Tribhuvan University
Institute of Engineering
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Department of Electronics & Computer Engineering

Bachelor’s Degree in Electronics, Communication & Information Engineering
(IV Year II Part)

Chapter Four
Applications of RE Sources to power Electronic Equipments

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Chapter Outline

Chapter 4 Applications of RE Sources to power Electronic Equipments (8 hours)

- Simple Design of PV power system to power institutional electrical appliances in remote areas without access to National Grid
- Simple Design of PV power system to power telecommunication equipment such as BTS and Earth Station installed at remote areas without access to National Grid

Solar Energy

- ✓ Source of all forms of energy
- ✓ Renewable Source of Energy
- ✓ Nepal is very rich in Solar Energy. We have very high solar PV potential. We have an average sunshine days of 300 Days/Year

Two basic types:

- ✓ Solar Thermal:
- ✓ Solar Photovoltaic

Solar Energy contd…

First Generation Solar Water Heater

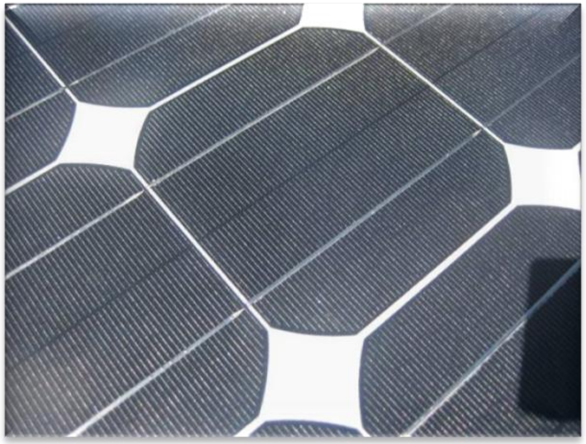
Second Generation Solar Water Heater

Solar Photovoltaic Panel

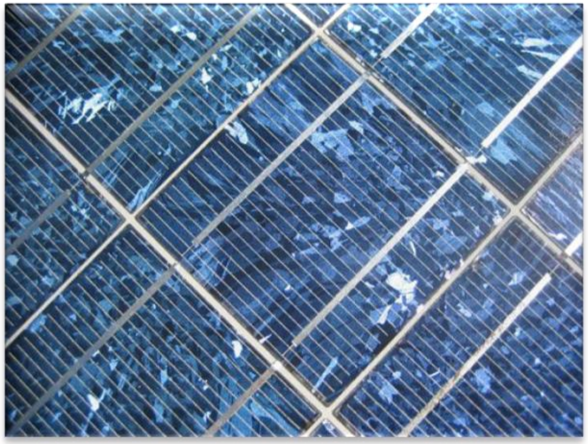
Photovoltaics Cells (or Solar Cells)

- ✓ Photovoltaic cells or solar cells are the semiconductor junction devices used for converting radiation energy into electrical energy. These cells generate a voltage proportional to electromagnetic radiation intensity and are called the photovoltaic cells because of their voltage generating capability (Gupta, 2013).
- ✓ 86% of PV modules are made of crystalline silicon solar cells
- ✓ Crystalline silicon solar cells produce about 0.5-0.6 volt independent of cell area at 25^{o}C
- ✓ The current output of a solar cell depends on the cell area and the level of incident solar irradiance
- ✓ Modern crystalline silicon solar cells are up to 15 cm by 15 cm and produce up to 4 watts and 8 amps under full sunlight

Photovoltaics Cells (or Solar Cells) Contd..



Monocrystalline silicon cell



Polycrystalline silicon cell

PV Module

Individual solar photovoltaic cells are quite small. Since each cell can produce a very small voltage (~0.6V), it is normal to wire many cells in series- one after another like beads on a string to form a module so that overall voltage of the panel is the sum of the voltage drops across all the individual cells.

PV Panel

The larger solar panels that we see as self-contained units are actually many individual PV modules wired together, either in series or in parallel. Because individual solar panels produce relatively little energy, any practical PV system consists of many panels. The PV panels are usually connected, often in series, and sometimes in parallel or in combination so as to provide required current and voltage.

