COMPONENT BASED SOLAR HOME SYSTEM – MAXIMUM ARRAY SIZE 1kWp - SYSTEM DESIGN GUIDELINES

1 Introduction

This guideline provides an overview of the formulas and processes undertaken when designing (or sizing) a stand-alone Solar Home System. It provides information for designing a Solar Home System using d.c. bus (with battery charging directly from the panels) configuration. The content includes the minimum information required when designing a Solar Home System. The design of a Solar Home System shall meet the required energy demand and maximum power demands of the end-user. However, there are times when other constraints need to be considered as they will affect the final system configuration and selected equipment. These include:

- available budget;
- access to the site;
- the need to easily expand the system in the future; and
- availability of technical support for maintenance, troubleshooting and repair.

Whatever the final design criteria, a designer shall be capable of:

- Determining the expected power demand (loads) in kW (and kVA) and the end-user's energy needs in kWh/day;
- Determining the size of the PV array (in kWp) and the capacity of the battery bank (in Ah and Wh) needed to meet the end-users' requirements;
- Selecting the most appropriate PV array mounting system;
- Determining the appropriate d.c. voltage of the battery bank;
- Determining the rated capacity of the battery bank;
- Determining the size of the battery inverter in VA (or kVA) to meet the end-user's requirements;
- Ensuring the solar array size, battery and any inverters connected to the battery are well matched;
    - Determining the size of the solar controller with respect to the PV array For Pulse Width Modulated (PWM) solar controllers matching the array to the controller so that
        - ✓ The controller operating voltage is appropriate for the array voltage is appropriate to the battery voltage:
        - ✓ The array current does not exceed the maximum controller input current.
    - For MPPT solar controllers, matching the array configuration to fit the controller's:
        - ✓ maximum allowable input voltage
        - ✓ input voltage operating window;
        - ✓ maximum allowable d.c input power rating; and
        - ✓ maximum d.c. input current rating.

A Solar Home Systems with a maximum solar array of 1 kWp shall have a maximum open circuit voltage of less than 50 V d.c.

2 Typical Off-Grid PV Power System Configuration.

Figure 1 shows the configuration of a system that provides d.c. power only. These systems are typically installed on rural housing and small businesses where the d.c. power directly feeds lights and small d.c. appliances. Figure 2 shows a solar home system that can also power small a.c. appliances that are powered by an inverter operating off the d.c. power. These installations typically range between 100 Wp to 1000 Wp smaller or larger installations. The d.c. voltage provided to loads is usually 12 V, 24 V or 48 V. These types of systems are covered in this guideline.

