PV SYSTEM SIZING

Introduction

- Sizing is an important part of designing of stand-alone systems
- Initial investments requirement is a major component
- Over sizing has a detrimental effect on the price of the system
- Under sizing has an effect on supply reliability

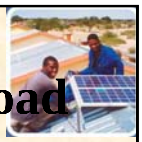
Load Determination

- **First step is to find out applications of the system**
- **Then decide whether the system will be AC or DC**
- **Determine the rating of the appliance**
- **Establish the daily usage hours for each appliance**

Determination of the daily average load

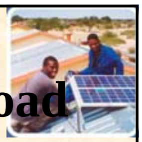
- Identification of the loads to be connected
- For each load to determine the ratings (voltage and power), and daily load operating hour. For some loads the operation may vary daily, monthly or seasonal (e.g. in schools) this should be put into consideration
- For simplicity daily variation of consumption can be considered
- **Separate ac loads from dc loads**
- Determine the daily energy usage for each appliance and then the total (Wh/day)

… Determination of daily average load



- If dc loads differ in voltage rating then the sizing must put into consideration the possible losses in the dc-dc converters
- For ac loads the dc input into the inverter must be determined by considering the efficiency of the inverter
- If the system comprises of both dc and ac then the demand for both should be added together
- **Then the wiring efficiency factor (or loss factor) and battery efficiency factor to be used to determine the overall size of the PV generator**

… Determination of daily average load



- **Note that the total ac power is used to determine the size of the inverter**
- **The power demand for the loads is used to determine the wire sizes**

Calculation of Daily Demand (example of a dc system)

Load	No. of load	Rating of @ load [W]	Total power, P [W]	Expected daily Usage [hrs/day]	Expected energy usage [Wh/day]
Lamps	2	8	16	3	48
Lamp	1	11	11	10	110
Radio	1	6	6	6	36
		$\sum P =$	33	$\sum E =$	194

Array sizing and tilt

- Determine the design power for each month by dividing corrected Wh load for the system for each month by the monthly average peak sun hour at the optimal tilt array/module
- If one value is used then a month with lowest insolation is used
- For fixed mounting to select the optimal tilt angle
- Determine the number of modules in parallel (to meet power requirements)
- Determined series strings (to meet system voltage requirements)

Determining PV Generator

- The size of PV generator are given in Watt-peak (W_P)
- ***Required:*** Average insolation, H_0*[peak-hours per day]* of the site and the expected overall losses in the system
- Peak-hours are the equivalent number of hours of sunlight at an irradiance of 1000 W/m^2.
- The design is considered to be static whereby losses in the system are integrated into one factor (i.e. overall efficiency, η is assumed)

…. Determining PV Generator

- Efficiency, $\eta = \eta_{BAT} \cdot \eta_{PC} \cdot \eta_{cables}$
- This factor is assumed to be 80% ($\eta = 0.8$)
- In the calculation of daily energy demand, it should be noted that E_L = 194 Wh/day represents the daily energy requirement by the load
- Daily generation from the module is
- $E_{PV} = E_L / \eta \approx 243$ Wh/day

…. Determining PV Generator

- To use the average insolation of the site or nearby site.
- Data on insolation is available in standard tables, given as monthly average values in $kWh/m^2.day$ or peak-hour/day
- Always a month with the lowest value of insolation is used
- In this example we use $H_0 = 5.00$ peak-hours per day (for Kampala site)
- Watt-peak of PV Generator, $P_{WP} = E_{PV}/\ H_0 \approx 48.60\ W_P$

…. Determining PV Generator

- Note that there are various sizing methods, some of the methods the sizing in based on the current, I_{MPP} not the P_{MPP} (assumed to operate at MPP at STC)
- I_{MPP} obtained from the daily charge demand by the load for a system voltage (e.g. 12 volts, 24 volts DC)
- All methods give approximately the same size of PV generator

