

UNIT-III SOLAR PHOTOVOLTAIC SYSTEMS

Introduction: Solar Photovoltaic System Converts Solar Energy directly into Electrical Energy.

The Conversion process is called photovoltaic effect. The device used is called Solar photovoltaic cell.

Advantages: It Converts Solar Energy directly into Electrical Energy.
into without using thermomechanical Link

Solar P.V Systems are Reliable, durable, maintenance free.

3. These systems are quite operation suitable for all environmental conditions. & Respond for Solar Radiation.

4. The life span is 20 years.

5. These are installed nearer to load centres

Hence distribution cost is less.

Disadvantages: 1) Cost of the solar cell is high

2) Efficiency is less

3) Solar Energy is Intermittent to store the Energy Requires Batteries. Which is Expensive

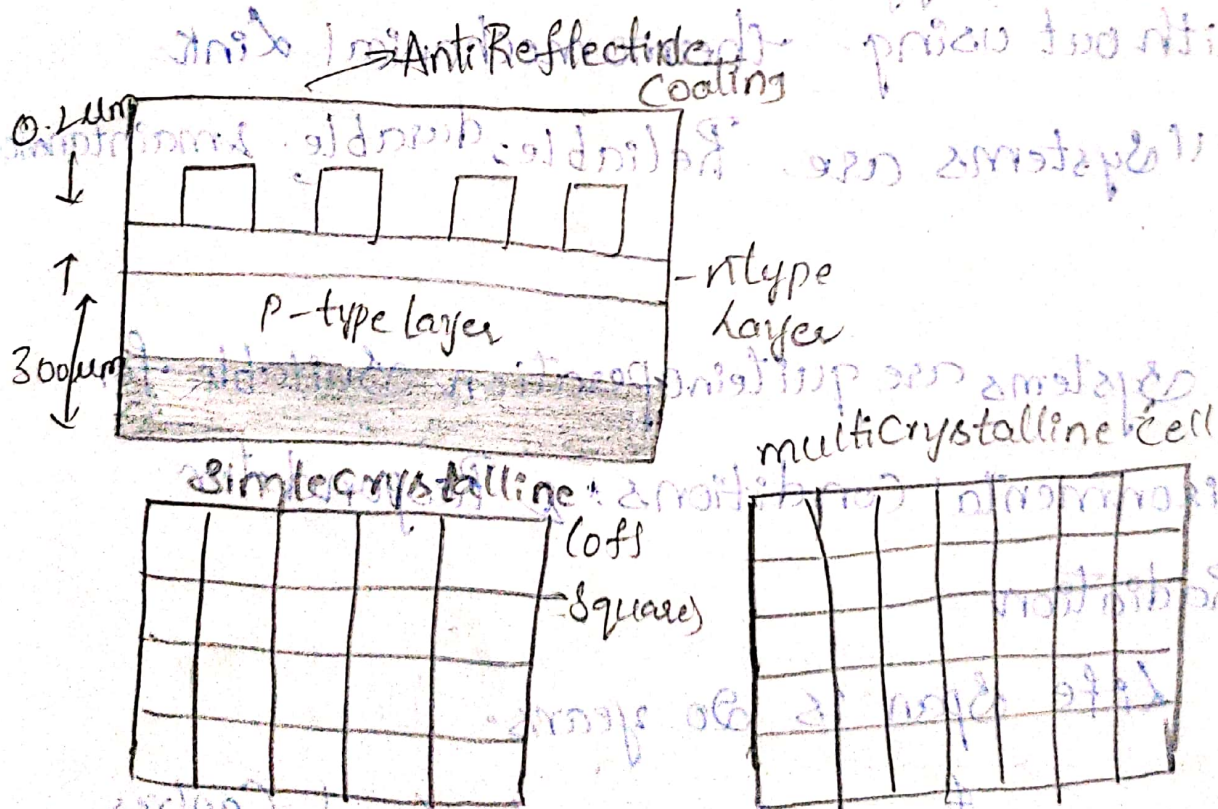
Solar cell: Solar cell is made with silicon material.

It consists of 2 Junctions one is p & layers one is p -type and another is n -type.

The silicon material is doped with trivalent Impurities it is called p -type Semiconductor.

The silicon material is doped with pentavalent Impurities it is called n -type these 2 are

Joined together to form a pn -Junction.

