Design Of Solar Electric System For A Home

AYE MAR OO[1], PWINT PHYU THAE[2]

[1, 2] *Department of Electrical Power Engineering, Technological University (Sagaing)*

Abstract- This study aimed at developing a living standard procedure for the design of small-scale grid-unconnected solar Electric systems using the roofs of buildings and car parks. The standard procedure developed was validated in the design of a 5 kW grid-off solar electric system for a home.The purpose of this thesis paper is to provide a rural remote commercial purposed shelter with energy demand throughout the whole year by designing a solar PV off-grid system on a tilted rooftop. Also comprehensive overview was conducted throughout the paper for Solar PV systems, parts and components, principle of operation. The design criteria of the off-grid solar PV system were divided into several detailed stages where each stage was conducted upon numerated values thoroughly.

Indexed Terms- small-scale, roofs, grid-off, solar, electric system.

I. INTRODUCTION

The sun provides the energy to sustain life in our solar sys-tem. In one hour, the earth receives enough energy from the sun to meet its energy needs for nearly a year [1]. Photovoltaic is the direct conversion of sunlight to electricity. It is an attractive alternative to conventional sources of electricity for many reasons: it is safe, silent, and non-polluting, renewable, highly modular in that their capacity can be in-creased incrementally to match with gradual load growth, and reliable with minimal failure rates and projected service lifetimes of 20 to 30 years [2, 3]. It requires no special training to operate; it contains no moving parts, it is extremely reliable and virtually maintenance free; and it can be in-stalled almost anywhere. The intensity of the sunlight that reaches the earth varies with time of the day, season, location, and the weather conditions. The total energy on a daily or annual basis is called irradiation and indicates the strength of the sunshine. Irradiation is expressed in Wh.m2 per day or for instance kWh.m2 per day.

Different geographical regions experience different weather patterns, so the site where we live is a major factor that affects the photovoltaic system design from many sides; the orientation of the panels, finding the number of days of autonomy where the sun does not shine in the skies, and choosing the best tilt angle of the solar panels. Photo-voltaic panels collect more energy if they are installed on a tracker that follows the movement of the sun; however, it is an expensive process. For this reason they usually have a fixed position with an angle called tilt angle β. This angle varies according to seasonal variations [4]. For instance, in summer, the solar panel must be more horizontal, while in winter, it is placed at a steeper angle. Many researchers presented procedure to design stand-alone photovoltaic systems [7].

II. PV SYSTEM TYPES AND COMPONENTS

Photovoltaic System Types Photovoltaic system types can be broadly classified,

- the utility's transmission grid- connected
- the alternating current (AC) or direct current (DC) electrici-ty, or both
- battery back-up
- back-up by a diesel, gasoline or propane generator set

This paper will focus on systems that are connected to the utility transmission grid-off. The variously referred to as utility-connected, grid-connected, grid-interconnected, grid-tied or grid-intertied systems. These systems generate the same quality of alternating current (AC) electricity as is pro-vided by your utility. The energy generated by a grid-connected system is used first to power the AC electrical needs of the home or business. Any surplus power that is generated is fed or "pushed" onto the electric utility's transmission grid. Any of the building's power requirements that are not met by the PV system are powered by the transmission grid. In this way, the grid can be thought of as a virtual battery bank for the building.

a. Common System Types

Most new PV systems being installed in the United States are grid-connected residential systems without battery back-up. Many grid-connected AC systems are also being in-stalled in commercial or public facilities.

The grid-connected systems we will be examining here are of two types, although others exist. These are:

• Grid-connected AC system with no battery or generator back-up. • Grid-connected AC system with battery back-up.

Example configurations of systems with and without batteries are shown in Figures 1 and 2. Note there are common variations on the configurations shown, although the essential functions and general arrangement will be similar.4

Is a Battery Bank Really Needed? – The simplest, most reliable, and least expensive configuration does not have battery back-up. Without batteries, a grid-connected PV system will shut down when a utility power outage occurs. Battery back-up maintains power to some or all of the electric equipment, such as lighting, refrigeration, or fans, even when a utility power outage occurs. A grid-connected sys-tem may also have generator back-up if the facility cannot tolerate power outages.