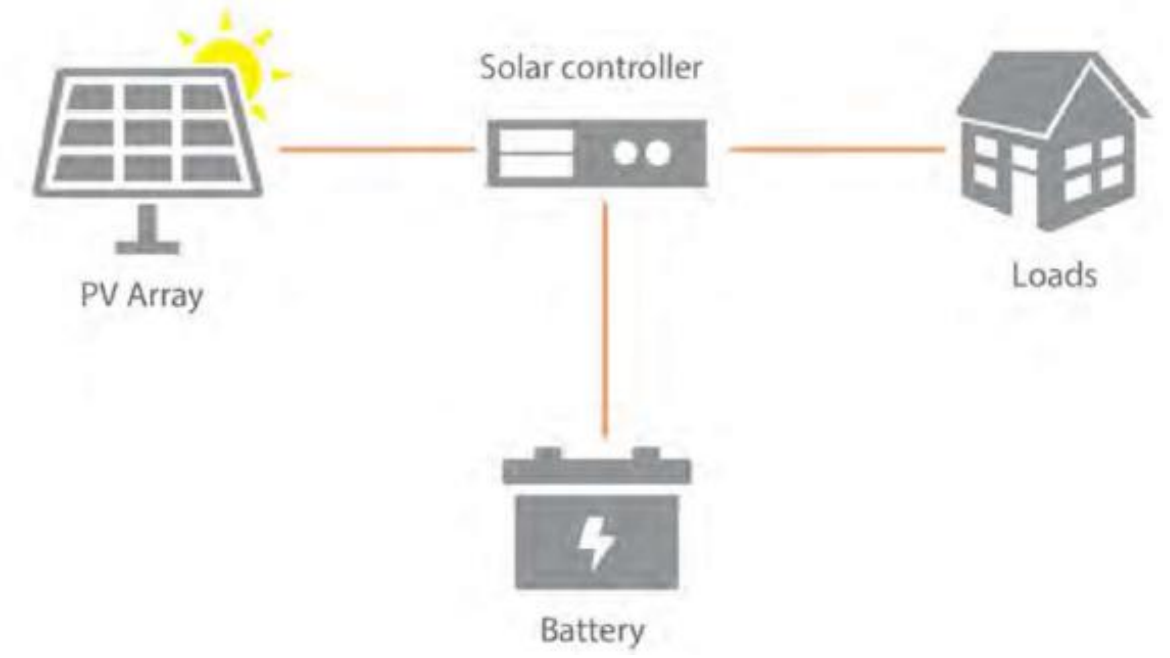


Figure 1: System powering d.c. loads (this is also a simple d.c. bus system)

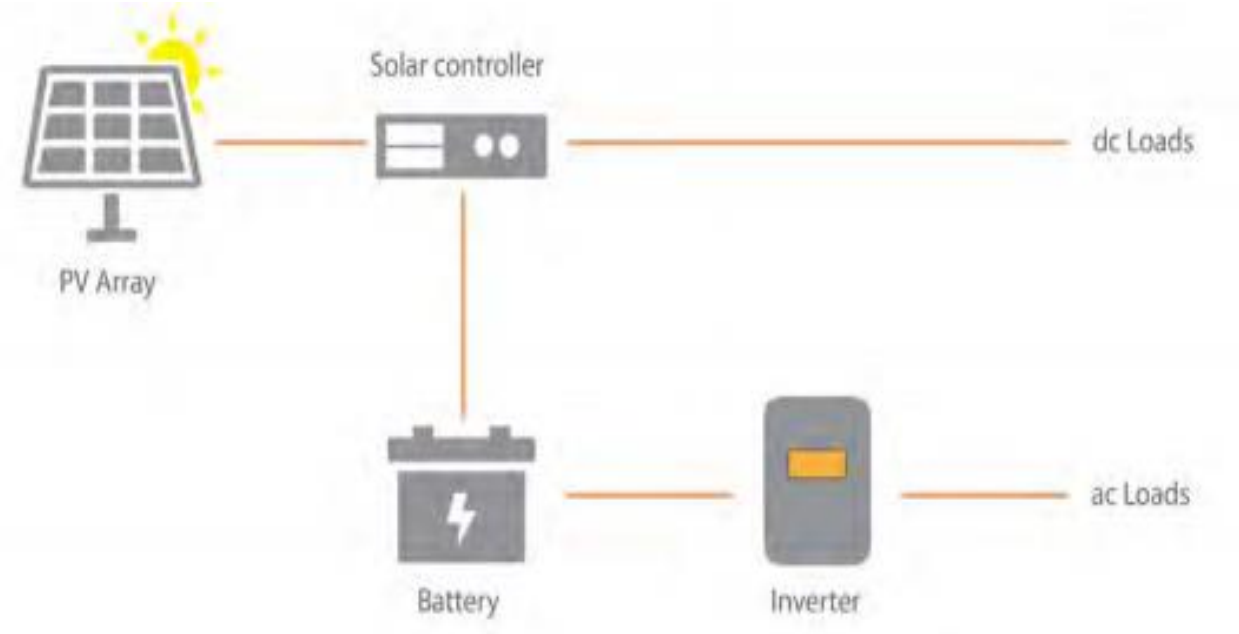


Figure 2: d.c bus system (system providing a.c. and d.c. loads)

3 Steps in designing a Solar Home System

Four major issues arise when designing a Solar Home System:

1) the load (power and energy) required to be supplied by the system is not constant over the period of one day;

2) the daily usage varies greatly over a week;
3) the daily energy usage varies over the year;
4) the energy available from the PV array will vary greatly during the day according to the time of day and cloud passages;
5) the energy available from the PV array will vary during the year as weather conditions vary over the year and as the sun changes its position in the sky over the year.

Since the system is based on photovoltaic modules, the designer shall compare the available energy from the sun over a typical year. If the energy usage varies throughout the year, then the energy usage for each month shall be compared with the irradiation for the respective month to determine the design month (refer section 11) for sizing the array frame. If the energy demand is relatively constant thorough out the year, the design month will be the month with the lowest monthly average daily irradiation.