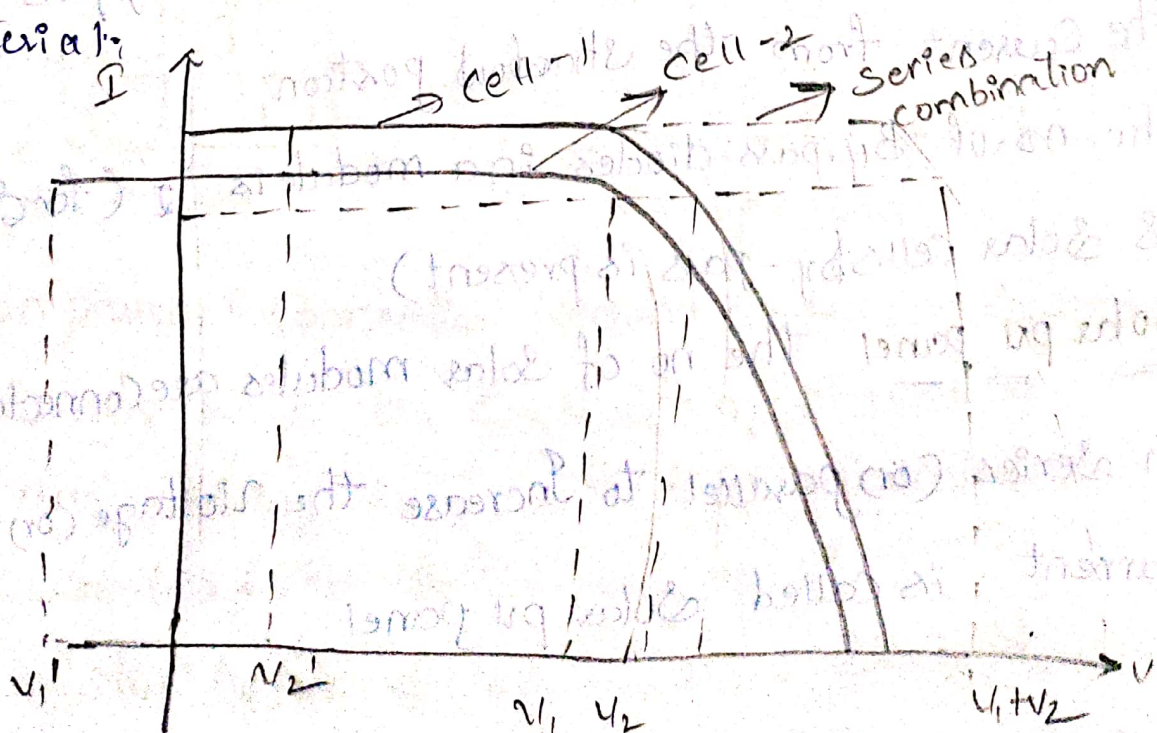


Along with Solar cell Metallic Contacts & anti Reflecting Coating are provided.

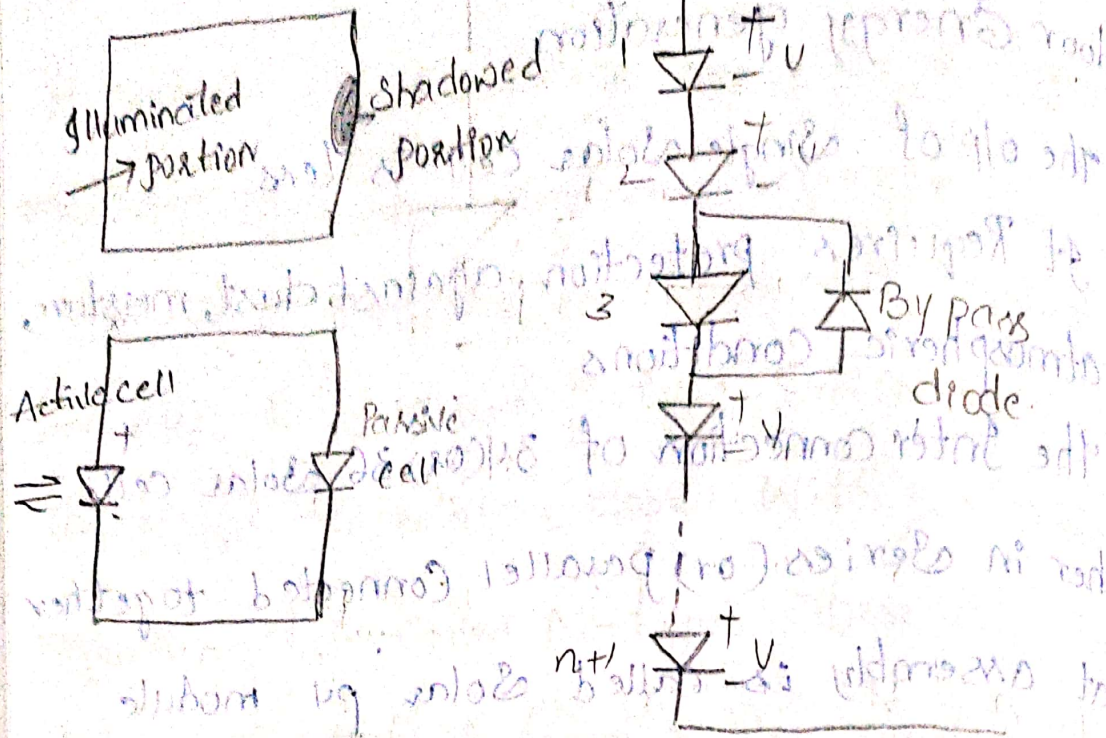
Solar PV module: The basic cell cannot be used for outdoor energy generation

- 1) The o/p of single solar cell is less
- 2) It Requires protection against dust, moisture, & atmospheric conditions
- 3) The Inter connection of 34 (or) 36 solar cells either in series (or) parallel connected together that assembly is called solar PV module

Cell Mismatch in a module: A no. of solar cells are interconnected in a module if 2 different solar cells are interconnected it causes mismatch in their characteristics. To avoid mismatching losses the solar cells must be taken same batch material.