PV Module Types

a-Si: Amorphous Silicon
CdTe: Cadmium Telluride
Poly-Si: Polycrystalline Silicon

Mono-Si: Monocrystalline Silicon
CIS: Copper Indium Selenide

Module Efficiency, Area, Cost & Degradation

Mono-Si

Poly-Si

CdTe

CIS

a-Si

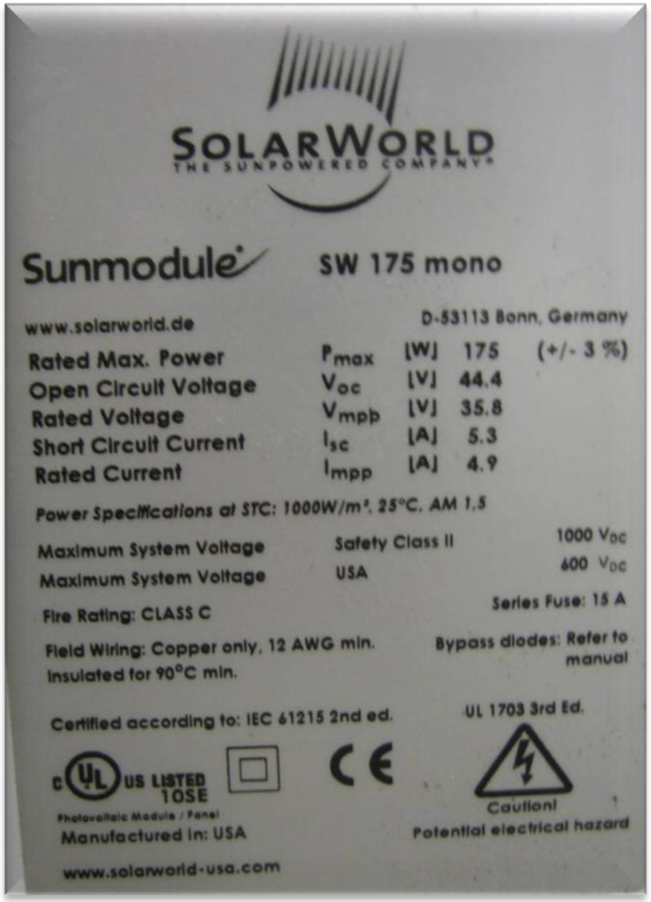
TYPICAL

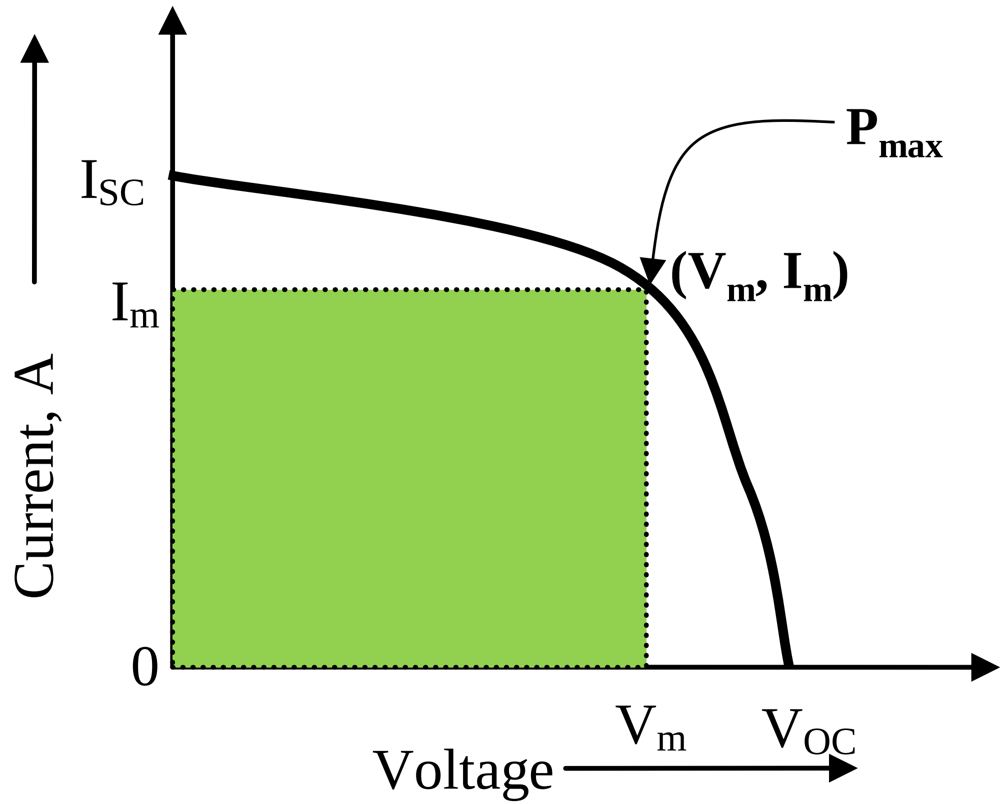
Efficiency	15-20%	13-15%	9-11%	9-11%	5-8%
Area per kW	Lowest				Highest
Cost per kW	Highest				Lowest
Annual Degrad	0.5-2.0%	0.5-2.0%	1.0-2.0%	1.0-2.0%	1.5-2.5%

Source: (USAID, 2016)

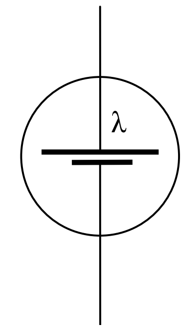
Marking

- All PV modules must be marked with the following information (if not, then they might not be from a reputable source):
    1. Open-circuit voltage (Voc)
    2. Short-circuit current (Isc)
    3. Operating voltage (Vmp)
    4. Operating current (Imp)
    5. Maximum power (Pmp)
  - Polarity of terminals
  - Maximum permissible system voltage

