

On Grid Solar System Built on Residential House Roof

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Abstract

This paper presents an analysis of the (5KW) solar system connected to the grid is designed to feed a residential building with a total daily load of 22870 Wh/day, and the system is installed on an area of $24 m^2$ from the ceiling, where it contains 10 panels connected to each other in series of the Trina solar 500Wp type, a 5Kw inverter from GoodWe, and 12 of 50AH Lead acid batteries belonging to pylontec that connected to each other in series to store the energy generated by the panels in the daytime and use it later, in which use the helioscope software to see the available area of the roof to determine the most appropriate place to install the panels, and PVsyst7.2, which analyzes the project and concludes the results related to the project for development and improvement. The system produces about 8178 Kwh per year with an estimated performance rate of 67.9% and the normal daily production of the system is 4.14 Kwh, while the loss resulting from the panels is estimated at 1.42 Kwh/day, the project also has an added value as it is considered environmentally friendly as it emits carbon radiation of about 98.1 tco_2 .

Key words-Photovoltaic, Net meter, Trina solar, PVSyst, helioscope, Roof system.

I. INTRODUCTION

Energy has a large number of different forms, and there is a formula for each one. These are: gravitational energy, kinetic energy, heat energy, elastic energy, electrical energy, chemical energy, radiant energy, nuclear energy, mass energy[1]. Renewable energy is energy that is collected from renewable resources that are naturally replenished on a human timescale. Although most renewable energy sources are sustainable. Solar energy is a radiant light and heat from the sun that is harnessed using a range of technologies such as solar power to generate electricity, solar thermal energy(including solar water heating) and solar architecture, Solar power is conversion of energy from sunlight into electricity, directly by using PHOTOVOLTAIC (PV),indirectly by using concentrated solar power or a combination. The solar photovoltaic use a semiconductor device called solar cell for the conversion. It is in most advance stage of development as compared to other direct conversion methods. PV modules can be connected in series or in parallel to produce larger voltages or currents[2], it the basic unit of a PV system and consists of an association between two thin layers of different semiconductor materials, which are only materials that absorb the energy of photons from sunl[3]ight [3]. The photovoltaic solar system have many types, on grid system, stand alone and hybrid system. Stand alone: It most commonly used in rural or remote areas where mains power is not available due to high cost of grid extension[4]. On grid: On-grid or gritted solar photovoltaic system is the one that generates electrical power with the help of solar photovoltaic harvesters and delivers the power to electric utility[5]. (No need expensive batteries, you have another source of energy (utility Grid) and easy maintenance), but you can't use in remote areas from the utility grid. It contains of: PV module, inverter, charge controller, net metering, combiner box and the batteries. A researcher analysis nine of PV systems installations located in south

eastern Poland, Eight of the systems are grid connected and one (PV with energy a storage), New technology modules with efficiencies between 19% and 21%, as well as various PV system configurations related to orientation and tilt, were taken into consideration, the average annual specific yield of all analyzed PV systems was found to be 990.2 kwh/kwp. The amount of energy produced in the summer half year was found to be significantly higher than in the winter period, about 90% of the energy was exported to the grid during the summer[6]. One studied the case of grid type solar panel on the rooftop of block-7 at Chandigarh University located in $30.7690^{\circ}N$, $76.5787^{\circ}E$, and installing a 2 KW Solar power plant it was a step toward renewable energy utilization which reduce the cost of electricity it can supply energy to grid when it's a holiday and provide better electrical supply to the department[7]. This paper illustrate of the on-grid solar system built on house roof, PV Syst is used as the simulation software to design and simulate the whole system, design parameters such as module orientation, shading, inter-row spacing and loss factors are evaluated. Shading loss mainly occurs during winter for the ground area and summer for roof surfaces, a good way was followed for Installation the roof on a building to reduce space and make some benefits for use of the roof.

II. PROJECT SITE

The total covered Area of the residential building is $117.68 m^2$ or $(1294.5 ft^2)$ and the total available area of the roof for PV installation is $121.6 m^2$ or $(1337.6 ft^2)$, The layout of the rooftop PV system was designed in Helioscope software, this software helps towards the advanced modeling of rooftop PV systems by modeling the PV arrays based on their physical design due to its design- integrated approach, Fig(1) below is the site from the helioscope program.

