production. SunPower SPR-E19-310-COM module has 19.06 % efficiency at the STC. By this, 8536 KWh of the electricity will be produced in a year by the PV array. After that and due to the PV panel losses, inverter losses and wiring losses about 6984 KWh of electricity is available to the grid in a year.

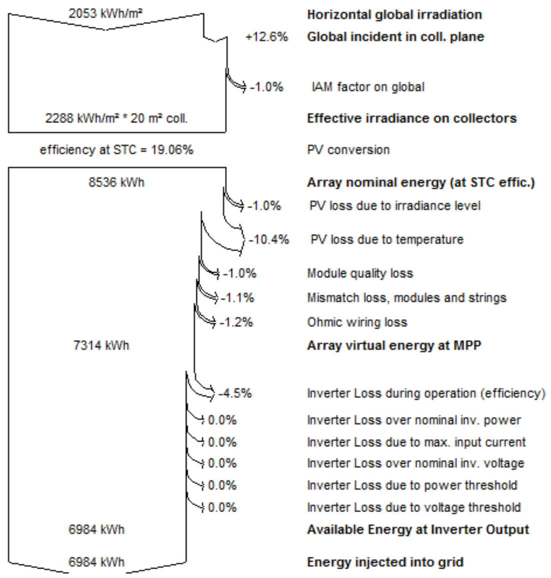

Figure 11 Loss diagram

9 CONCLUSION

Photovoltaic technology have shown great potential especially around the middle-east where high solar radiation exists. The present study provides reason to why solar power need to be implemented in Libya. In this study a grid connected photovoltaic system for the load of a house in Misrata city is designed using the PVsyst software. By the help of PVsyst software PV system configuration, output electricity and system losses are analyzed. The accurate size of the grid connected photovoltaic system is determined, suitable PV module and inverter are selected. It is founded that 12 PV panels of 310 W solar panel and 2 grid tie inverter of 1.8 kW are suitable for supplying the load of the house throughout the year.

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