بسم الله الرحمن الرحيم

Benha University

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Renewable Energy Systems

By

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Lecture (9)

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Solar Energy

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How to Design Solar PV System?

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Solar PV system sizing

1. **Determine power consumption demands**

The first step in designing a solar PV system is to find out the total power and energy consumption of all loads that need to be supplied by the solar PV system as follows:

a) Calculate total Watt-hours per day for each appliance used.

b) Calculate total Watt-hours per day needed from the PV modules.

2. **Size the PV modules**

To determine the sizing of PV modules, calculate as follows:

a) Calculate the total Watt-peak rating needed for PV modules.

b) Calculate the number of PV panels for the system

3. Inverter sizing

- An inverter is used in the system where AC power output is needed.
- The input rating of the inverter should never be lower than the total watt of appliances.
- The inverter must have the same nominal voltage as your battery.
- For stand-alone systems, the inverter must be large enough to handle the total amount of Watts you will be using at one time.
- 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.

4. Battery sizing

- The battery type recommended for using in solar PV system is deep cycle battery.
- Deep cycle battery is specifically designed to be discharged to low energy level and rapid recharged or cycle charged and discharged day after day for years.
- The battery should be large enough to store sufficient energy to operate the appliances at night and cloudy days.

$$\text{Battery Capacity (Ah)} = \frac{\text{Total Watt-hours per day used by appliances} \times \text{Days of autonomy}}{(0.85 \times 0.6 \times \text{nominal battery voltage})}$$

5. Solar charge controller sizing

- The solar charge controller is typically rated against Amperage and Voltage capacities.
- Select the solar charge controller to match the voltage of PV array and batteries and then identify which type of solar charge controller is right for your application.
- Make sure that solar charge controller has enough capacity to handle the current from PV array.

Example

A house has the following electrical appliance usage:

1. One 18 Watt fluorescent lamp with electronic ballast used 4 hours per day.
2. One 60 Watt fan used for 2 hours per day.
3. One 75 Watt refrigerator that runs 24 hours per day with compressor run 12 hours and off 12 hours.
4. The system will be powered by 12 V_{dc}, 110 W_p PV module.

Answering

1. **Determine power consumption demands**

Total appliance use = (18 W x 4 hours) + (60 W x 2 hours) + (75 W x 24 x 0.5 hours)
= 1,092 Wh/day

Total PV panels energy needed = 1,092 x 1.3
= 1,419.6 Wh/day.

2. **Size the PV panel**

2.1 Total Wp of PV panel capacity needed = 1,419.6 / 3.4
= 413.9 Wp

2.2 Number of PV panels needed = 413.9 / 110
= 3.76 modules

Actual requirement = 4 modules

3. **Inverter sizing**

Total Watt of all appliances = 18 + 60 + 75 = 153

For safety, the inverter should be considered 25-30% bigger size.

The inverter size should be about 190 W or greater.

4. **Battery Sizing**

Total appliances use = (18 W x 4 hours) + (60 W x 2 hours) + (75 W x 12 hours)
Nominal battery voltage = 12 V
Days of autonomy = 3 days

$$\text{Battery capacity} = \frac{[(18\ W \times 4\ hours) + (60\ W \times 2\ hours) + (75\ W \times 12\ hours)]}{(0.85 \times 0.6 \times 12)} \times 3$$

Total Ampere-hours required 535.29 Ah

So the battery should be rated 12 V 600 Ah for 3 day autonomy.

5. **Solar charge controller sizing**

PV module specification

$P_m = 110\ W_p$

$V_m = 16.7\ V_{dc}$

$I_m = 6.6\ A$

$V_{oc} = 20.7\ A$

$I_{sc} = 7.5\ A$

Solar charge controller rating = (4 strings x 7.5 A) x 1.3 = 39 A

So the solar charge controller should be rated 40 A at 12 V or greater.

- **Note:**

Adjusting the generation factor for different climates.

- The amount of energy from the panels will be greater than our estimate if the climate is sunnier than a tropical coastal climate.
- The energy from the panels will be less than our estimate if the climate is cloudier than a tropical coastal climate.
- For the sunnier climate, use a Panel Generation Factor of **3.86**
- For the tropical coastal climate, use a Panel Generation Factor of **3.43**.

