

Energy Calculation for the Design and Implementation of a Solar System

Mogakolodi
Mokgathi
UG Scholar, ECT
BIUST
Botswana

S.Ravi
Faculty of ECT
BIUST
Botswana

Abid Yahya
Faculty of ECT
BIUST
Botswana

Bakary Diarra
Faculty of ECT
BIUST
Botswana

Abstract—The project focused on one of the factors that affect the world at large which is the energy crisis. It is very clear that Grid power can no longer sustain the world on its own as fossil fuels are disbursed at a very high rate. This project focuses more on the solar energy as a way of supplementing the already existing grid power. Energy from the sunlight is harnessed using photovoltaic cells/ panels which work with charge controllers to charge the battery storage and an inverter to invert dc current to AC current that will be supplied to the various loads. Energy calculations will be done to correctly estimate the amount of power that will be needed to power up a certain location or area. Calculating cable sizes for the system will be done using software called power plus which is very convenient and easy to use. Generally other calculations can be done online or manually. Design and implementation of the project will be done in real time with a smaller model to show the working capabilities of any given system. The system will include PV array which harvest energy from the sunlight, then the charge controller, which regulates charging of the battery bank/storage. This will be followed by an inverter which then inverts the DC current to AC current to be used in the load.

Keywords— *Photo Voltaic Cell, AC Current, Battery, DC Current.*

I. INTRODUCTION

Its history is from the 7th century to date. We started using it to make fire where the sun's heat was concentrated through glass or mirror [5]. Nowadays we have solar powered buildings, vehicles; basically anything that needs electricity can be powered by solar. Solar energy is radiant heat and light from the sun that is harnessed using the proper techniques and the ever changing technologies such as photovoltaic, solar heating, solar thermal energy etc. Similarly, solar energy is the energy from the sun which without it all life on earth will end, solar energy is also a major source of energy because of its large amounts of energy freely available for use if harvested by the modern techniques [4]. Solar energy is a very important renewable source of

energy and can be characterized in two technologies, which are active and passive solar, photovoltaic cells depending on how they convert or distribute solar energy into solar power.

A. Passive Solar

Passive solar system was used by early people, who built their houses using clay or stones which will absorb the sun's heat during the day so as to keep it warm during the night. Modern day technology has seen constructors constructing buildings using large double or triple paned windows that get direct sunlight to capture and magnify the sun's warmth. Other methods of passive solar energy capture are using stone flooring and using thick insulated walls to keep the energy in buildings.

B. Active Solar

Active solar energy systems use the same principles as those of passive solar energy except that in active solar energy a fluid like water is used to absorb the heat. A solar collector placed on the roofs of buildings heats the fluid and then pumps it through a system of pipes to heat the whole building.

C. Photovoltaic Cells

Photovoltaic cells, commonly known as solar panels are more involved than passive or active solar energy systems, as they convert sunlight to electricity using thin sheets of silicon. People in remote areas such as mountain tops and islands, cattle post, camp sites etc. often use photovoltaic cells to generate electricity for their homes and businesses.

II. PROPOSED SYSTEM

The Botswana International University of Science and Technology (BIUST) is a great science and technology school to do one's studies. The major area of concern is how the university is lacking behind in the use of alternative energy sources such as solar, wind mills etc. Efforts have been seen in our water heating system as it is solar powered and energy efficient also saving money yearly.

The use of fossil fuels and coal used by major industries to produce power has led to increased greenhouse gases in the atmosphere which cause negative climate change and problems to the environment. Also the prices of resources are rising yearly which calls for change. Therefore, more ways to reduce these problems have to be implemented to turn BIUST main hostels into a green energy zone.

The design and implementation of a solar system in BIUST main hostels will be a major technological growth to the institution and will benefit it in many ways. Using the sun as the ultimate energy source is the best solution as we will have less gas emissions, reducing global warming due to greenhouse gasses, as long as the right technology is used to harness the power. In this case a photovoltaic system ("a system that converts energy from sunlight directly into electricity") will be implemented, and has proved to be feasible as the cost of solar implementation is declining [2]. Solar provides clean energy, also helps in annual savings on electricity bills and the structure of the school allows to build a solar plant as there is ample space [1-3].