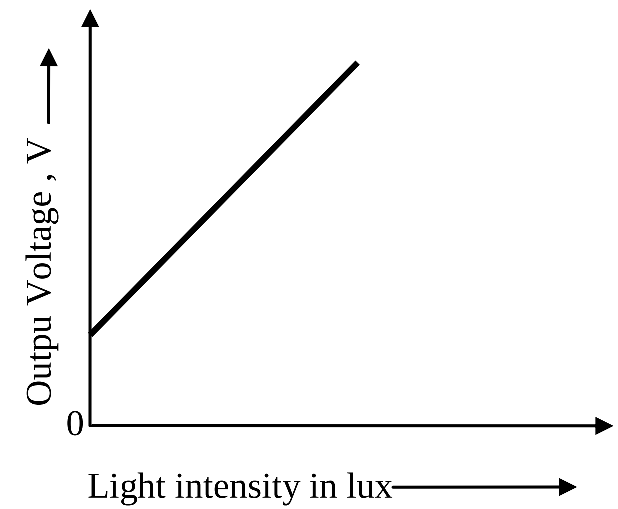




IV Characteristics of a Solar Cell



Symbol of a Solar PV Cell

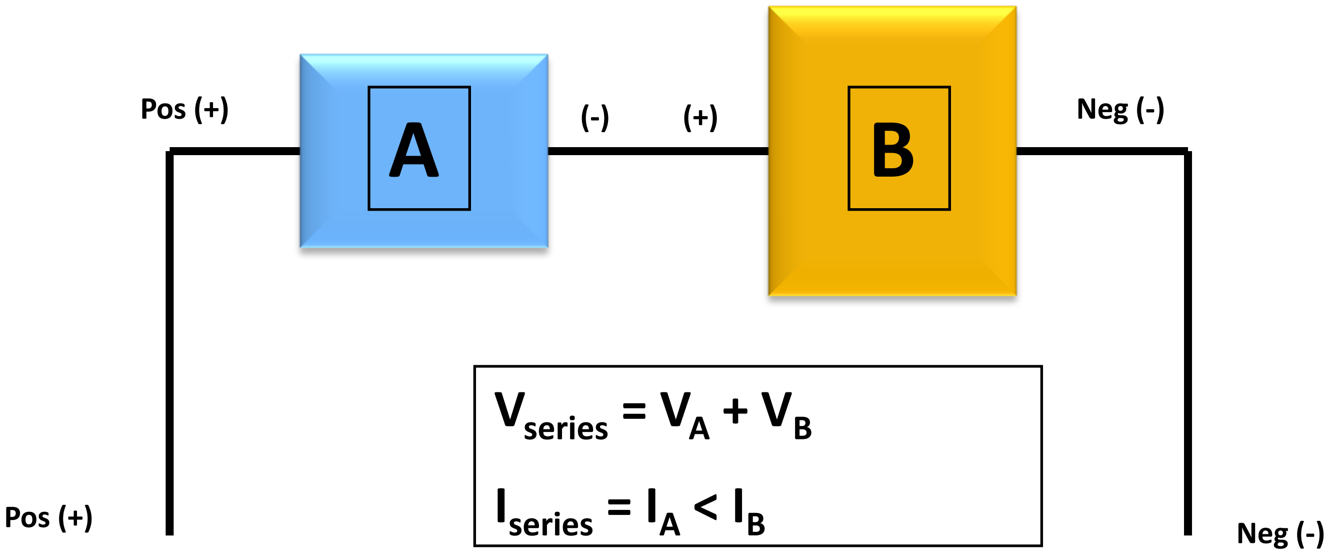


Output Voltage Characteristics of a Solar PV Cell

Fill Factor: $$\frac{V_m I_m}{V_{OC} I_{SC}}$$

Dissimilar Modules in Series

When dissimilar PV devices are connected in series, the voltages still add, but the current is limited by the lowest current output device in series