The data are collected from household in Karary to design and simulate, it located

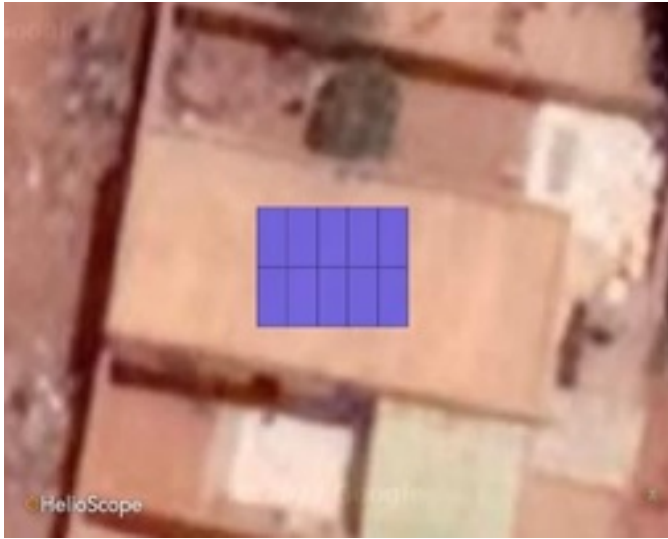


Fig. 1: Layout of Rooftop PV system for residential building

in the Northern part of Omdurman at 15.776481°E, 32.528372°N. Tilt angle of the photovoltaic (PV) array is the key to yield an optimum energy output, and it kept equal to the latitude of the location, and the best Tilt angle for all year is:

$$\text{Tilt angle} = 15.776481 \times 0.84 + 1 = 14.25^\circ \cong 14^\circ.$$

It is important to make a landscape survey to find the best spot for the modules. When the sun is behind the buildings, shading factor is around zero because no direct irradiance is falling on the PV modules and when no object is between the sun and the modules, the shading factor is one, So for this design, there's a little shadow and I shall neglect it mean assume a shade factor equal to zero as we show in Fig(2) bellow.

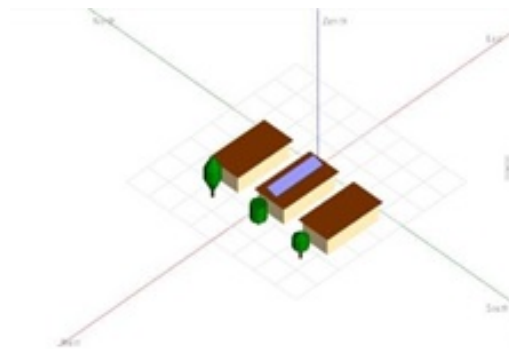


Fig. 2: Shadings designed by PVsyst 7.2

III. SYSTEM SIZING

A. Load estimation

The first steps to design PV solar system is to calculate total energy consumption of the loads needs to be supplied by the solar PV system.

The total watts/day=22870 watts/day.

B. PV array size

Total PV panels energy needed=Total loads in day × safety factor

We assume safety factor=1.3.

The Sun insolation (kWh/m²/day) =6.

$$\text{Total PV array } W_p = \frac{\text{Total demand}}{\text{Sun insolation}} \quad (1)$$

$$\text{Total PV array} = \frac{22870 \times 1.3}{6} = 4955.16 \text{ watt/day.}$$

$$\text{Number of PV panels} = \frac{\text{PV system power}}{\text{Module power}} \quad (2)$$

$$\text{Number of module} = \frac{4955.16}{500} = 9.91 \text{ module.}$$

It must use 10 modules from Trina solar module (500 Wp), and there specification at illustrated in bellow.

Specification of Trina solar 500 wp module were: Peak power (wp) =500 wp.

Maximum power voltage (Vmpp) =42.8 v.

Open circuit voltage (Voc) =51.7 v.

Short circuit current (Isc) =12.28 Amp.

Module efficiency (η) =20.9%.

Maximum Power current (Imp) =11.69 Amp.

C. Inverter size

For grid tie systems or grid connected systems, the input rating of the inverter should be same as PV array rating to allow for safe and efficient operation.

Inverter size=Total PV array energy=4955.16 watt.

It used hybrid inverter 5 KW from Goodwe company, model is GW5000D- NS have operating voltage from (80 to 550) v and it maximum input voltage is580 v. Hybrid inverter is a smart inverter it have inside charge controller to control the charge of batteries, this inverter have 2 MAXIMUM POWER POINT TRACKING (MPPTs). And there specification are illustrated in Table(I) bellow.