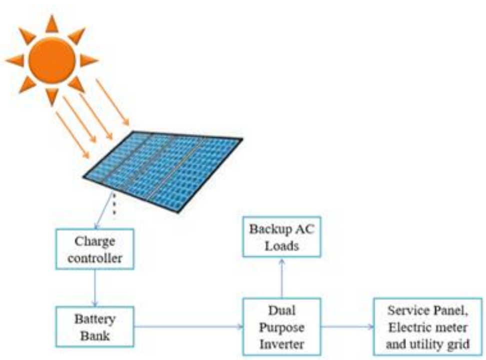


Figure 1: Interactive PV System Schematic

b. Off-Grid Solar PV System

One might encounter such solar system when there is no grid in such a rural area or even when the utility power pricing is quite high. Here, the solar panels become the utility company and generate the needed energy by one's home or any energy dependent system. There may be no option other than to go with an off-grid solar system. Off-grid systems require more care and maintenance but can give a strong sense of independence, so one is no longer being subjected to the risk of a loss of power from the utility grid. Off-grid solar systems where the solar energy is generated and consumed in the same place meaning it does not interact with the main grid at all. Figure [4] shows a simple schematic for the off-grid solar PV system.

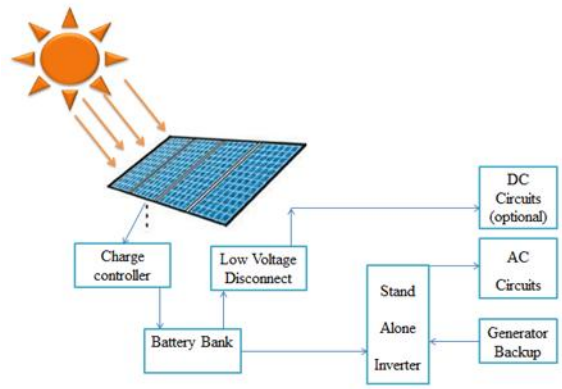
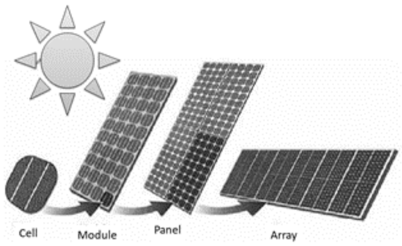


Figure 4: Off-grid PV System Schematic
Components of Off-grid PV System

c. PV Array

A solar PV Array is comprised of PV modules, which are fixed accumulations of PV Cells. A PV array is the entire electric power creating unit. It comprises of any number of PV modules. The most crucial segment of any solar PV sys-tem is the PV module, which are made out of various inter-connected solar cells. Solar PV modules are associated together into strings to meet different vitality needs, as appeared in Figure [5]. The solar system is associated with an inverter that changes over the Direct Current (DC) created by the sun powered PV cluster into Alternating Current (AC) perfect with the power provided from the lattice. Air conditioning yield from the inverter is associated with the home's electrical board or utility meter, contingent upon the design.



Types of Solar PV Modules

One may wonder, what is the sole aspect that creates all forms of PV types, but apparently it is the purity of the silicon used in manufacturing the panel itself. The more perfectly aligned the silicon molecules are, the better the solar cell will be at converting solar energy (sunlight) into electricity. The efficiency of solar panels goes hand in hand with purity, but the processes used to enhance the purity of silicon are expensive. Efficiency should not be one's primary concern. As a general rule of thumb one might find out that cost and space-efficiency are the determining factors for most people. Figure [6] shows types of PV modules.

It is realized that there are few sorts of PV modules produced these days yet the most three surely understood sorts are:

1. Monocrystalline Silicon Modules they offer high efficiency (15-20) % and good heat tolerance characteristics in a small footprint but it is quite expensive.
2. Polycrystalline Silicon Modules They offer less efficiency than the monocrystalline modules (13-16) %. Moreover, the process of manufacturing them is simpler and cheaper and also less heat tolerance characteristics in a small footprint.
3. Thin film. They offer an efficiency of (4-12) % and heat tolerance characteristics that are less than the crystalline modules. Also, they are available in a price that are slightly higher than the polycrystalline and lower than the monocrystalline modules.

III. RESIDENCE DEVICE

The daily load profiles were determined by calculating the power demand (kWh/day) for all load types in the college. The estimated daily energy demand is given in Table 1 be-low. All the appliances used in the college are ac-appliances. Furthermore, all appliances mentioned in Table 1 are AC ones, so one might encounter this crucial piece of information later at the system main components design and selection but specifically at the inverter design step as it re-quires both type and portion of the energy demand by the appliances.