$$V_{series} = V_A + V_B$$

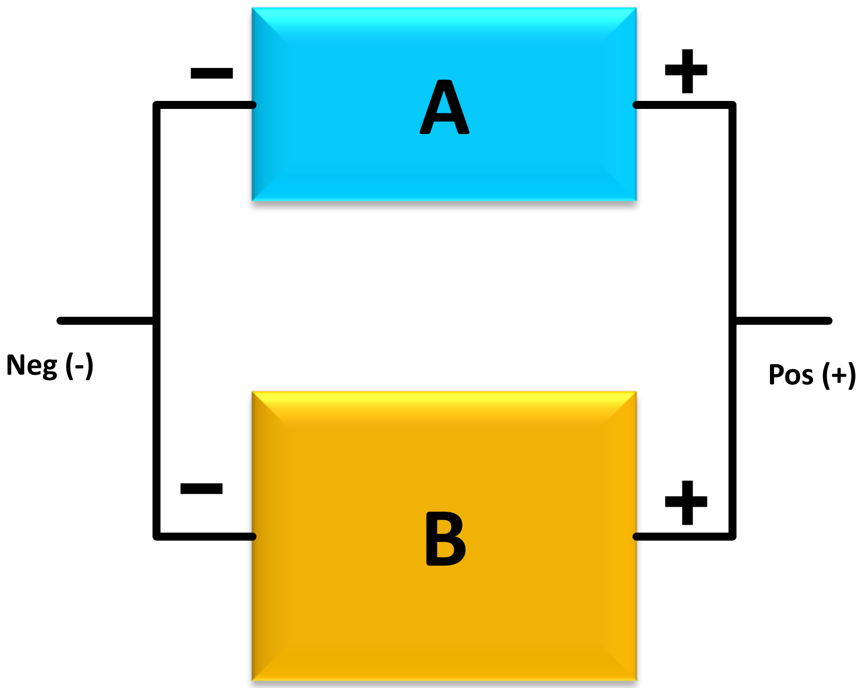
$$I_{series} = I_A < I_B$$

Dissimilar Modules in Parallel

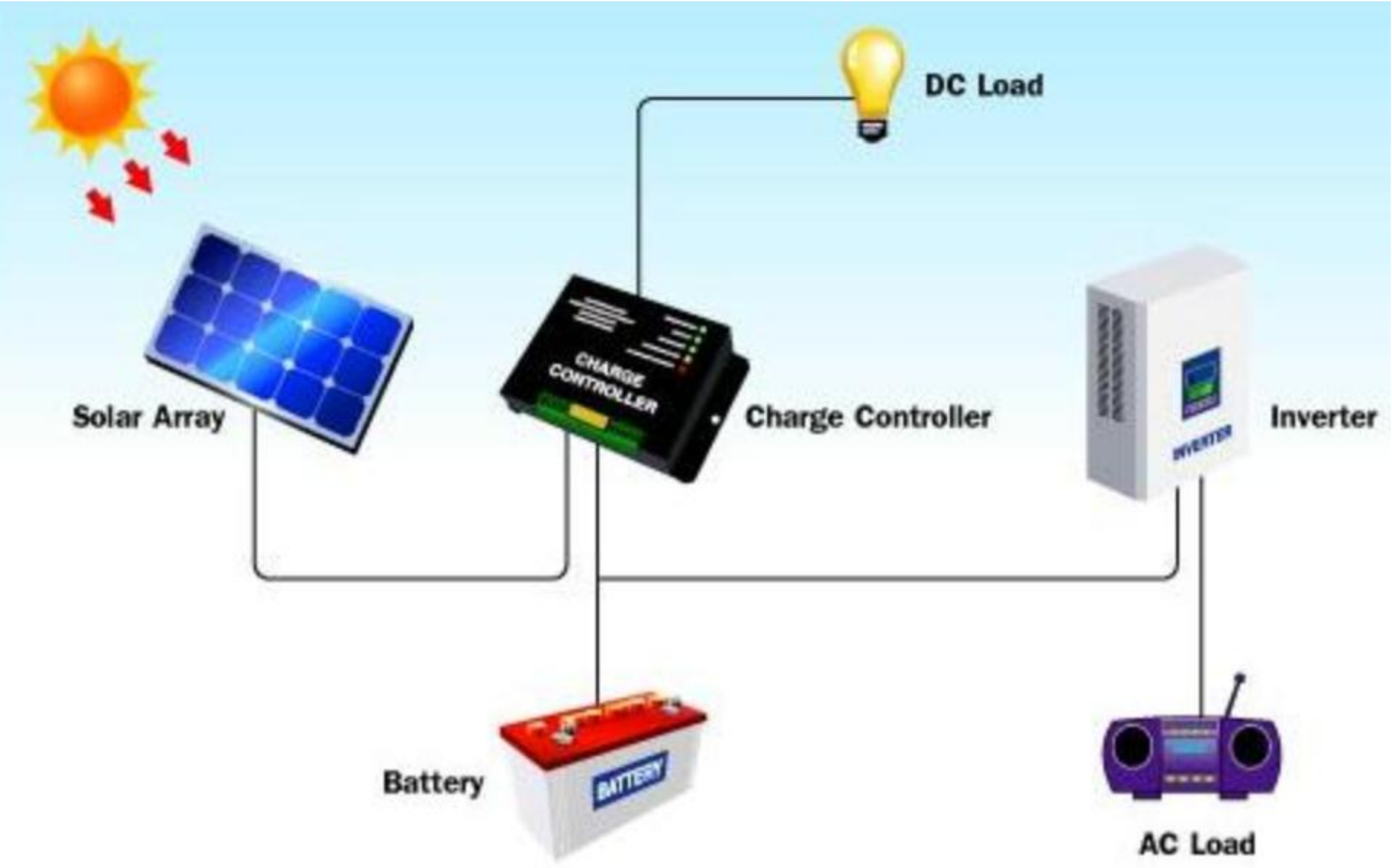
- When dissimilar devices are connected in parallel, the individual currents add, and the voltage is the average of devices