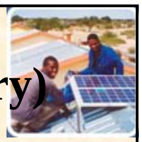
…. Determining PV Generator

- Assuming 12 volts panels to be use, then the next step is to check for the available size of panels available
- This helps to determine the number of modules to be connected in parallel
- For example if $50W_P$ modules are available then number of modules in parallel is
- No. of modules in parallel = Calculates W_P / Size of available modules (W_P) = 48.60 / 50 = 0.97 ≈ 1 panel/module in parallel

Steps in Selecting Battery

- Determine the number of days storage is required (or days of autonomy) – of course this depends on whether conditions
- Determine the amount of storage required in Ah (product of daily Ah/day and days of autonomy)
- Determine the allowable level of discharge (DoD)
- For the known system voltage determine the number of batteries to be connected to the system. The number is calculated from the required storage capacity and the capacity of the available batteries

Determining storage capacity (battery)



- The important parameters used here are the DoD and the days when the generation from the panel is expected to be poor, i.e. these are the days when the radiation is very poor or overcast days
- Days with poor radiation are known as days of Autonomy or reserve days, symbol S. Used to calculate reserve capacity
- S is greater for sites with low insolation than those sites with higher insolation

…. Determining storage capacity (battery)

- Solar batteries are expected to be of very good quality, i.e. are deep cycle batteries with high depth of discharge (DoD)
- High quality solar deep cycle batteries with DoD ≈ 0.8
- For modified solar batteries; $0.5 < DoD < 0.7$
- And for poor quality SLI batteries; $DoD < 0.5$
- In this case let us assume good quality solar batteries
- And for the considered site let us assume that reserve days; S = 2 days

…. Determining storage capacity (battery)

- Assumed that all the energy required at night and overcast conditions comes from the battery
- Then E_S (Energy supplied) is related to expected generation as: $E_S \approx E_{PV} \approx$ Energy supplied from the battery
- For the system voltage of 12 volts, the daily charge (Ah/day) required is obtained as: Ah/day = E_S / (12V) ≈ 20 Ah/day
- The total charge needed for S (2) reserve days = 40 Ah

…. Determining storage capacity (battery)

- But the battery MUST NOT be fully drained during use, a certain percentage must be left in the battery
- Then only 80% is drained from the battery
- Therefore the required capacity of the battery, C = Ah / DoD = 40 Ah / 0.8 = 50 Ah

…. Determining size of the BCU

- BCU are rated either in current input from the panel or current output to the loads
- The current output to the loads is calculated using the total load power (33 W)
- To cater for losses in the system we use a multiplying factor e.g. of 1.2
- $I_L \approx (1.2 \times 33\ W)/12\ V = 3.3\ A$ (select from standard or available BCU mainly that BCU with a close higher rating)

Calculation of Daily Demand (example of an ac system)

Load	No. of load	Rating of @ load [W]	Total power, P [W]	Expected daily Usage [hrs/day]	Expected energy usage [Wh/day]
Lamps	2	8	16	1	16
Lamps	2	8	16	4	64
Lamps	2	8	16	10	160
Radio	1	15	15	6	90
TV	1	32	32	2	64
		$\sum P =$	95	$\sum E =$	394

Determining PV Generator and other Components

- The procedure is almost similar to the one given for the DC system, except:
- AC loads are considered and efficiency of inverter must be included in the sizing calculation
- Good quality, high efficient inverters can be considered with efficiency in the range ($0.9 < \eta_{INV} < 0.98$)
- Note that the output of inverters is 240 V, 50 Hz AC, but other system components operate under DC conditions

Exercise

- A rural dwelling is located at site which receives insolation of about 5 peak-hours in day. The dweller wants electricity whereby the only option is to use a stand alone solar PV system. You are required to size a PV system to power the following electrical loads: 2 x 11 W lights for 2 hours a day, 2 x 15 W lights for 5 hour a day and 60 W TV set to operate for 3 hours every evening. (Assume: 3 days of energy storage are needed for lack of enough sunshine, battery efficiency is 85% and should only be discharged to 70% of its capacity). Use a step by step sizing procedure and state all the assumptions