Sizing of the Solar Array Before sizing the array, the total daily energy in Watt-hours (E), the average sun hour per day T (min), and the DC-voltage of the system (VDC) must be determined. Once these factors are made available we move to the sizing process. To avoid under sizing, losses must be considered by dividing the total power demand in Wh.day-1 by the product of efficiencies of all components in the system to get the required energy Er. To avoid under sizing we begin by dividing the total average energy demand per day by the efficiencies of the system components to obtain the daily energy requirement from the solar array:

$$E_r = \frac{\text{daily average energy consuption}}{\text{product of component's efficiencies}} = \frac{E}{\eta_{overall}}$$

To obtain the peak power, the previous result is divided by the average sun hours per day for the geographical location T_{min}.

$$P_p = \frac{\text{daily energy requirement}}{\text{minimum peak sun} - \text{hours per day}} = \frac{E_r}{T_{min}}$$

The total current needed can be calculated by dividing the peak power by the DC- voltage of the system.

$$I_{DC} = \frac{\text{peak power}}{\text{minimum peak sun} - \text{hours per day}} = \frac{E_r}{T_{min}}$$

Modules must be connected in series and parallel according to the need to meet the desired voltage and current in accordance with:

First, the number of parallel modules which equals the whole modules current divided by the rated current of one module I_r.

$$N_p = \frac{\text{whole module current}}{\text{rated current of one module}} = \frac{I_{DC}}{I_r}$$

Second, the number of series modules which equals the DC voltage of the system divided by the rated voltage of each module V_r.

$$N_s = \frac{\text{system DC voltage}}{\text{module rated voltage}} = \frac{V_{DC}}{V_r}$$

Finally, the total number of modules Nm equals the series modules multiplied by the parallel ones:

$$N_m = N_s \times N_P$$

Individual Load	Quantity	V	Amps	Watts AC	Use h/d	Use d/W	+days	Wh AC
Computer and Accessories	1	220	0.5682	120	2	7	7	240
Refrigerator	1	220	0.0909	200	7	7	7	1400
Air Conditioner	1	220	4.5454	1000	2.5	7	7	2500
Celling Fan	1	220	0.4545	120	3	7	7	360
Light, 4 Comp	4*10	220	0.2727	60	6	7	7	360
Radio	1	220	0.3636	80	2	7	7	160
Television	1	220	0.5681	125	5	7	7	625
AC Total Connected				1705	AC Average Daily Load			5645

Total Average Energy Consumption 5645 approximated to 5700.

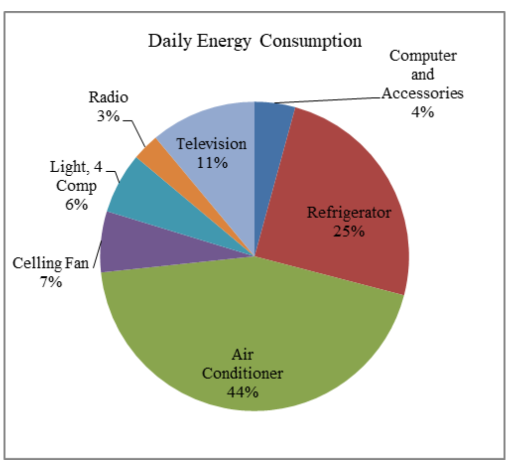


Fig. 1. Residence Devices and Daily Energy Consumption

From Fig. 1. it is vital to mention that the air conditioner has the highest energy demand (44%) and secondly comes the Refrigerator (25%) and third one Television demand.

IV. BATTERY BANK SIZING AND BATTERY SELECTION

The first decision that one needs to make for battery bank sizing is 'how much storage you would like your battery bank to provide to provide the off-grid PV system would be. Normally, this is expressed as 'days of autonomy'; because it is based on the number of days that one expects his/her system to provide electric power without receiving any input charge from the off-grid solar PV array.

V. SIZING OF THE VOLTAGE CONTROLLER

According to its function it controls the flow of current. A good voltage regulator must be able to withstand the maximum current produced by the array as well as the maximum load current. Sizing of the voltage regulator can be obtained by multiplying the short circuit current of the modules connected in parallel by a safety factor F_{safe}. The result gives the rated current of the voltage regulator I.

$$I = I_{SC} \times N_P \times F_{safe}$$

The factor of safety is employed to make sure that the regulator handles maximum current produced by the array that could exceed the tabulated value. And to handle a load current more than that planned due to addition of equipment, for instance. In other words, this safety factor allows the system to expand slightly. The number of controller equals the Array short current Amps divided by the Amps for each controller.

$$N_{controller} = \frac{I}{Amps\ each\ controller}$$

VI. SIZING OF THE INVERTER

When sizing the inverter, the actual power drawn from the appliances that will run at the same time must be deter-mined as a first step.