$V_{parallel} = (V_A + V_B) / 2$

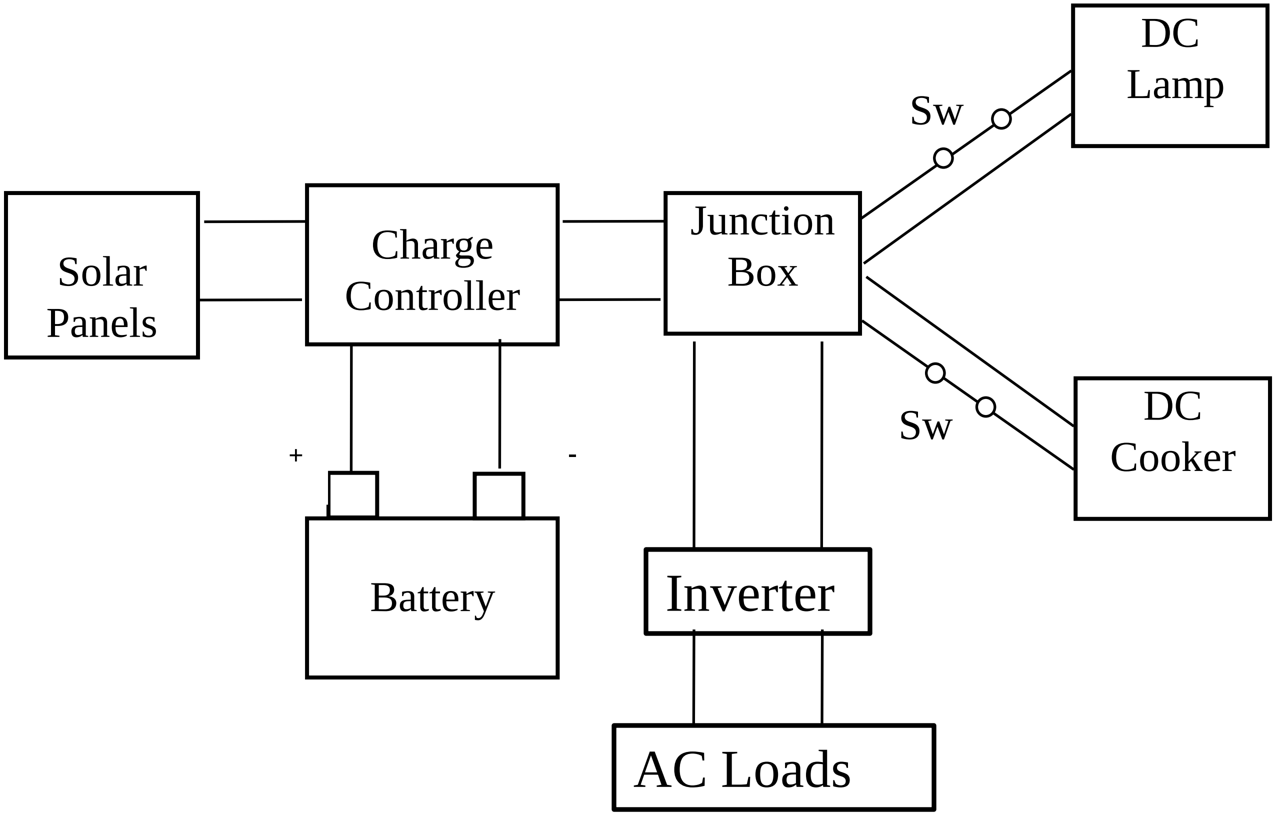
$I_{parallel} = I_A + I_B$



Solar Home System



Solar Home System



Solar Home System Design

Different Steps of Solar Home System Design

- ✓ Load Calculation in Wh or Ah
- ✓ Size of Battery
- ✓ Size of Solar PV Panel
- ✓ Wire Sizing
- ✓ Sizing of Charge Controller
- ✓ Sizing of Inverter in case of using AC loads
- ✓ Sizing of Switch

Solar Home System Design Contd…

1. Load Calculation:

The load (or the energy consumed) is generally expressed in Watt-hours (Wh). But for more accurate sizing of the array and battery, sometimes the load is expressed in Ampere hours(Ah). If Wh is known, Ah can be calculated as:

$$Ah = \frac{Wh}{SystemVoltage}$$

Load Calculation

AC Loads						
SN	Equipments	Power(W)	Quantity	Hours(h)	Days of use in Week	Wh/Day
1	TV	60	2	10	7	1200.00
2	Mercury Lamp	30	4	8	7	960.00
3	Induction Cooker	1000	1	1	4	571.43

Total Wh, W_1	2731	Wh/Day
DC Eq. Wh, W_2	$W_1/0.9$	
	3034.44	Wh/Day

DC Loads						
SN	Equipments	Power(W)	Quantity	Hours(h)	Days of use in Week	Wh/Day
1	LED	5	4	4	7	80
2	Router	2	1	20	6	34.29

W_3	114.28571	Wh/Day
E =	$W_2 + W_3$	
	3148.73	Wh/Day

Daily Ah = Daily Wh/System Voltage = 3149/12 = 262.4 Ah/Day

Sizing of Array/Module

$$I_{Array} = \frac{\text{Daily Ah}}{\text{Peak Sun} \times \text{Derating Factor} \times \text{Columbic Efficiency}}$$

$$= \frac{262.4}{4.5 \times 0.9 \times 0.95} = 68.09 \text{ A}$$

If $I_{mp} = 7$ A

Then $N_P = \dfrac{I_{Array}}{I_{mp}} = \dfrac{68.09}{7} = 9.72 \approx 10$

$$N_S = \frac{\text{System Voltage}}{\text{Nominal Module Voltage}} = \frac{12}{12} = 1$$