Effect of Shadowing



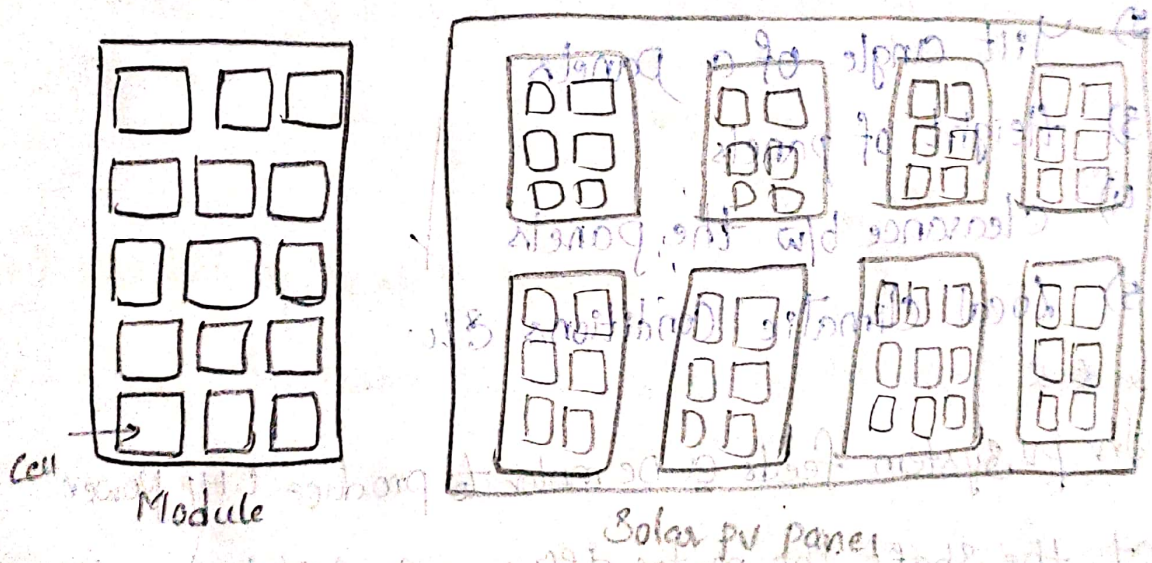
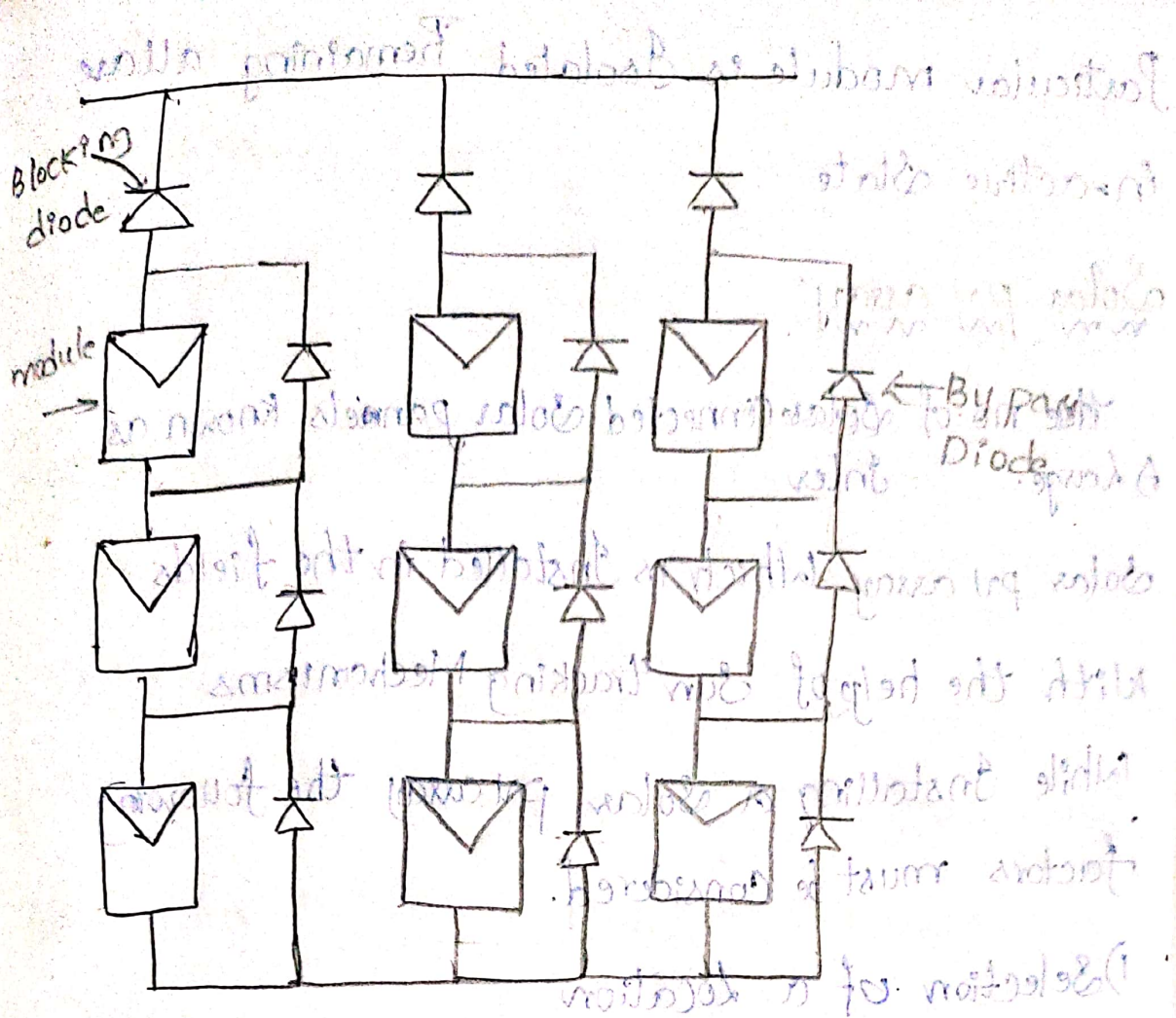
Due to shadow portion the circulating currents flows in a solar cell which causes excessive heating the phenomenon is called hot-spot effect.

To avoid this damage a by-pass diode is connected across a module.

The main function of by-pass diode is it by-pass the current from the shadowed portion.

The no. of By-pass diodes in a module is '2' (for every 18 solar cells by-pass is present).

Solar pv panel The no. of solar modules are connected in series (or) parallel to increase the voltage (or) current is called solar pv panel.



In a parallel Connection blocking diodes are Connected in Series with the Each String of modules. If any string is failed. that particular string is Isolated by the blocking diode. The by pass diodes are used across Each module. if any one of the module is failed that

Particular module is Isolated Remaining all are in active state

Solar p.v array:-

The no. of Solar Connected Solar panels known as Array.

Solar p.v array. Which is Installed in the fields

With the help of Sun tracking Mechanisms

While Installing a Solar p.v array the following factors must be considered.

1) Selection of a location

2) Tilt angle of a panels

3) Height of panels

4) Clearance b/w the panels

5) Local climatic Conditions etc.

In p.v system feeds a Dc motor to produce 1 Hp power

at the shaft the motor Efficiency is 85% Each module

has 36 Monocrystalline Silicon Solar cells arranged

in a 4/6 Matrix. The cell size is 125mm x 125mm and

the cell Efficiency is 12%. Calculate the no. of modules

Required in the p.v array. Assume Global Radiation

Incident on the panel is 1 kW/m^2

Motor power = 1 Hp = 735 Watts.

Efficiency (η) = 85% = 0.85

$$\eta = \frac{o/p}{g/p} \Rightarrow \text{Input} = \frac{o/p}{\eta} = \frac{735}{0.85} = 864.7 \text{ Watts.}$$

Let n is the number of modules Required.