VII. SIZING OF THE SYSTEM WIRING

Selecting the correct size and type of wire will enhance the performance and reliability of a photovoltaic system. The National Electrical Code is NEC.

VIII. RESULT DATA OF SOLAR ELECTRIC SYSTEM FOR A HOME

a. Sizing of the Solar Array

The select panel is (Mitsubishi - MF180UD4, 180W, 24-V, 7.45-A).

The Specification of PV panel

1) Manufacturer: MITSUBISHI ELECTRIC.
2) Model name: PV-MF180UD4.
3) Cell type: Poly-crystalline Silicon.
4) Number of cells: 50 cells.
5) Maximum power rating STC (P_{max}): 180 watts.
6) Open circuit voltage (V_{oc}): 30.4V.
7) Short circuit current (I_{sc}): 8.03A.
8) Maximum power voltage (Vmp): 24.2V.
9) Maximum power current (Imp): 7.45A.

The daily energy requirement from the solar array can be determined as following:

$$E_r = \frac{E}{\eta_{overall}} = \frac{5700}{0.8} = 7125 \text{ Wh/d} = 7.125 \text{ KWh/day}$$

To obtain the peak power of the PV.

$$P_P = \frac{E_r}{T_{min}} = \frac{7.125}{3.84} = 1.855 \text{ kWp}$$

The total current needed can be calculated by:

$$I_{DC} = \frac{P_P}{V_{DC}} = \frac{1855.46}{24} = 77.311 \text{ Amps}$$

Modules must be connected in series and parallel according to the need to meet the desired voltage and current in accordance with:

The number of parallel modules:

$$N_P = \frac{I_{DC}}{I_r} = \frac{77.3111}{7.45} = 10.3773 \text{ panel} = 11 \text{ panel}$$

The number of series modules which equals to:

$$N_s = \frac{V_{DC}}{V_r} = \frac{24}{24} = 1$$

The total number of modules, $N_m = N_s \times N_P$

$$N_m = 11 \times 1 = 11 \text{ panel}$$

The PV array of the system consists of 11 panels in parallel.

b. Sizing of the Battery Bank

Total Average Energy Use = 5700 W.h.

Days of autonomy or the no-sun days = 3 days.

According to the selected battery

(UB-8D AGM 250 AH, 12V-DC).

The amount of energy storage required is,

E_{rough}= 5700×3 = 17.1 kWh,

For Energy safety, $E_{Safe} = \frac{E_{rough}}{MDOD} = \frac{17100}{0.75} = 22800$kWh

The capacity of the battery bank needed can be evaluated:

$$C = \frac{E_{safe}}{V_f} = \frac{22800}{12} = 1900 \text{ Ampsh}$$

The total number of batteries is obtained by:

$$N_{batteries} = \frac{C}{C_b} = \frac{1900}{250} = 7.6 \text{ Batteries}$$

Choose 8 Batteries

The number of batteries in series equals to: N_S= 24/12=2

The number of parallel paths N_p is obtained by: N_p=8/2=4

The number of batteries needed is, $N_{batteries}$ =8 batteries. Four parallel branches and 2 series batteries.

c. Sizing of the Voltage Controller

In this research paper, selected controller (Xantrex C-60, 24V, 60-A), the rated current of the voltage Controller I:

$I = I_{SC} \times N_P \times F_{safe}$ =8.03×11×1.25 =110.4125 Amps

The number of controller equals to,

$$N_{controller} = \frac{I}{\text{Amps each controller}} = \frac{110.4125}{60} = 1.84.$$

Therefore, this research work needs two regulators connected in parallel.

d. Sizing of the Inverter

The power of devices that may run at the same time is:

P Total= 2555 Watt.

The inverter needed must be able to handle about 2555 W at 220-Vac.

Therefore, this project select the Latronics inverter, LS- 3024, 3000-W, 24-Vdc, 220-Vac.

IX. CONCLUSION

The geographical location of Sagaing, Myanmar makes it a relatively sun-rich region with an annual solar irradiance of more than 2200 kWh.m2. There is a great tendency for the use of stand-alone photovoltaic stations distributed in re-mote areas due to the known benefits of this source of energy. This subject needs to be defined for people living in these areas. The design and sizing of every piece of equipment used in the system have also been presented. Over- and under-sizing have also been avoided to ensure adequate, reliable, and economical system design. The same procedures could be employed and adapted to applications with larger energy consumptions and could also be employed for other geographical locations, however, the appropriate design parameters of these locations should be employed.

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