The steps in designing a system shall include:

1. Carrying out a site visit and determining the limitations for installing a system and examining the location where the equipment will be installed (see section 4).
2. Determining the energy needs of the end-user (see section 6).
3. Determining the voltage and capacity of the battery bank (see sections 7 & 8).
4. Determining the size of any inverter connected to systems supplying d.c. power (Section 10).
5. Determining the size of the array (sections 13,13.1 and 13.2).
6. Determining the size of the solar controller (Section 14 for PWM/MPPT controllers).
7. Prepare bill of quantity (Section 17).
8. Providing a quotation to the end-user. (Section 18).

4 Site visit

If possible, a site visit shall be undertaken. The designer shall visit the site and undertake/determine/obtain the following:

1. Discuss the energy needs of the end-user. (Section 6).
2. Complete a load assessment form (See Section 6 for more detail).
3. Assess the occupational safety and health risks when working on that particular site.
4. Determine the solar access for the site or determine a position where the solar has the most available sunlight.
5. Determine whether any shading will occur and estimate its effect on the system.
6. Determine the orientation and tilt angle of the roof if the solar array is to be roof mounted. (See the guide for Installation of Solar Home Systems for further information)
7. Determine the available area for the solar array.
8. Determine whether the roof is suitable for mounting the array (if roof mounted).
9. Determine how the modules will be mounted on the roof (if roof mounted).
10. Determine where the batteries will be located.
11. Determine where the solar controller will be located.
12. Determine where the battery inverter will be located (if applicable).
13. Determine the cabling route and therefore estimate the lengths of the cable runs.
14. Determine whether system monitoring panels or screens are required and determine a suitable location with the end-user.

Following the site visit, the designer shall estimate the available solar irradiation for the array based on the available solar irradiation for the site and the tilt, orientation and effect of any shading. (See section 12.1, 12.2 and 12.3.) If the site is too remote, then all the above information might need to be obtained through discussions with the end-user and the final location of all equipment selected at the time of installation.

5 Energy Efficiency

Discuss energy efficient initiatives that could be implemented by the site owner. These could include:

I. replacing inefficient electrical appliances with new energy-efficient electrical appliances;
II. replacing incandescent light bulbs with efficient LED lights;

6 Load (Energy Assessment)

A system designer can only design a system to meet the power and energy needs as stated by the end user. The system designer must therefore use this process to clearly understand the needs of the end user and at the same time educate the end-user regarding the capacity of the system to be installed. Completing a load assessment form correctly does take time (refer to table 1 and 2 below); designer may need to spend 1 to 2 hours or more with the potential end-user completing the tables. It is during this process that designer will need to discuss all the potential sources of energy that can meet their energy needs and you can educate the end-user about energy efficiency.

Tables 1 and 2 are used throughout the guideline as a worked example. If the loads are d.c. then table 1 will be used. If the loads are a.c. then table 2 will be used. The tables show d.c. lighting loads and a.c. appliance loads.

Table 1: d.c. Load (energy) Assessment

Appliance	Number	Power	Daily usage		Contribution to max demand
			Usage time	Energy	
		W	h	Wh	VA
Lights	5	7	5	175	35
Fans	2	22	12	528	44
Daily load energy-d.c. loads (Wh)				1056	
Maximum d.c demand (VA)					79

Table 2: a.c. Load (energy) Assessment

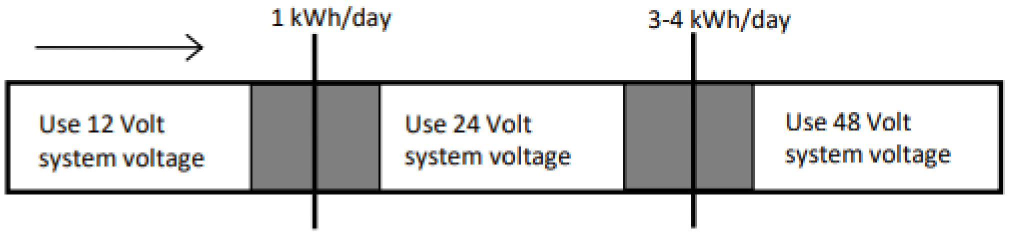
Appliance	No.	Power	Daily usage		Power factor	Contribution to max demand	Surge factor	Contribution to surge demand	
			Usage time	Energy				Potential	Design
		W	h	Wh		VA		VA	VA
TV	1	25	4	100	0.8	31	1	31	31
Refrigerator	1	100	14	1400	0.8	125	4	500	500
				1500					
Maximum a.c demand (VA)						154			
Surge demand (VA)								531	

Tables 1 and 2 show the daily energy usage for each appliance. The daily energy usage of each appliance are added together to provide the daily load energy for the d.c. loads and daily load energy for the a.c. loads.