TABLE I: the specification of GW5000D-NS

Model name	GW5000D-NS
Max recommended PV power(w)	6500 w
Max PV voltage	580 v
MPPT voltage range	80-550 v
Max PV current	27.6 Amp
Max AC power (w)	5000 w
Nominal AC output	50/60Hz, 230 Vac
Max AC current	22.8 Amp
Max efficiency	97.8%

D. Size of batteries

$$\text{Battery capacity} = \frac{\text{total applisnce on use days of autonomy}}{\text{system efficiency system voltage DOD}} \quad (3)$$

Sudan and some African countries are considered to be rich countries in the solar energy, and the sun is bright most of the week, so we can say that (the days of autonomy for 1 day).

$$\text{battery capacity} = \frac{22870 \times 1}{0.98 \times 48 \times 0.8} = 607.73 \text{AH}. \quad (4)$$

So it's used the batteries system it used 50 Ah Pylontech battery.

Number of batteries in series = $\frac{48}{48} = 1$ batteries.

Number of batteries in parallel = $\frac{607.73}{50} \approx 12$ batteries.

It used 12 batteries of 50 Ah Pylontech connect parallel with each other in one string, then connect parallel with inverter device, and there specifications are illustrated Table(II) in bellow.

TABLE II: Battery specification

Model name	US2000B_50Ah
Typical capacity(AH)	50 Ah
Typical voltage	48 V
Dimensions	625×195×355 mm
Max. charge current	6 A
Max. discharge current	20 A
cycle life	>6000(80% DOD)

E. Net meter

There are two types of On-grid typologies: Feed in Tariff, Net metering. Net metering: Is mean one of the billing systems legislated by the competent authorities in countries to allow domestic and commercial users to install renewable energy systems and connect them to the public electrical networks. Whenever the PV system delivers more power than home needs at that moment, the electric meter runs backwards, building up a credit with the utility. This arrangement, in which a single electric meter runs in both directions, is called net metering since the customer's monthly electric bill is only for that net amount of energy that the PV system is unable to supply.

F. PV system Installation

The PV modules are mounted on the rooftop of the building, it installed on the locally manufactured mounts, because the rooftop was flat and there's no sliding in it. A ten PV modules of Trina Solar (500w) were installed on the mounted roof and it connection Series with each other to be the total of (Voc) is, $V_{oc} = 51.7 \times 10 = 517 \text{ V}$. This is within the range of the Direct current voltage of the GW5000D-NS inverter, the ten modules gave us one group mean one string to get out one neutral to be connected after that parallel with the inverter device as illustrated in Fig(3) bellow

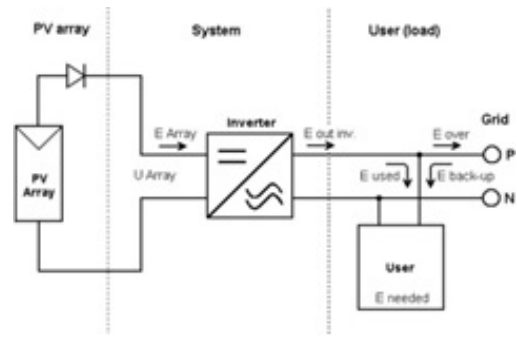


Fig. 3: Sketch whole system by PVsyst 7.2

IV. RESULTS AND DISCUSSION

The design process and implementation of the system into PVsyst requires entering data and defining plenty of parameters in order to create a precise, valid and detailed grid-connected system. PVsyst has several built-in mathematical models for component such as photovoltaic module, inverter, batteries and other tools. It makes the users to interconnect this component to develop a virtual PV system and simulates that. The daily system output energy throughout the year is shown in figure below, the output energy stable increase in the summer season (February, March, April) because of high temperature and stable most of the year that present in Fig(4) below.

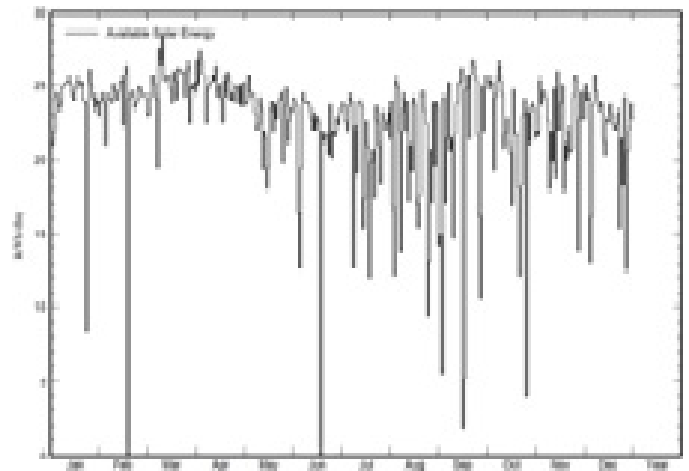


Fig. 4: Daily system output energy

The system loss by PV array is 23.3% and other is 3.3% that mean the percentage of useful energy is 73.4%, as it shown in Fig(5) below from PVsyst 7.2. Software.