Total Number of Modules = $N_P \times N_S = 10 \times 1 = 10$

Battery Sizing

$$C_B = \frac{E \times N_A}{B_V \times DOD \times \eta_B}$$

Where,

C_B = Battery Capacity in Ah

E = Daily Wh requirement

N_A = Autonomy Days

DOD = Depth of Discharge

η_B = Battery Efficiency

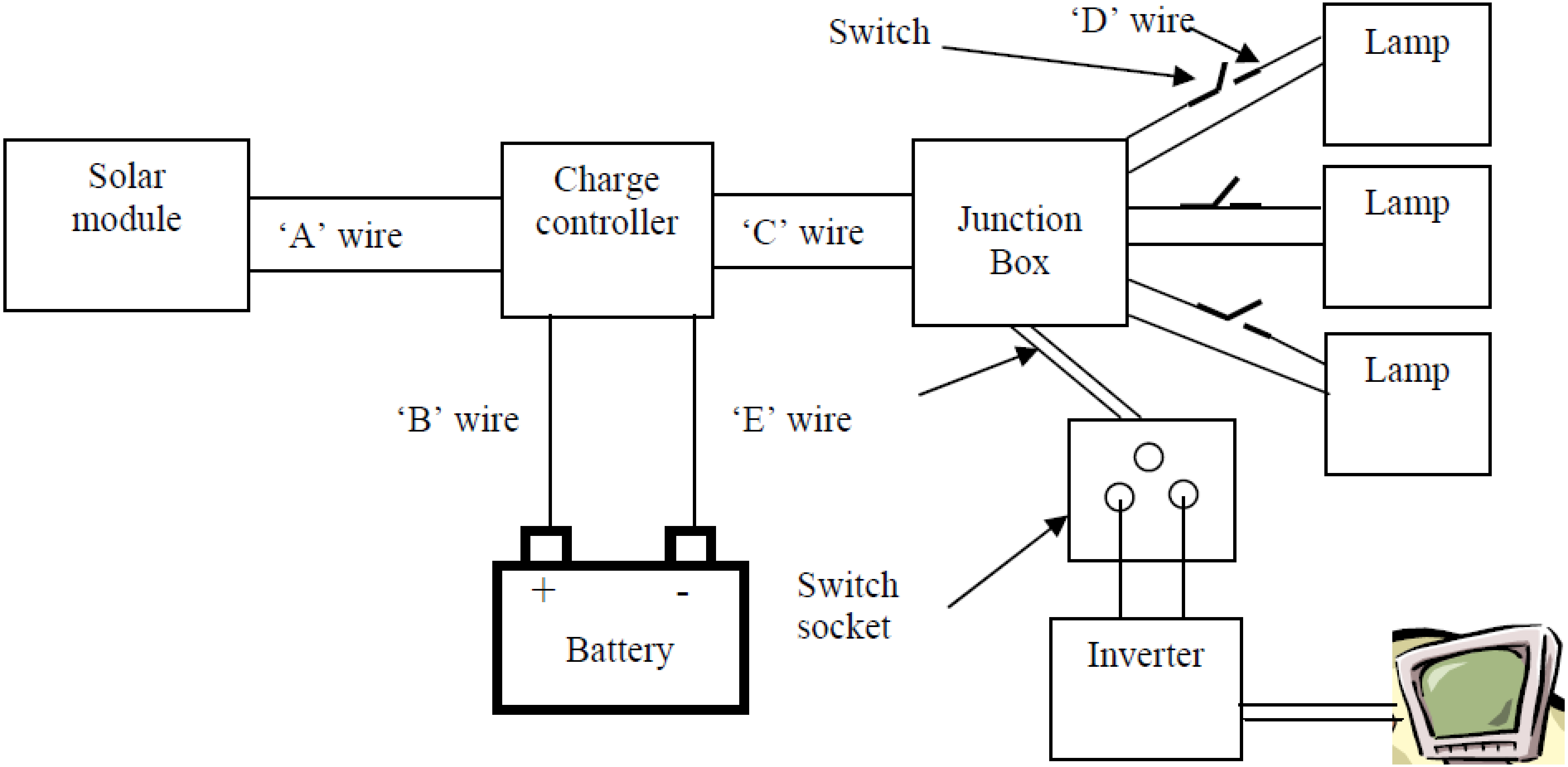
$$C_B = \frac{3149 \times 2}{12 \times 0.8 \times 0.8} = 820 \text{ Ah}$$

Sizing of Charge Controller

$$I_{Lmax} = \frac{P_T}{B_V} = \frac{1240/0.9W + 22W}{12V} = 116.65A$$

Generally Charge Controller having capacity of two times I_{Lmax} at the load side and two times I_{SC} at the panel side must be used

Wiring Diagram



Wire Sizing

$$S = \frac{0.3LI_m}{\Delta V}$$

Where

S = Required wire size (cross-sectional area of the copper wire in sq. mm)

L = Length of the wire in meters

I_m = The max. current in Ampere

ΔV = Max. Allowable voltage drop in percent

Wire Sizing Contd…

For Wire Connecting Loads and Charge Controller: $\Delta V = 5\%$

For Wire Connecting Panel (array) and Charge Controller: $\Delta V = 3\%$

For Wire Connecting Inverter and Charge Controller: $\Delta V = 3\%$

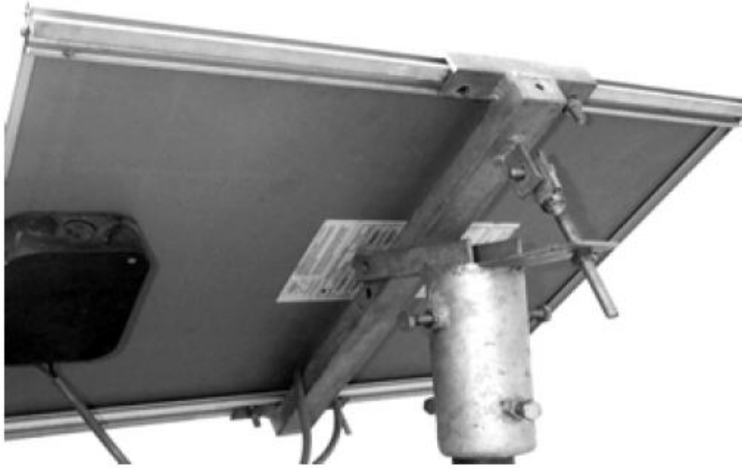
For Wire Connecting Battery and Charge Controller: $\Delta V = 1\%$

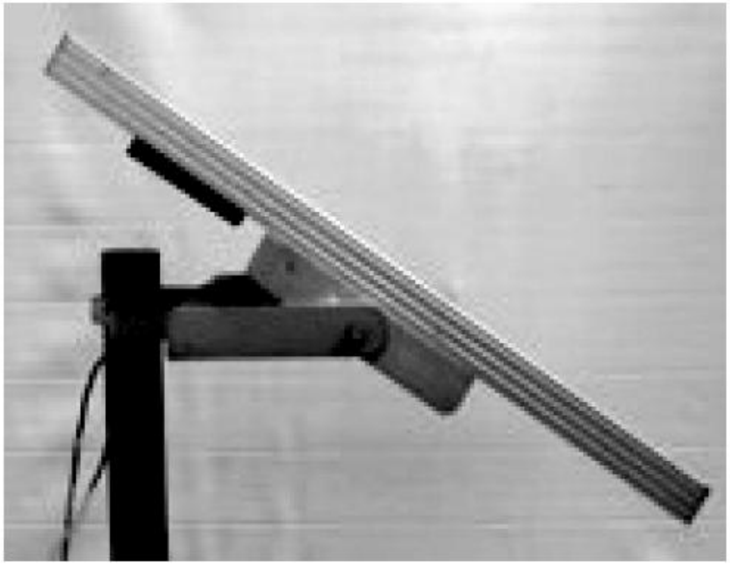
Inverter Sizing

$$P_{\text{Inverter}} = \frac{P_{\text{Load}}}{\text{Power Factor} \times \eta}$$