Worked Example 2
(Based on the load table1 and 2) This example shows how to determine the energy at the battery bank for both the humid season and the rest of the year. Assume the overall efficiency of the chosen inverter is 90%. Daily battery load (energy use) from d.c. loads = 1056 Wh Daily battery load (energy use) from a.c. loads = 1500 Wh ÷ 0.90 = 1667 Wh To estimate the total load (energy) as seen by the battery, you add the two figures together: 1667 + 1056= 2723 Wh

7 Selecting Battery Voltage

As a general rule, the recommended system voltage increases as the total daily energy usage increases. For small daily loads, a 12 V system voltage can be used. For intermediate daily loads, 24 V is used and for larger loads 48 V is used.



8 Determining the Required Capacity of the Battery Bank

Worked Example 3
From example 1: the energy usage is 2723 Wh/day, so select a battery system voltage of 24 V. This means that the Ah/day usage on the battery bank will be: Ah/day = Wh/day ÷ system voltage = 2723 Wh/day ÷ 24 V = 114 Ah/day The minimum size battery to meet the daily energy requirements in the example is: 114 Ah (for lead-acid battery) or 2723 Wh (for a lithium-ion battery).

However, for long-life, lead-acid batteries shall not regularly be discharged more than 50% or 60%, with 20-30% being a common daily average discharge level for Solar Home System installations so the actual Ah of the battery installed will be at least double and often five times the calculated one day Ah requirement to account for a potential string of cloudy days.

In addition, battery capacity is determined by whichever is the greater of the following two requirements:

1. The ability of the battery to meet the energy usage of the system, typically for one to five days, sometimes specified as "days of autonomy" of the system;
   OR
2. The ability of the battery to supply maximum power demand in delivered watts (amperes delivered times volts at the battery terminals). (Refer to maximum demand values in Tables 1 and 2)
   How to determine the daily energy usage of the system was shown in example 3.

Worked Example 4.
The maximum d.c. demand in table 1 is 1056 W.

The maximum a.c. demand in table 2 is 154 VA. This is the demand out of the inverter so at the battery terminals the maximum demand would be 154/0.9= 171.1 VA.

The maximum current that will discharged from the batteries= (171.1 + 28)/24 = 8.3 A

Parameters relating to the energy requirements of the battery include:

1. Daily energy usage.
2. Daily average depth of discharge and maximum depth of discharge.
3. Number of days of autonomy.

Parameters relating to the discharge power (current) of the battery:

1. Maximum power demand (maximum demand discharge current).
2. Surge demand (surge demand discharge current).

Parameters relating to the charging of the battery:

1. Maximum charging current.

Based on these parameters there are a number of factors that will increase the required battery capacity in order to provide satisfactory performance. These factors must be considered when specifying the system battery.

9 Days of Autonomy

Extra capacity is necessary where the loads require power during periods of reduced solar input. The battery bank is often sized to provide for a number of days of autonomy (days of operation without solar charging or in case of no sunny days). A common period selected is between two to three days, but it depends on how critical the loads are. The minimum that shall be used is 2 days is preferred for remote sites because battery life may be significantly increased relative to a 1 1/2-day period of autonomy.

Worked Example 5

Assume 1 ½ days autonomy .

Adjusted battery capacity = 114 Ah x 1.5 = 171 Ah for lead-acid batteries.
and Adjusted battery capacity = 1.5 x 2723 Wh = 4085 Wh for lithium-ion batteries

Maximum Depth of Discharge Battery manufacturers recommend a maximum depth of discharge (DOD). If this is regularly exceeded the life of the battery is severely reduced. This could be 50% for some residential sized lead-acid batteries or as high as 80% for some large industrial quality solar batteries.

In lithium-ion batteries the term usable power is applied. This may be between 60% and 100% of the rated capacity.

Note: If the usable energy of a lithium-ion battery is specified at say 80%, it is recommended that the battery does not go more than 70%. This is because if some lithium-ion batteries reach their lowest value, they might "lock-up" and then become unusable. The cut-off point though is usually based on a specified minimum voltage.

Worked Example 6

Assume a maximum DOD of 60% for a lead-acid battery, and the usable capacity with a lithium-ion battery is 90% but 80% is applied.