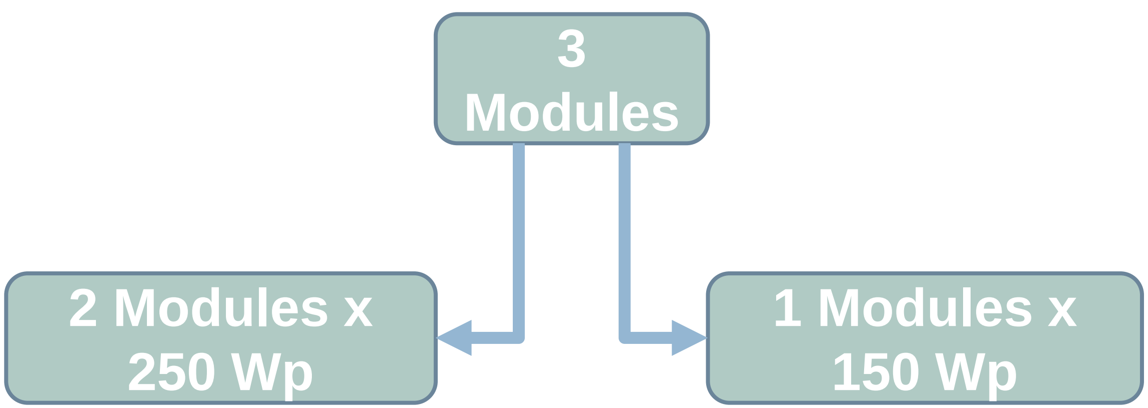
Example

- **Design PV system for Residential Load (Home)**

1. **Solar PV system sizing**

Appliances	Working Hours (Hrs/day)	No.	Power (W)	Total Wattage (W)	WH/day
Lamps	5	10	20	200	1000
T.V	5	1	150	150	750
Receiver	5	1	50	50	250
Fans	5	3	60	180	900
Refrigerator	12	1	75	75	900
Total				**655**	**3800**

- Total appliance use = 3800 Wh/day.
- Total Wp of PV panel capacity needed = (Total Wh/panel generation factor).
- panel generation factor for Egypt = 6 Hours in Summer and Winter.
- Total Wp of PV panel capacity needed = (3800/6) = 633.33 Watt.
- Select Wp of PV panel capacity = (12 V) 250 Wp & 150 Wp.
- Number of PV panels needed = 2 x 250 Wp & 1 x 150 Wp