III. PROPOSED SYSTEM DESIGN

A. Photo Voltaic Module/ Solar Panel

Photovoltaic is the conversion of light into electricity at the atomic level. Some materials show a property known as the photoelectric effect that causes them to absorb photons of light and release electrons. When these free electrons are caught, electric current results that can be used as electricity. Traditional solar cells are made from silicon, are commonly flat-plate, and mostly are the most efficient. Second-generation solar cells are called thin-film solar cells because they are made from amorphous silicon or non-silicon materials such as cadmium telluride [5]. Thin film solar cells use layers of semiconductor materials that are a few micro meters thick. Because thin film solar cells are flexible, they can double as rooftop shingles and tiles, building facades, or the glazing for skylights. Third-generation solar cells are being constructed from a variety of new materials excluding silicon, these materials include solar inks, using conventional printing press technologies, solar dyes, and conductive plastics. Some new solar cells use plastic lenses or mirrors to concentrate sunlight onto a tiny piece of high efficiency PV material. The PV material is costlier, but because so little is required, these systems are becoming cost effective for use by utilities and industry [6]. Nevertheless, because the lenses must be pointed at the sun, the use of concentrating collectors is limited to the brightest parts of the country (sunniest parts).

B. Photo Voltaic Module Performance

The performance of PV modules and arrays are usually rated according to their maximum DC power output (watts) under Standard Test Conditions (STC). Standard Test Conditions are well-defined by a module (cell) operating temperature of 25 oC, and incident solar radiant level of 1000 W/m² and under Air Mass 1.5 spectral distribution. Since these conditions are not always characteristic of how PV modules and arrays work in the field, actual performance is usually 85 to 90 percent of the STC rating[3] [6]. Photovoltaic modules today are very safe and reliable products, with minimal failure rates and service lifetime of 20 to 30 years.

C. Battery

An electric battery is a device consisting of one or more electrochemical cells with external connections provided to power electrical devices such as flashlights, smartphones, and electric cars. Many types and classifications of batteries are manufactured today, each with specific design and performance characteristics suited for particular applications. Each battery type or design has its individual strengths and weaknesses [7]. In PV systems, lead-acid batteries are most common due to their wide availability in many sizes, low cost and well understood performance characteristics. In a few critical, low temperature applications nickel-cadmium cells are used, but their high initial cost limits their use in most PV systems [8]. There is no "perfect battery" and it is the task of the PV system designer to decide which battery type is most appropriate for each application. In general, electrical storage batteries can be divided into two major categories, primary and secondary batteries. Primary batteries can store and deliver electrical energy, but cannot be recharged. Typical carbon-zinc and lithium batteries commonly used in consumer electronic devices are primary batteries. Primary batteries are not used in PV systems because they cannot be recharged. A secondary battery can store and deliver electrical energy, and can also be recharged by passing a current through it in an opposite direction to the discharge current. Common lead-acid batteries used in automobiles and PV systems are secondary batteries. Table 1 lists common secondary battery types and their characteristics which are of importance to PV system designers.

D. Charge Controllers

Charge controllers are included in most photovoltaic systems to protect the batteries from overcharge or excessive discharge. Overcharging can boil the electrolyte from the battery and cause failure. Allowing the battery to be discharged too much will cause premature battery failure and

possible damage to the load. The controller is a critical component in the PV system. A controller's function is to control the system depending on the battery state-of-charge (SOC). When the battery nears full SOC the controller redirects or switches off all or part of the array current. When the battery is discharged below a pre-set level, some or the entire load is disconnected if the controller includes the low voltage disconnect (LVD) capability. Most controllers use a measurement of battery voltage to estimate the state-of-charge. Measuring battery temperature improves the SOC estimate and many controllers have a temperature probe for this purpose.