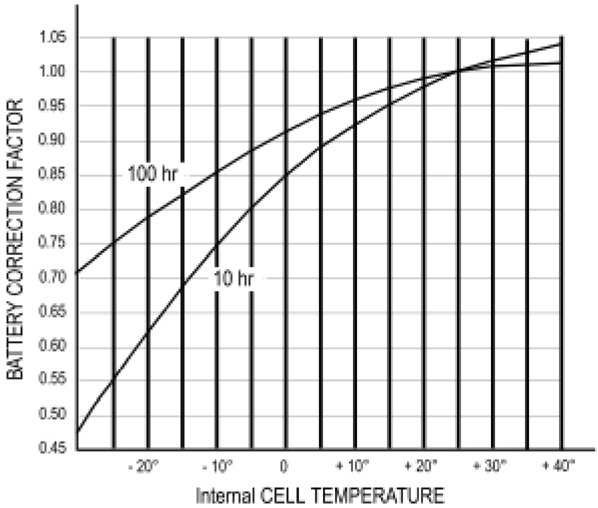
Adjusted battery capacity = 171 ÷ 0.6 = 285 Ah for the lead-acid battery

And

Adjusted battery capacity = 4085 ÷ 0.8 = 6808 Wh for the lithium-ion battery

Battery Temperature Derating

The capacity of lead-acid batteries is affected by temperature. As the temperature goes down, the battery capacity also goes down. Figure 4 gives a battery correction factor for low-temperature operation. Note that the temperature correction factor is 1 at 25°C, as this is the temperature at which battery capacity is specified in some standards, while the European standards now uses 20o C as the test temperature.



Battery Selection

For lead-acid batteries, a deep discharge type battery/cells must be selected and they must provide the required system voltage and capacity in a single series string of battery cells.

Parallel strings of batteries are not recommended. Where paralleling strings cannot be avoided, each string must be separately fused.

Worked Example 6 Allow 5% to the capacity to allow for effect of temperature. Adjusted battery capacity = 185 x 1.05 = 195 Ah for the lead-acid battery and Adjusted battery capacity = 3336 x 1.05 = 3502 Wh for the lithium-ion battery.

For the worked example a battery of at least 24 V and 195 Ah (at C20) or 3502 Wh is recommended

10 Selecting an Inverter

When selecting an inverter to power an a.c. appliance that is to be connected to a Solar Home System, the inverter must have an input d.c. voltage rating that is the same as the voltage of the d.c. power provided by the battery.

The type of inverter selected for the installation depends on factors such as availability, cost, surge requirements and power quality requirements. Selection of Sine wave inverters is recommended because they are increasingly affordable and often provide even better quality power than the urban grid supply.

BATTERY INVERTER SIZING

For systems where there are only a few a.c. appliances (e.g. as shown in table 2) the selected battery inverter shall be capable of supplying continuous power to all loads that are connected to it and must have sufficient surge capacity to start all loads that may surge when turned on, shall they all be switched on at the same time. Electric motors are particularly likely to have a large surge capacity requirement. For households with many a.c. loads where some loads, e.g. microwave, are only operating occasionally it is not practical to select an inverter based on the total power rating of all the loads. The inverter shall be selected based on determining what loads would typically be operating at the same time. Attention might need to be given to load control and prioritisation strategies. For example, if the inverter has surge capacity sufficient for only one motor but there are several motors that it powers, the motor switching design shall make it impossible for two or more of the connected motors to be switched on at the same time.

Worked Example 7
From the load (energy) assessment on page 8, the selected inverter must be capable of supplying 154 VA continuously with a surge capability of 531 VA for a short period of time-typically only a few seconds.

11 Solar Irradiation

Solar irradiation is typically provided as kWh/m2, however, it can be stated as daily peak sun-hours (PSH). This is the equivalent number of hours to equal the kWh/m2 listed if the solar irradiance always equals 1 kW/m2.

One important source for solar irradiation data that is available at no cost is the following site established through funding from the World Bank:

https://datacatalog.worldbank.org/dataset/pakistan-solar-radiation-measurement-data

12 Oversize Factor

If the system does not include a fuel generator which can provide extra charging to the battery bank, if the system includes lead acid batteries, then the solar array shall be oversized to enable equalisation charging of the battery bank (lead-acid). Otherwise, the battery life will be shortened due to it having to remain in a partially charged condition for many days during cloudy periods. That leads to sulfation of the battery and the loss of some battery capacity unless an equalizing charge is carried out shortly after the sulfation occurs.