$G \cdot R \cdot I$ on the panel = $1 \text{ kW/m}^2 = 1000 \text{ W/m}^2$

Cell efficiency = 12% = 0.12

Cell area in one module = $9 \times 11 \times 125 \times 125 \times 10^{-6} = 0.5625 \text{ m}^2$

o/p of solar p-v array = Input of Dc motor

$$1000 \times 0.12 \times 0.5625 \times n = 864.7 \text{ Watts.}$$

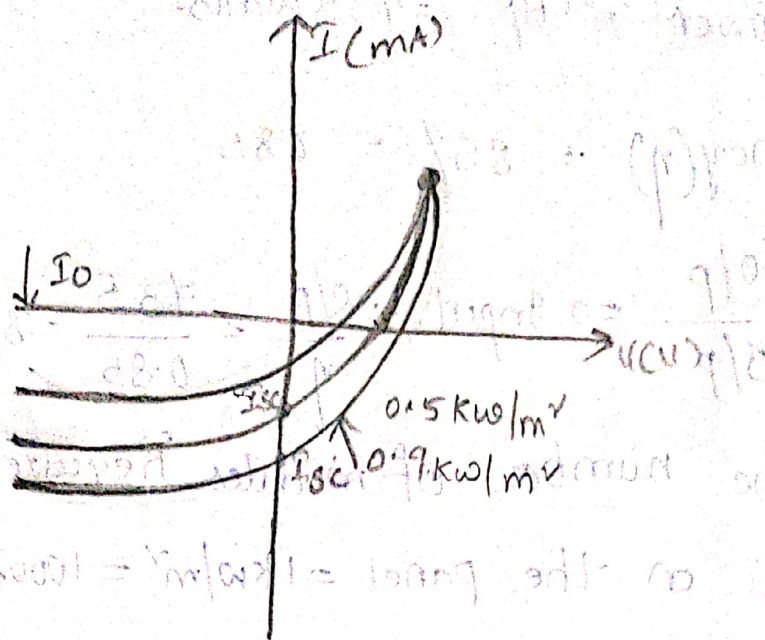
$$n = 12.8 \approx 13 \text{ modules.}$$

V-I Characteristics of a Solar cell:

The V-I Characteristics are drawn by taking current

on y-axis Voltage on x-axis

In Normal diode the V-I Characteristics are Represented in 1st quadrant But in photo voltaic cell the Characteristics are opposite.



Normal diodes the Current Expression is

$$I = I_0 \exp \left(\left(\frac{V}{V_T} \right) - 1 \right) \text{ Amp}$$

In photo voltaic Cell. the Current is Expressed as.

$$I = -I_{sc} + I_0 \exp \left(\left(\frac{V}{V_T} \right) - 1 \right) \text{ Amp}$$

Where I_{sc} is Short Circuit Current

When the Junctions are Short Circuited.

at it's terminals. Then voltage $V = 0$

$$\boxed{I = -I_{sc}}$$

The minimum Voltage Required. to become Current Zero is called Open Circuit voltage V_{oc}

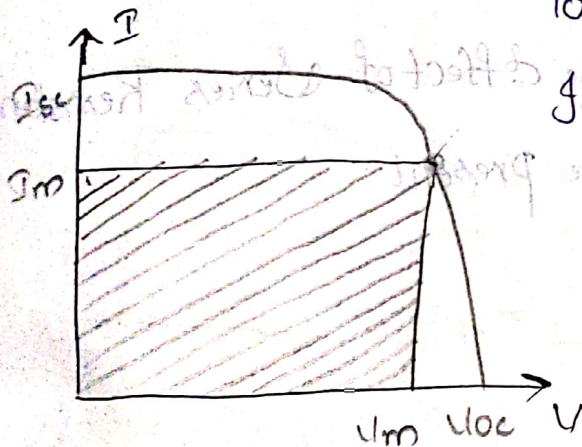
$$V = V_T \ln \left[\frac{I_{sc}}{I_0} + 1 \right] \text{ volts.}$$

Fill factor: The fill-factor Indicates the quality of a cell. It is defined as the Ratio of Peak power to the product of open Circuit voltage & Short Circuit Current.

$$\text{Fill factor} = \frac{V_m I_m}{V_{oc} I_{sc}}$$

for an Ideal Solar cell fill factor is unity.

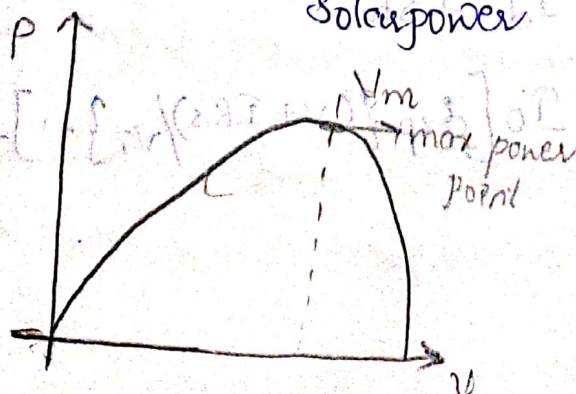
for practical Solar cell (Silicon Cell) the value is 0.5 to 0.83.



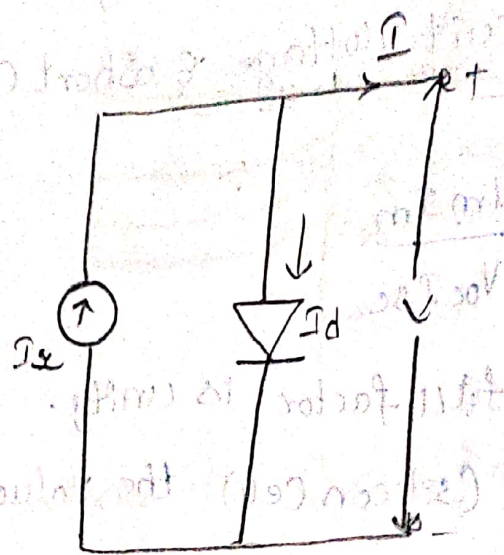
To Increase the fill factor
Internal Series Resistance
must be Zero
Shunt Resistance must
be Infinity.