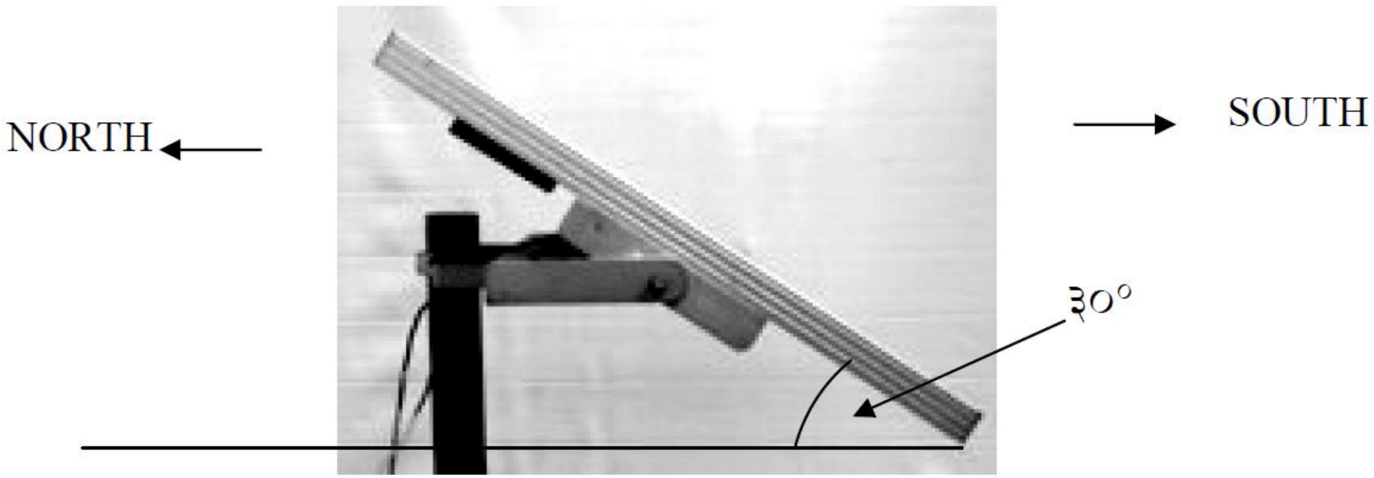
Measurement of Module Voltage

Solar Module with Support Structure





Tilting of Solar PV Module



Example:

Design a Solar PV system to supply a constant power for telecommunication equipment of 950 Watt for 24 hours a day. The operating voltage of equipment is 48V DC. Given peak sun hour is 4.5 hours and DOA 3 days. Assume other suitable data whenever is necessary. Also, draw the installation layout of the system.

Solution:

Total daily load in Wh = 950 W × 24h = 22800 Wh

Total daily load in Ah = Daily Wh/System Voltage = 22800 Wh/48 V = 475 Ah

Array Size:

$$I_{Array} = \frac{\text{Daily Ah}}{\text{Peak Sun} \times \text{Derating Factor} \times \text{Columbic Efficiency}}$$

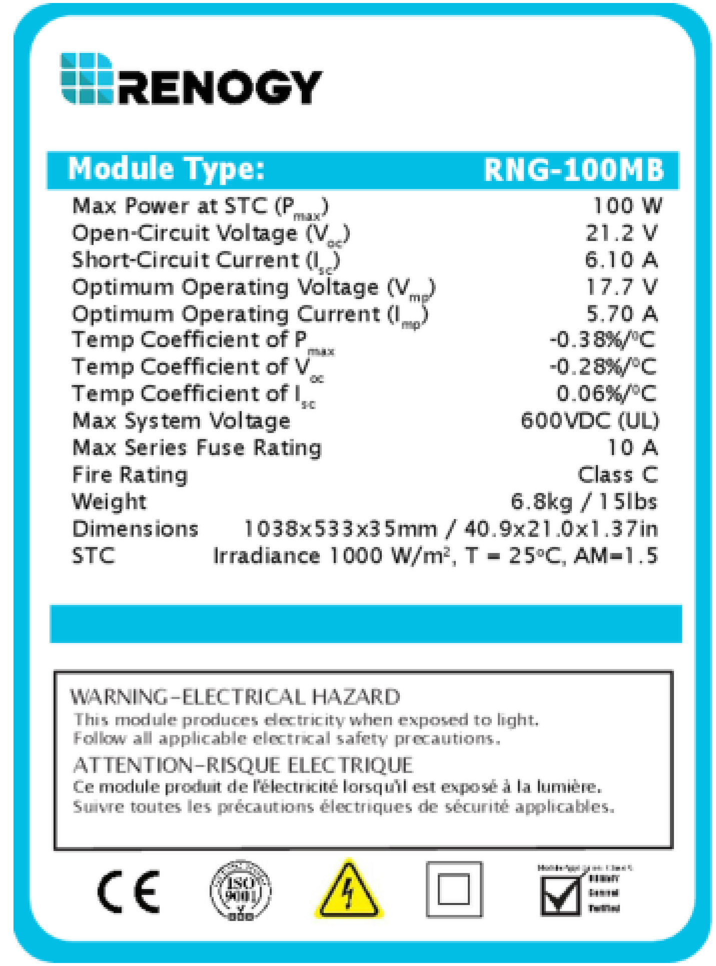
$$= \frac{475\,\text{Ah}}{4.5\text{h} \times 0.9 \times 0.95}$$