Therefore, when designing a solar system that includes lead acid batterie, the array shall be oversized by at least 30% to allow for rapid full charging of the battery and to provide equalizing charging when needed. An oversize factor of 30% shall also effectively cover the ageing of the solar module. This oversize factor of 30% is required for Solar Home Systems comprising of lead-acid batteries. An oversize factor of 10%, to effectively cover the aging of the solar module shall be included with systems that include lithium-ion batteries.

13 Sizing a solar array

The calculations for determining the size of the PV array are dependent on the type of controller used. The designer shall take in to account the following factors while selecting the PV array:

a) seasonal variation of solar irradiation
b) manufacturing tolerance of modules
c) dirt accumulation
d) temperature of array (the effective cell temperature)
e) inverter efficiency (if applicable)
f) battery efficiency
g) controller efficiency
h) cable losses
i) oversize factor to allow for effective charging and allowing for the
j) module efficiency decreasing over time(ageing)

The designer shall also take in to account the sub-system losses in the circuit from the output of the PV array to the load.
If the system is only providing d.c. loads, then the sub-system losses are:

- cable losses (due to voltage drop).
- solar controller losses; and
- battery losses.

If the system is only providing a.c. loads, then the sub-system losses are:

- cable losses (due to voltage drop).
- solar controller losses (d.c. bus system).
- battery losses; and
- battery inverter losses.

Notes:

- The design month's daily load energy shall be used for determining the size of the PV array. In order to determine the energy required from the PV array these sub-system losses need to be taken into account. That means that the output of the PV array must be greater than the daily

load it is supplying. The total required output is calculated by dividing the required daily load energy by all the sub-system losses in the system expressed as decimal fractions.
- When sizing the array, convention has been to be conservative and assume that all the loads are supplied by the battery bank so that the battery efficiency was taken into account for all loads when determining the size of the solar array required to meet the daily energy demand.
- Since the system does not include a fuel generator or any other alternate source which can provide extra charging to the battery bank therefore, when designing a solar system that includes lead acid batterie, the array shall be oversized by at least 30% to allow for rapid full charging of the battery and to provide equalizing charging when needed. An oversize factor of 30% shall also effectively cover the ageing of the solar module.
- This oversize factor of 30% is required for Solar Home Systems comprising of lead-acid batteries. An oversize factor of 10%, to effectively cover the aging of the solar module shall be included with systems that include lithium-ion batteries.

13.1 Sizing a PV Array—Switching Type PWM Solar Controller

When using a PWM solar controller, the calculations are all based on determining the required Ah from the array. The losses in the cable and the solar controller are only reflected as voltage drops, which therefore dictates the operation point on the IV curve of the solar array. That is, if the battery is at 12V then the PV array will be operating at 12V plus the voltage drop in the connecting cable plus any voltage drop across the controller. Since the maximum power point of a nominal 12V module will be at 17-18V and the maximum charge voltage of a lead acid battery is between 14.4V and 15V, then the typical voltage drop of around 1V that occurs between the array and the battery is not an issue for most of the time the battery is being charged.

The only losses that need to be taken into account are any battery inverter losses (when a.c. appliances are powered by an inverter connected to the system) so the battery losses are assumed to be the average coulombic efficiency (in terms of Ah in and Ah out) of a new battery. That is typically 90% (variations in battery voltage are not considered).

Worked Example 15
Figures used in this example are from table 1 and 2. Assume the site is near Islamabad and the lowest irradiation is 4.6 kWh/m^2 or 4.6 PSH.

Assume all the loads are supplied by the PV array charging the battery bank

Assume The efficiency of the chosen inverter is 90%.

(Note the actual inverter efficiency varies depending on the load connected. Many good quality inverters will have an efficiency equal to or greater than 90% for most of their operating power range)

Daily battery load (energy) due to a.c. loads = 1500Wh ÷ 0.9 = 1667 Wh

Daily battery load (energy) due to d.c. loads = 1056 Wh

To get the total load (energy) as provided by the battery, you add the two figures together:
1667 + 1056= 2723 Wh

The system voltage is 24 V.

The daily energy requirement expressed in Ah from the battery is 114 Ah (2723 Wh/24 V).

Allowing for the battery efficiency, the solar array then needs to produce:

114 Ah ÷ 0.9 = 126.66 Ah

The PSH in the design month is 4.6

Therefore, the required PV array derated output current is:
126.66 Ah ÷ 4.6 PSH = 27.5 A

The oversize factor then needs to be applied. A minimum of 30% is recommended for Uganda when using lead acid batteries and 10% when using lithium ion batteries.