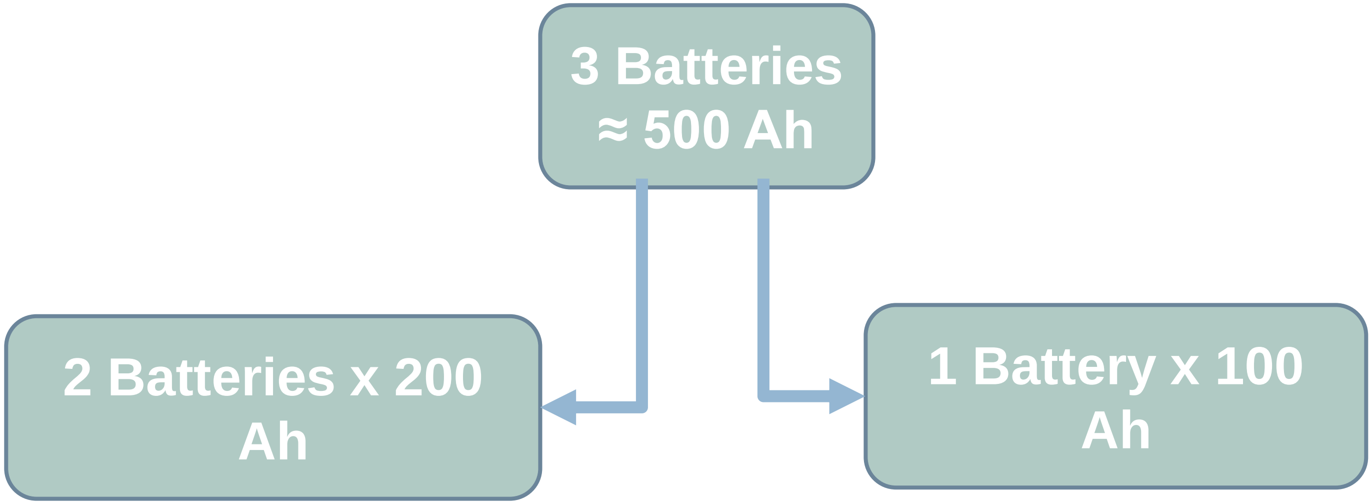
2. **Battery Sizing**

- Total appliances use = 3800 Wh/day
- Nominal battery voltage = 12 V

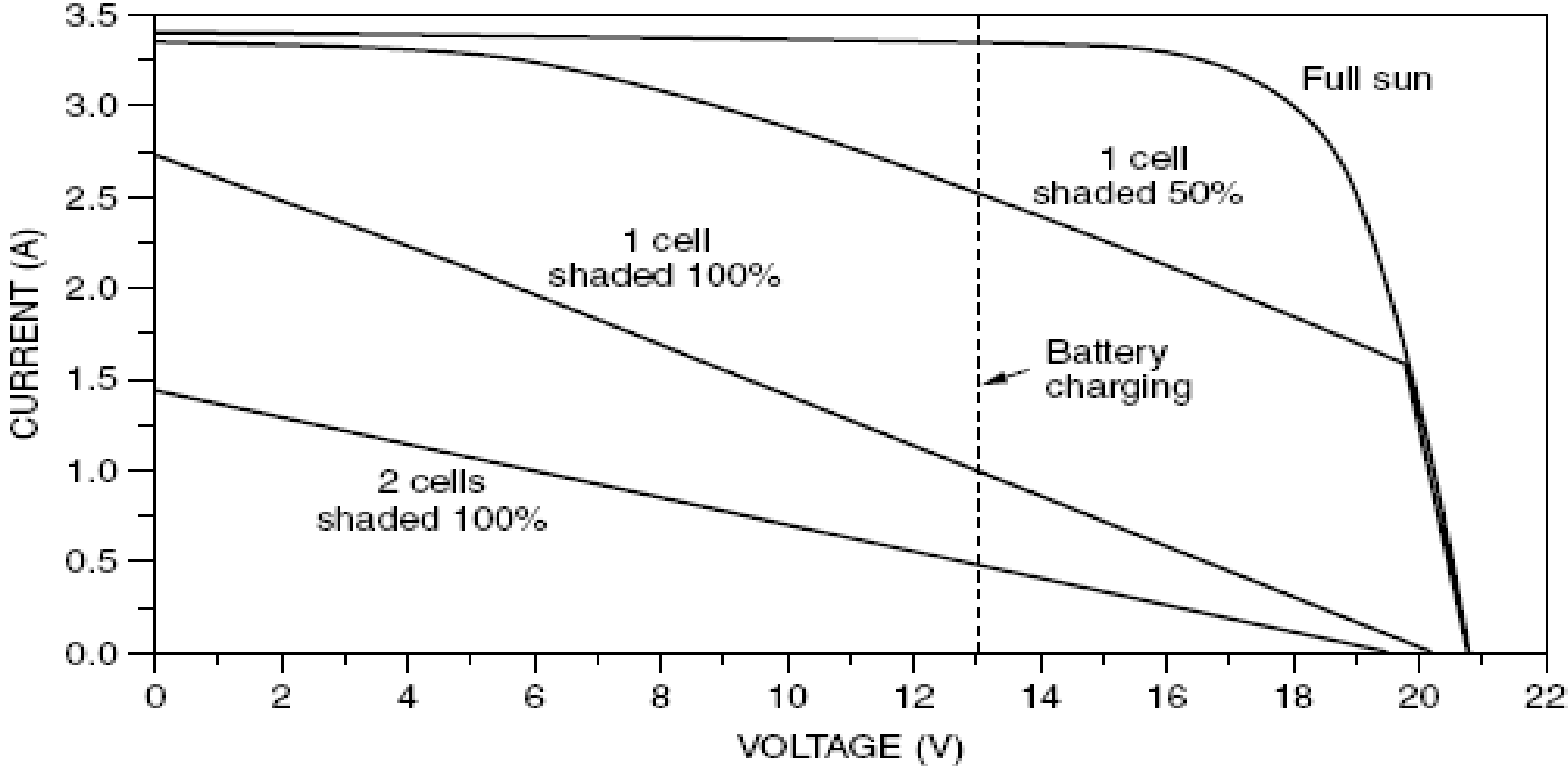
$$\text{Battery Capacity (Ah)} = \frac{\text{Total Watt-hours per day used by appliances x Days of autonomy}}{(0.85 \text{ x DOD x nominal battery voltage})}$$

$$\text{Battery capacity (Ah)} = \frac{3800 \text{ x } 1}{(0.85 \text{ x } 0.8 \text{ x } 12)}$$

- Where; **DoD** is the Depth of Discharge which is inversely proportional to life time of battery.
- Total Ampere-hours required 465.68 Ah