Conversion Efficiency: It is defined as the Ratio of Peak power to the Solar power.

$$\text{Conversion Efficiency} = \frac{V_m I_m}{\text{Solar power}} = \frac{\text{Fill factor } V_{oc} I_{sc}}{\text{Solar power}}$$

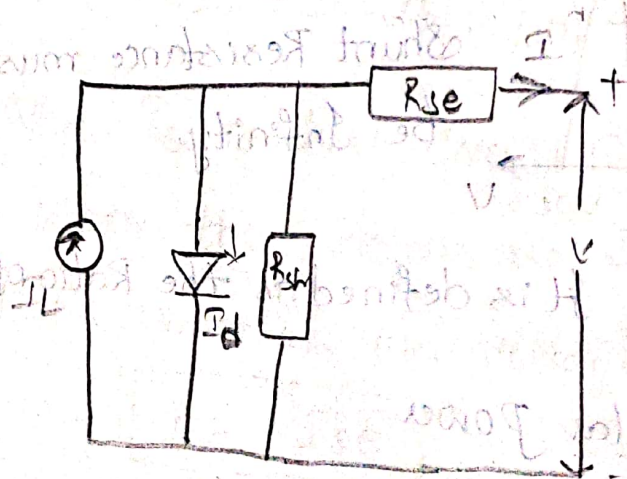


Equivalent Circuit: for Ideal Solar cell Series Resistance is zero & Shunt Resistance is ∞



Ideal Cell

In practical solar cell the effect of Series Resistance & Shunt Resistance are present.

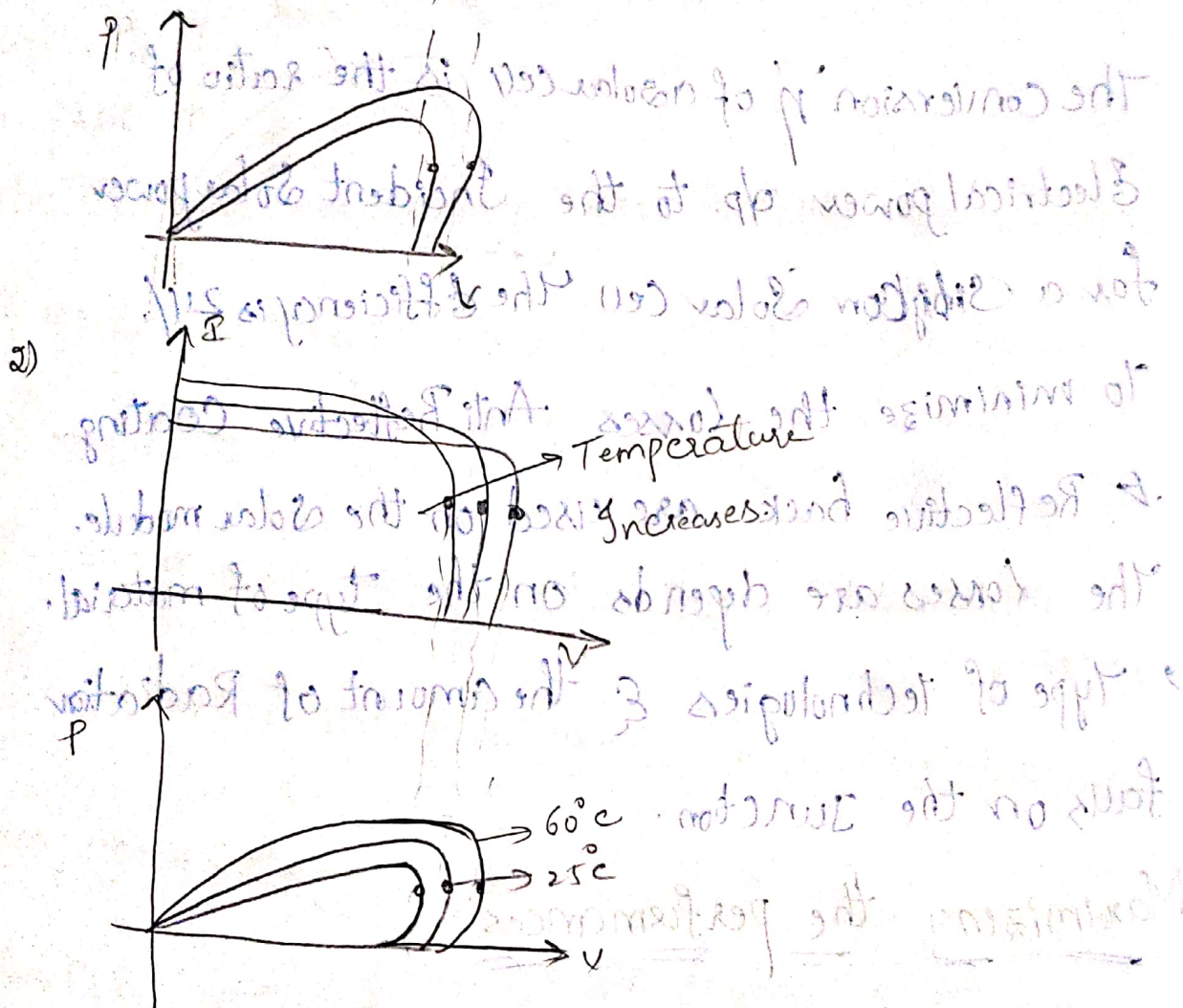
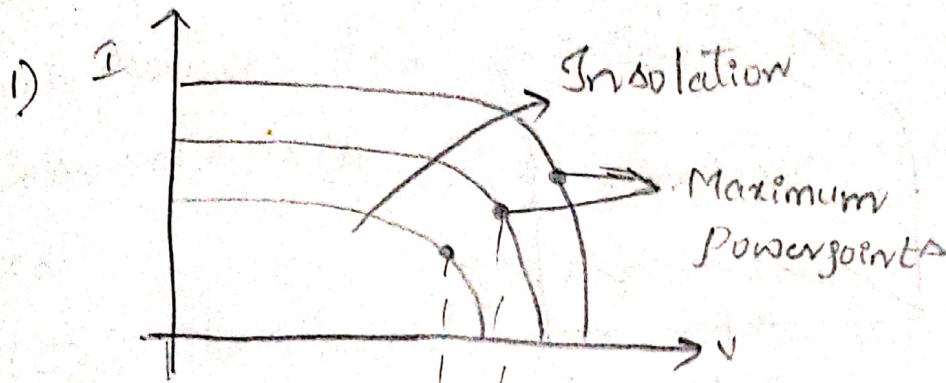