Worked Example 16
Since the worked example has been based on lead acid batteries, the adjusted required PV array derated output current is:
27.5 A x 1.3 = 35.7 A

The designer shall also take in account that PV array will be derated due to:

- Manufacturer's Tolerance
- Dirt
- Module Temperature greater than 25°C
- and potentially for ageing of the module that results in decrease in efficiency and hence power output; however, the oversizing takes this into account.

The designer, when using a switching type PWM solar controller, shall use solar modules that have a nominal voltage rating that is appropriate for the battery voltage.

13.2 Sizing a PV Array- MPPT Solar controller

When using a MPPT controller the calculations are in Wh and the d.c. sub-system losses in the system shall include:

- Battery losses (Watt-hour efficiency)
- Cable losses
- MPPT losses (controller efficiency); and
- Inverter losses (inverter efficiency)

In order to determine the energy required from the PV array, it is necessary to increase the energy from the battery bank to account for all the sub-system losses.

Worked Example 10

The energy supplied by the battery bank allowing for the inverter efficiency = 2723 Wh
Assume

- cable losses is assumed to be 3% (transmission efficiency of 97%),
- MPPT efficiency of 95% and
- battery efficiency of 80%
- All the load energy is provided by the battery.

d.c. Subsystem efficiency = 0.97 x 0.95 x 0.8 = 0.737

Energy required from the PV array = 2723 Wh ÷ 0.737 = 3694 Wh

The design month PSH is 4.6 therefore the required PV array derated output power is:
3694 Wh ÷ 4.6 PSH = 803 W

Allowing for an oversize factor of 30%, the adjusted required derated array output is:
803 W x 1.3 = 1044 W

The output of the solar module is affected by temperature, dirt, possibly manufacturer's tolerances and/or module mismatches and module ageing. This means that the power output of the solar module shall be derated when determining the energy output of the solar array.

Solar modules have a rated output measured at Standard Test conditions (STC). Based on the factors affecting the power output of the module (Pmod) as detailed above, the derated power output (Pderated) of the module is determined as follows:

Pderated= Pmod x ftemp x fdirt x fman

Ageing has been taken into account with the 20% oversize.

Worked Example 11

In the worked example
• Derating due to temperature ftemp= 0.883
• Derating due to dirt fdirt = 0.95
• Derating due manufacturers tolerance fman = 0.97

Module rating is 220Wp Derated module output = 220 x 0.883 x 0.95 x 0.97 = 179 W

The adjusted required derated array output = 1044 W

The required number of modules = 1044 ÷179 = 5.83 which must be rounded up to 6 modules

14 Selecting a solar controller- PWM/MPPT

Worked Example 12
If three modules in parallel are selected, the controller chosen must have a current rating > 1.25 x 5 x 6.18 A = 38.6 A at a system voltage of 24 V if the PWM controller is not current limited.

If it is current limited it needs to be rated at 5 x 6.18 A = 30.9 A at a system voltage of 24 V

Worked Example 13
The number of modules required was 3.82 so unless a different size module was chosen to select a MPPT which will be suitable for 4 modules.

The module rating is 220 Wp.
4 x 220Wp = 880 Wp

The MPPT controller shall also have an input current rating of 1.25 x short circuit of the array if the MPPT controller is not current limited.

14 Selection of d.c. cable for PV Array

Cables used within the PV array wiring shall:

- Be suitable for d.c. applications.
- Have a voltage rating equal to or greater than the PV array maximum voltage.
- Have a temperature rating appropriate for the application.
- It is recommended that string cables be sufficiently flexible to allow for thermal/wind movement of arrays/modules.
- Be UV resistant or housed in appropriate conduit.
- Have appropriate insulation and marking.

Correctly sized cables in an installation will produce the following outcomes:

  - No excessive voltage drops (which equates to an equivalent power loss) in the cables.
  - The current in the cables will not exceed the safe current handling capability of the selected cables [known as current carrying capacity (CCC)]

15 Voltage drop

- The voltage drop between the PV array – charge controller - the battery bank shall never exceed 5%.
- The voltage drop between the battery bank and any D.C. load shall never exceed 5%.
- The voltage drop between the PV array and MPPT shall never exceed 3%.