The batteries type is lithium ion it has high energy density and high depth of discharge that mean long lifespan and less maintenance and it used 12 batteries from 50 Ah lithium ion it can store 23.3 kWh at DEPTH OF DISCHARGE (DOD 80%), so from the 8280 kWh generated at the inverter's output, a 6780kWh/year that are specifically used for consumption, 690 kWh/year it is sold to grid. Only 5.5% of the time, the user need to purchase backup energy from the grid which represents value is 280 kWh/year. As a rule of thumb, a 20 KW generator can consume about 3 liters of diesel per hour

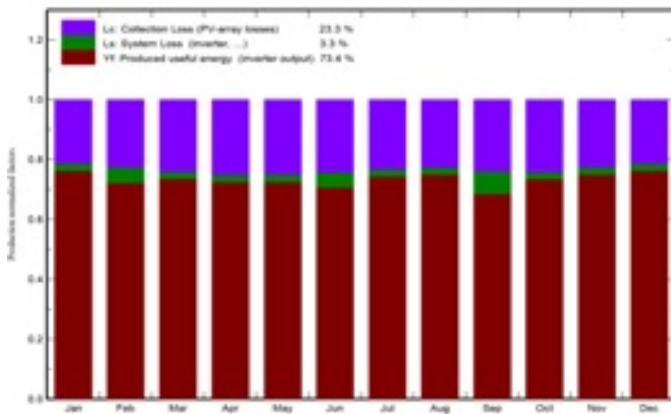


Fig. 5: Normalized production and loss factor

when operating at half load, and a liter of diesel weighting 0.85 KILLO GRAMS (KG) releases 2.6KG of carbon dioxide and 2KG water and some other greenhouse gases, So we should use the Renewable energy, The project is proving his environmentally friendship, it has low level of environmentally harmful radiation, it emissions around $98.1tCO_2$ with $400 gCO_2/kWh$ and the total amount of CO_2 emissions caused by the construction and operation of the PV installation is $9.09tCO_2$. as Fig(6) bellow.

$$\text{carbon emission} = \text{emitted generated kWh} \times \text{emitted} \frac{\text{kg}}{\text{kWh}} \text{ of } CO_2$$

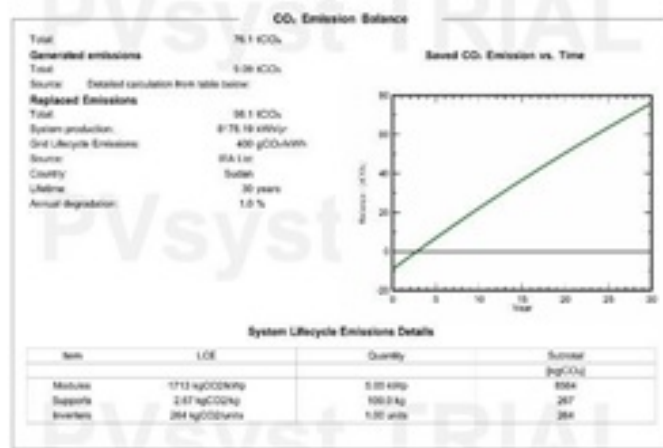


Fig. 6: System emissions

V. CONCLUSION

The main object of thesis to design the solar system can feed demand of 22870 Wh/day and reducing the electricity tariff by selling the surplus energy to the national grid, project depend on sun light energy, it contain about 10 of 500 Wp PV modules connected as one string those collect the electrical energy come from sun as a DC power and convert it to AC power to operate the AC devices by 5 kWp inverter, the inverter output energy for year is 8280 kWh stored of it energy in 12 batteries is 60.8% and remain

39.2% is direct use, all losses in the system is 26.6%, about 23.3% of output energy losses (1.42kwh/day) comes from array especially from the temperatures it represent 15.9% and the ohmic losses is 43.1mW, the remain of losses beside array 3.3% (0.2 kwh/day) comes from inverter during operation it. The system is a friend of the environment it emission around $98.1tCO_2$ with $400 gCO_2/kWh$

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