Practical solar cell

$$I = I_L - I_D - I_{sh}$$

$$I = I_L - I_0 \left[\exp \left\{ \frac{(V + IR_s)}{V_T} \right\} - 1 \right] - \frac{(V + IR_s)}{R_{sh}}$$

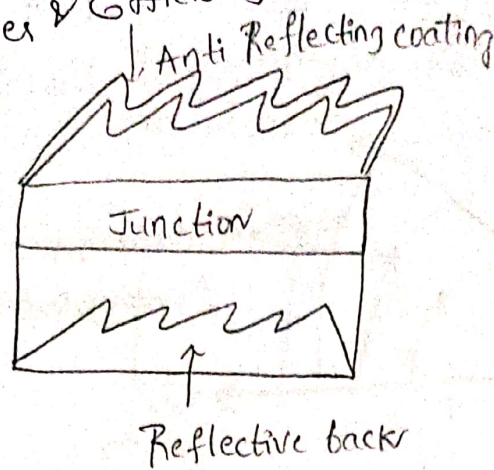
Effect of Variation of Insolation & Temperature:



- 1) When the Insolation is Increases power o/p changes & Max power point position changes-

- 2) As per the test Condition the amount of power Generated per unit area is 1 kw/m^2 at temperature of 25°C

~~Effect of Variation of Temperature~~
 Energy losses & Efficiency.



The conversion η of a solar cell is the ratio of Electrical power up to the Incident Solar power
 For a Silicon Solar Cell the Efficiency is 21%.

To minimize the losses Anti Reflective Coating

• Reflective back are used on the Solar module.

The losses are depends on the type of material.

• Type of technologies & the amount of Radiation falls on the Junction.

Maximizing the performances:

To maximize the Solar Cell performance Series Resistance must be Zero. Shunt Resistance is $\propto$

To Increase the Shunt Resistance avoid the leakages perimeter of Solar Cell.

To decrease the Series Resistance high down

materials are used. But doping increases layer & decreases. Radiation strikes on the Junction Reduces, which produces less of hence while designing. a solar cells proper level of doped materials are used

Cell Size: The terrestrial application demands. Use of large sized solar cells but it is difficult to maintain in practical.

The Silicon solar cells are divided into 4 types

- 1) 100mm [4 inches] diameter Single Crystalline.
- 2) 100cm² OF Square Single Crystalline
- 3) 100mm x 100 mm [4x4 inches] Square multi crystalline
- 4) 125mm x 125mm [5x5 inches] square multicrystalline.

Energy payback period: The length of time. Which a solar cell. Generates the Same amount of Energy. That it has consumed during its production is known as Energy payback period.

The life span of the solar cell is 3.5 to 5 years

Classification of Solar Cells:- Solar cells are classified on the basis of

- 1) Thickness of active Material
- 2) Type of Junction Structure
- 3) Type of material used in its fabrication.

Thickness of active Material:-

Thin film solar cells have Major Advantage of Less Material Consumption.

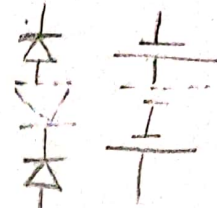
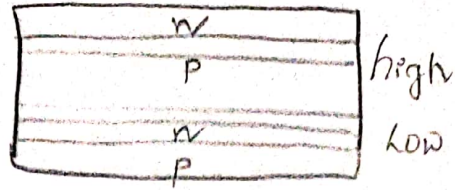
It is having a drawback of cell Mismatch, and does not withstand for outside Atmospheric Conditions.

Thin film Single Crystalline and multicrystalline Solar cells are tried, but not Succeeded.

Bulk Materials are used. To design Solar cells having advantages of Efficiency high, Cell mismatch Problem is Overcome.

on basis of Junction Structure:

- 1) PN homo Junction cell
- 2) Pn hetero Junction cell
- 3) Pn multi Junction cell
- 4) metal Semi Conductor Junction
- 5) p - I - n (p type - Intrinsic - n type)



In homogeneous pn junction the semi-conductor material on both sides of junction is same, only doping materials are different.

In heterogeneous pn junction the 2 dissimilar materials are used. the materials are gallium arsenide, cadmium sulphide, Copper Indium.

In multi junction solar cell 2 (or) more junctions are present. these are designed with decreasing order thickness but connected in series.

on the basis of type of Active Material:

- 1) Single Crystalline Silicon cell
- 2) multi Crystalline Silicon cell
- 3) Amorphous Silicon Cell [a-si]
- 4) Gallium Arsenide Cell
- 5) Copper Indium Cell
- 6) Cadmium Cell
- 7) organic p cell.

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A PV System having VI characteristics as shown in fig. It is supplying a power to a load whose load line

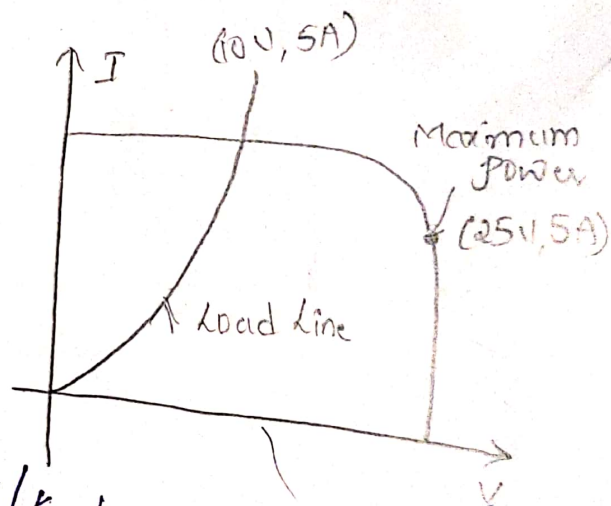
Intersects the characteristics (10V, 8A). Determine the additional power gained if an MPPT is interposed b/w the source and load. If the cost of the MPPT is Rs 4000 for how long thus the system need to operate to recover the cost of MPPT. The cost of electricity may be assumed as 3/-/kwhr. Assume MPPT efficiency is 95%.