16 Tables Providing Route Lengths for twin cables for a specified voltage drop

Maximum Distance in metres to produce 5% voltage drop (12 V system)

Current (A)	Cable Size						
	1 mm²	1.5 mm²	2.5 mm²	4 mm²	6 mm²	10 mm²	16 mm²
1	16.4	24.6	41	65.6	98.4	163.9	262.3
2	8.2	12.3	20.5	32.8	49.2	82	131.1
3	5.5	8.2	13.7	21.9	32.8	54.6	87.4
4	4.1	6.1	10.2	16.4	24.6	41.0	65.6
5	3.3	4.9	8.2	13.1	19.7	32.8	52.5
6	2.7	4.1	6.8	10.9	16.4	27.3	43.7
7	2.3	3.5	5.9	9.4	14.1	23.4	37.5
8	2.0	3.1	5.1	8.2	12.3	20.5	32.8
9	1.8	2.7	4.6	7.3	10.9	18.2	29.1
10	1.6	2.5	4.1	6.6	9.8	16.4	26.2
11	1.5	2.2	3.7	6.0	8.9	14.9	23.8
12	1.4	2.0	3.4	5.5	8.2	13.7	21.9
13	--	1.9	3.2	5.0	7.6	12.6	20.2
14	--	1.8	2.9	4.7	7.0	11.7	18.7
15	--	1.6	2.7	4.4	6.6	10.9	17.5
16	--	1.5	2.6	4.1	6.1	10.2	16.4
17	--	--	2.4	3.9	5.8	9.6	15.4
18	--	--	2.3	3.6	5.5	9.1	14.6
19	--	--	2.2	3.5	5.2	8.6	13.8

Maximum Cable Lengths in Metres for 12 V System 3% Voltage Drop

Current (A)	1 mm²	1.5 mm²	2.5 mm²	4 mm²	6 mm²	10 mm²	16 mm²
1	9.8	14.8	24.6	39.3	59.0	98.4	157.4
2	4.9	7.4	12.3	19.7	29.5	49.2	78.7
3	3.3	4.9	8.2	13.1	19.7	32.8	52.5
4	2.5	3.7	6.1	9.8	14.8	24.6	39.3
5	2.0	3.0	4.9	7.9	11.8	19.7	31.5
6	1.6	2.5	4.1	6.6	9.8	16.4	26.2
7	1.4	2.1	3.5	5.6	8.4	14.1	22.5
8	1.2	1.8	3.1	4.9	7.4	12.3	19.7
9	1.1	1.6	2.7	4.4	6.6	10.9	17.5
10	1.0	1.5	2.5	3.9	5.9	9.8	15.7
11	0.9	1.3	2.2	3.6	5.4	8.9	14.3
12	0.8	1.2	2.0	3.3	4.9	8.2	13.1
13		1.1	1.9	3.0	4.5	7.6	12.1
14		1.1	1.8	2.8	4.2	7.0	11.2
15		1.0	1.6	2.6	3.9	6.6	10.5
16		0.9	1.5	2.5	3.7	6.1	9.8
17			1.4	2.3	3.5	5.8	9.3
18			1.4	2.2	3.3	5.5	8.7
19			1.3	2.1	3.1	5.2	8.3
20			1.2	2.0	3.0	4.9	7.9

17 Prepare Bill of Materials

The basic design parameters shall be shared with PMIC & Implementation Consultant for verification and approval and then a bill of materials or bill of quantity shall be prepared to estimate the system cost and share with the MFI.

An example of a bill of materials for a typical Solar Home System is presented in the below table.

S/No.	Description	Specification	Quantity
1	Poly-crystalline solar PV module		
2	Storage battery		
3	Battery inverter		
4	MPPT		
5	Mounting structure for roof		
6	Battery rack		
7	Single core d.c. cable		
8	Two core a.c. cable		
9	Battery fuses		
10	d.c. switch to disconnect PV modules		
11	d.c. switch to disconnect battery		
12	a.c. switch to disconnect a.c. loads		
13	d.c. combiner box		

18 Providing a quotation

When providing a quotation to MFI, the designer shall provide (as a minimum) the following information.

- Full specifications of the system proposed including quantity, make (manufacturer) and model number of the solar modules, full specifications of any inverter(s) and drawings and specifications of the array mounting structure where applicable.
- A copy of the load assessment sheet showing the details of how the load was calculated.
- The expected performance of the system and how it will meet the power and energy requirements specified in the load assessment sheet.
- A firm quotation, which shows the installed cost of the complete system.
- Warranty information relating to each of the items of equipment and the overall system performance.
- A complete listing of the regular maintenance requirements for the installation.