E. Inverters

Inverters which are also known as Power conditioning units are necessary in any stand-alone PV system with ac loads. The choice of inverter will be a factor in setting the dc operating voltage of your system. When specifying an inverter, it is necessary to consider requirements of both the dc input and the ac output. All requirements that the ac load will place on the inverter should be considered, not only how much power but what variation in voltage, frequency, and waveform can be tolerated. On the input side, the dc voltage, surge capacity, and acceptable voltage variation must be specified. Selecting the best inverter for an application requires a study of many parameters.

The choice of inverter will affect the performance and reliability of a PV system.

IV. ENERGY CALCULATIONS

When sizing a photovoltaic system for a stand-alone photovoltaic power system, five steps are involved for a process which will permit the photovoltaic system designer or user to correctly size a system based on users expected needs, goals and budget. These steps are;

1. Estimating the electric load.
2. Sizing of an inverter
3. Sizing of batteries
4. Sizing an array
5. Sizing a charge controller

The Table.1 shows the energy calculation. The total number of lights was collect and their power ratings. Then the total wattage was found by multiplying the total number of light with the wattage of the light. This was done separately for light that had the same wattage. Then the operating hours for different rooms was estimated. The average daily load was computed by multiplying the total wattage by the hours of use.

Table 1. Energy Calculation

	No. of rooms lights	Balcony lights	Bathrooms lights	Inner lighting	Laundry rooms lights	Outside lighting
Total lights	528	48	144	248	12	76
Fluorescent	129* (18W) 135* (36W)	0	144*(36W)	64* (36W)	12*(36W)	0
Normal (12W)	0	48* (12W)	0	184* (12W)	0	76* (12W)
Total wattage (W)	7182	576	5184	4512	432	912
Hours of use (hrs)	8	6	6	8	8	8
Total watthours (Wh)	57456	3456	31104	36096	3456	7296

Total Watts = 18798 W
Total Watt Hours = 138864Wh

A. Size of PV Module

(Ppv) = energy consumption / (efficiency * sun hours)
Size of PV Module = $138864 / 6$
= 23144W
Using a 300 W solar panel we get
No. of panels = $23144W / 300W$
= 77.15
= 78 (300W) panels

B. Battery Sizing

3000Ah 2V batteries will be used for the project, as there will be days without enough sunlight, usually during cloudy days, our days of autonomy (days of useable storage) will be 3 days. The depth of discharge will be 40% and an efficiency of 80%. Size of battery (Ah) = (power consumption * days of autonomy) / (efficiency * depth of discharge * battery voltage)
= $(138864 * 3) / (0.8 * 0.4 * 2)$
= 650925 Ah
Since we are using a 3000Ah 2V battery; to find the total number of batteries we will use;
= $650925Ah / 3000Ah$
= 216.97 batteries
= 217 batteries

C. Inverter Calculations

If the total Wattage of the system is 18798 W, the inverter should be 30% bigger than the system size. This implies that for this case the inverter should be at least 24437.4 W. we further divide the power by efficiency to get our rating in VA which is the standard rating for Victron Energy inverters and other inverters at large.[2] The new rating for the inverter should at least be;
 $24437.4 / 0.8 = 30546.75 VA$
Since 10000VA inverters will be used then;
 $30546.75VA / 10000VA = 4$ (10000VA inverters)

D. Charge Controller Sizing

Solar charge controller rating = (short circuit current of panel * number of panels) * 1.3
 $(9.83A * 78) * 1.3 = 996.76A$
i.e. 10 * MPPT 150/100-MC4
(100A controllers)

V. CONCLUSION

The main aim of the project was to calculate the amount of power that the BIUST main hostels will need to be totally off grid, and as such the main aim was reached as the energy calculations were done. The total power consumption was calculated and found to be 136884Wh and the project required 78 300W panels, 217 2V/3000Ah batteries, 4 10000VA inverters and 10 100A charge controllers.

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