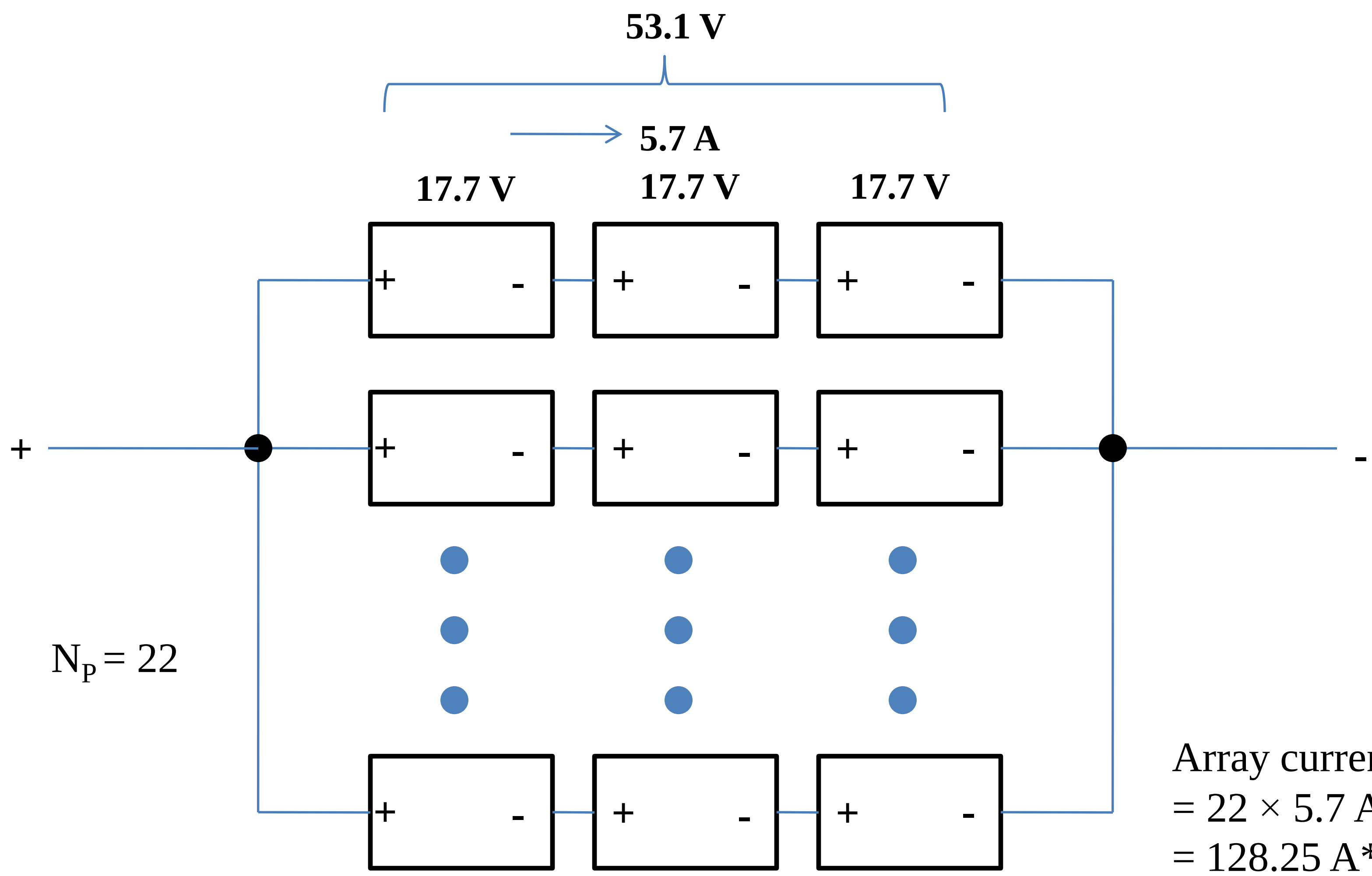
$$= 123.46\ \text{A}$$

Assuming derating factor = 0.9
And columbic efficiency = 0.95

Assuming only 100 W PV module capable of providing I_{mp} = 5.7 A is available to us.
then,
Total no. of modules in parallel, N_P
= Array current/I_{mp} of the module
=123.46/5.7
=21.65
=22(taking ceil value)

Total no. of modules in series, N_S
= System voltage/V_{mp} of the module
=48V/17.7 V
=2.711
=3





Array current
= 22 × 5.7 A
= 128.25 A*

$N_S = 3$

*Slightly higher than our required value

Battery Size:

$$C_B = \frac{E \times N_A}{B_V \times DOD \times \eta_B}$$
$$= \frac{22800\,\text{Wh} \times 3}{12 \times 0.8 \times 0.8}$$
$$= 8906.25\,\text{Ah}$$

Assuming,
Battery voltage = 12 V
DOD = 80 %
Battery Efficiency = 80%

If we take 300 Ah Trojan battery with 12 V terminal voltage, the battery bank requires a parallel connection of 8906.25/300 = 59.375 = 60 such batteries.

Size of Charge Controller:

$$I_{Lmax} = \frac{P_T}{B_V} = \frac{950\,\text{W}}{12\,\text{V}} = 79.17\,\text{A}$$

The charge controller must support two times I_{Lmax} at the load side i.e. 158.34 A
And two times I_{SC} of the PV array at the input side.

Assignment

Design a Solar Home System of your requirement by assuming suitable data.

a. Calculate daily load in Wh and Ah
b. Determine the size of PV array.
c. Determine the battery size in Ah
d. Determine the size of charge controller.
e. Draw a simplified layout of the system.

Thank You!!!