Sol: Given.

$$\text{cost of MPPT} = 4000/-$$

$$\text{cost of electricity} = 3/-/\text{kwhr}$$

$$\text{Efficiency of MPPT} = 95\%$$



$$\text{Power obtained without MPPT} = 10 \times 8 = 80W$$

$$\begin{aligned} \text{Power obtained with MPPT} &= 25 \times 5 = 125W \times 0.95 \\ &= 118.75W \end{aligned}$$

$$\text{Surplus power} = 118.75 - 80 = 38.75W$$

$$\text{Cost of MPPT} = \frac{4000}{38.75} \text{ Energy Generated}$$

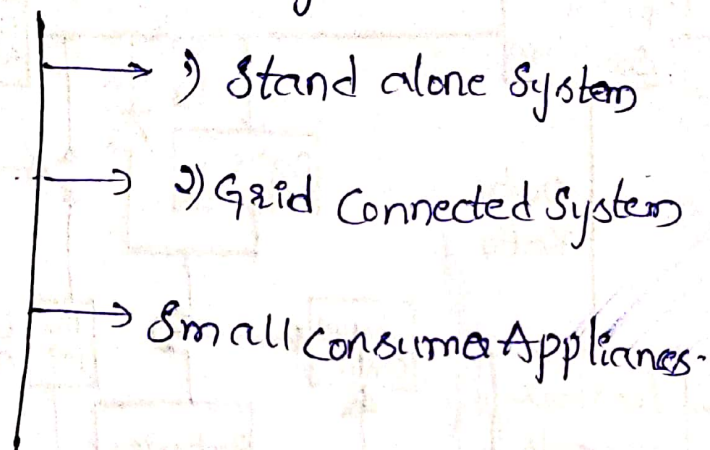
$$4000 = \frac{38.75 \times t}{1000} \times 3/-$$

$$t = 34408.62 \text{ hrs}$$

Time to Recover the Cost of MPPT = 34408.60 hrs

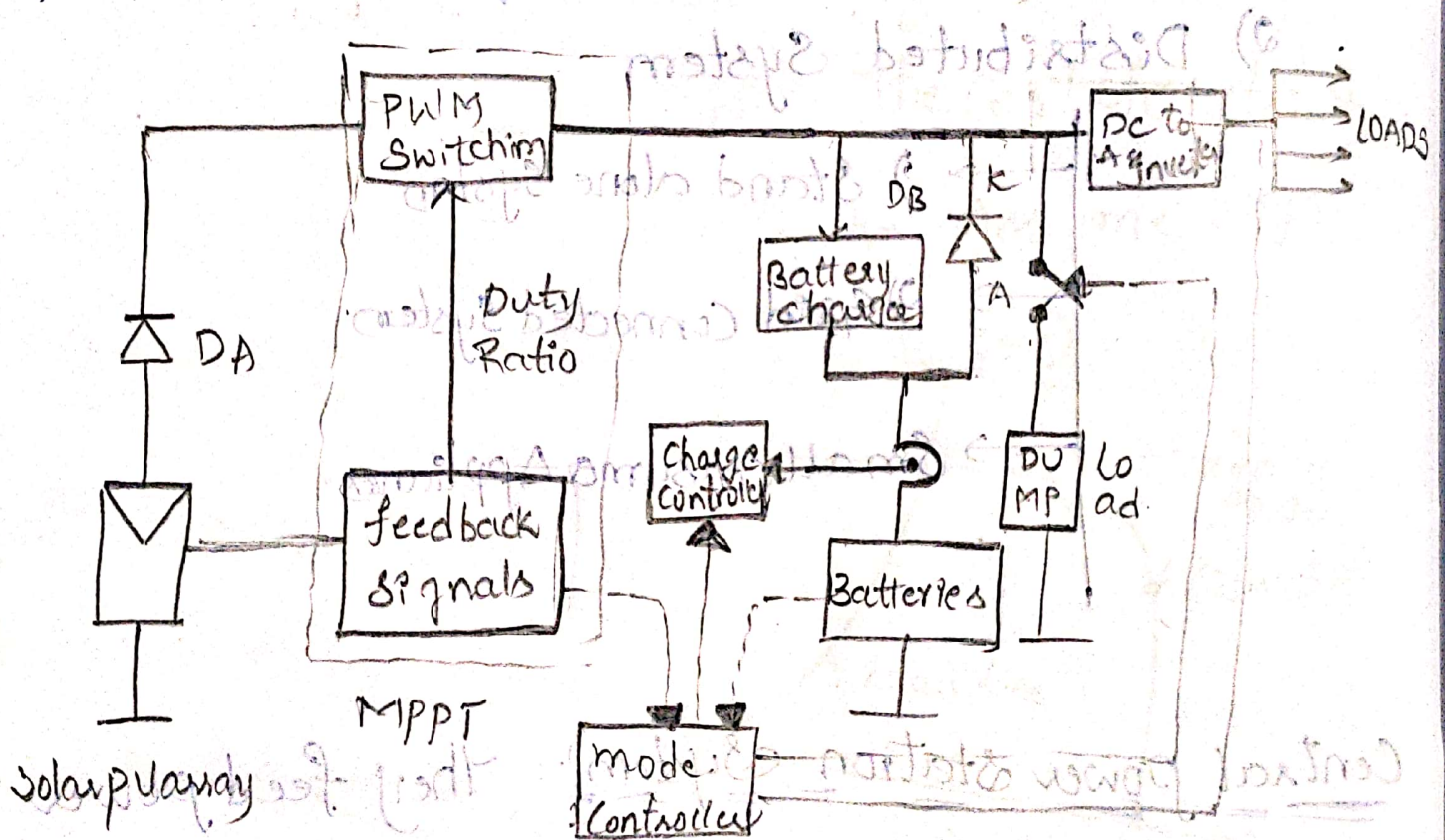
Solar PV Systems: The Solar PV Systems are classified as