Example

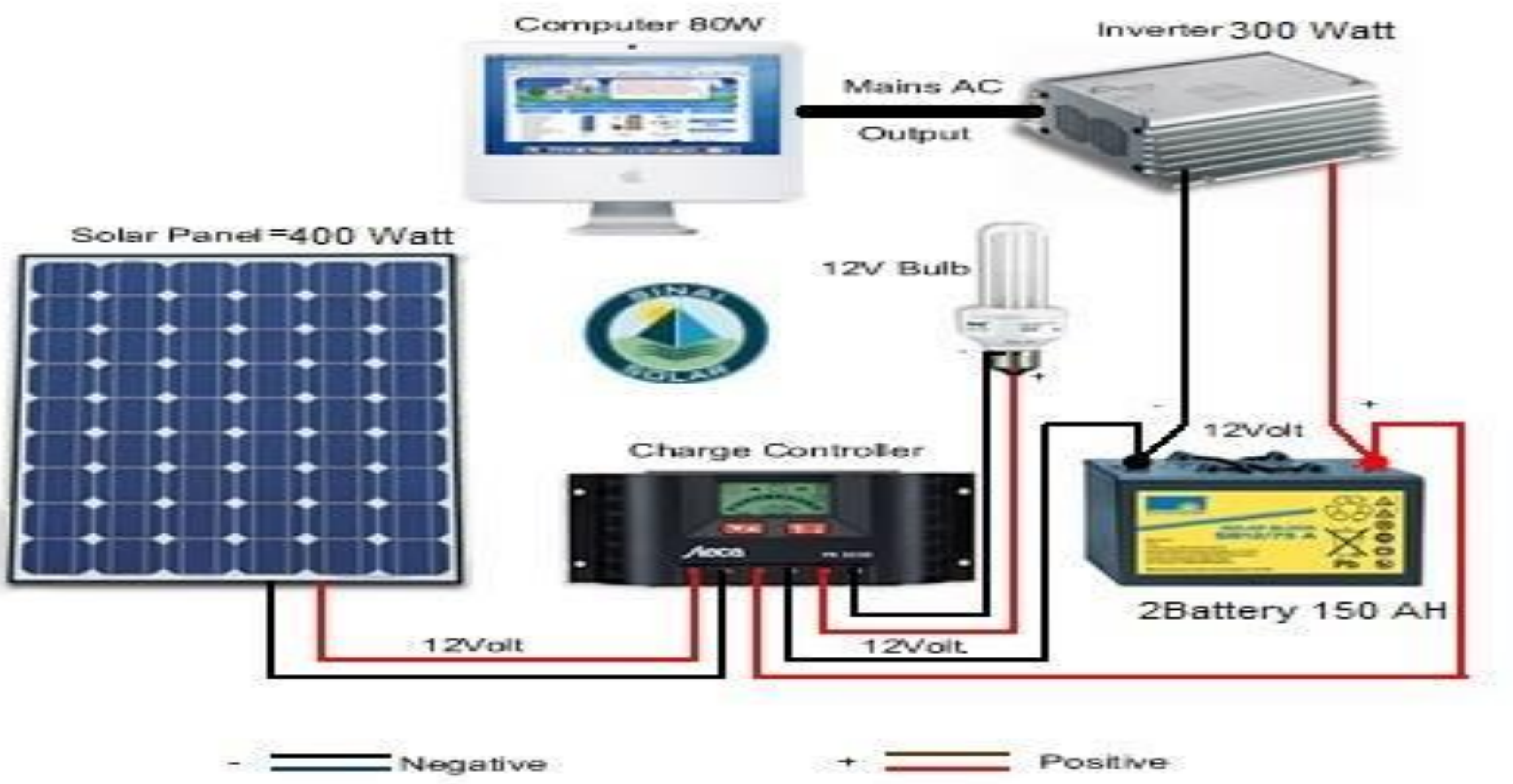


Effects of shading on the *I* –*V* curves for a PV module. The dashed line shows a typical voltage that the module would operate at when charging a 12-V battery; the impact on charging current is obviously severe.

3. **Inverter sizing**

- Total Watt of all appliances = 655 W.
- For safety, the inverter should be considered 20-30% bigger size.
- Inverter Size = 655 x 1.2 = 786 W.
- The inverter size should be about 800 W or greater

Connection



Computer 80W
Inverter 300 Watt
Mains AC
Output
Solar Panel =400 Watt
12V Bulb
Charge Controller
12Volt
2Battery 150 AH
12Volt
12Volt
- Negative
+ Positive