- 1) Central Power Station System
- 2) Distributed System

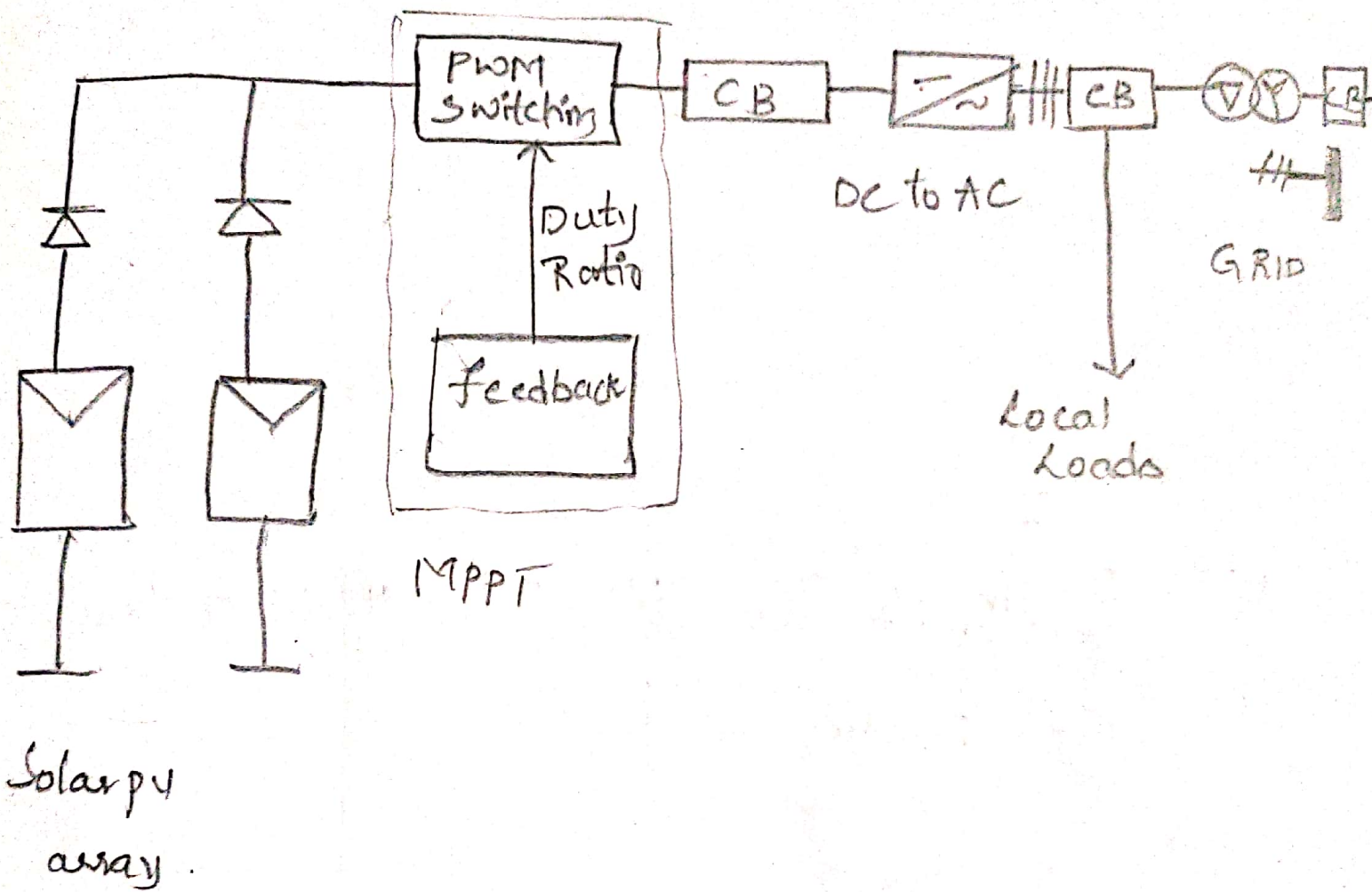


Central power station System: They feed power to the Grid. Central power stations are designed up to 6 MW peak capacity. They are operated by a synchronization process. DC converted to AC and it is filtered & the voltage levels are adjusted & connected to the load.

Stand alone system: It is used in rural areas for continuous power. Where the axis of grid is not available. where the axis is the operating power is low peak to the low peak. It is operated by mode controller with the support of batteries.

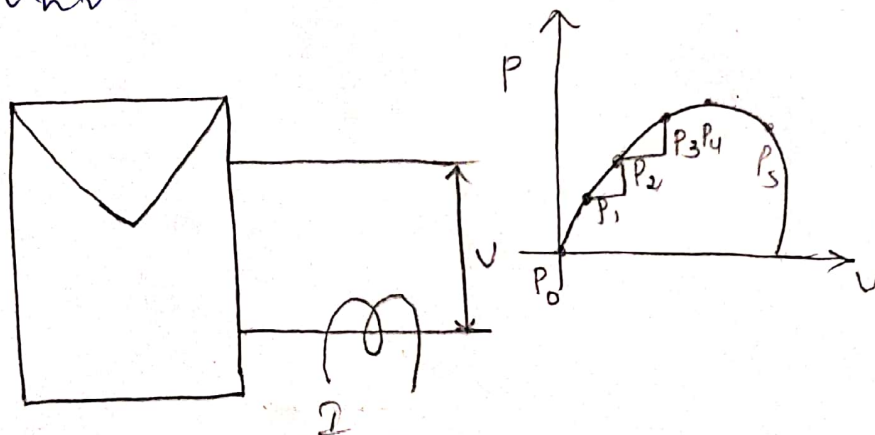


Grid Connected system

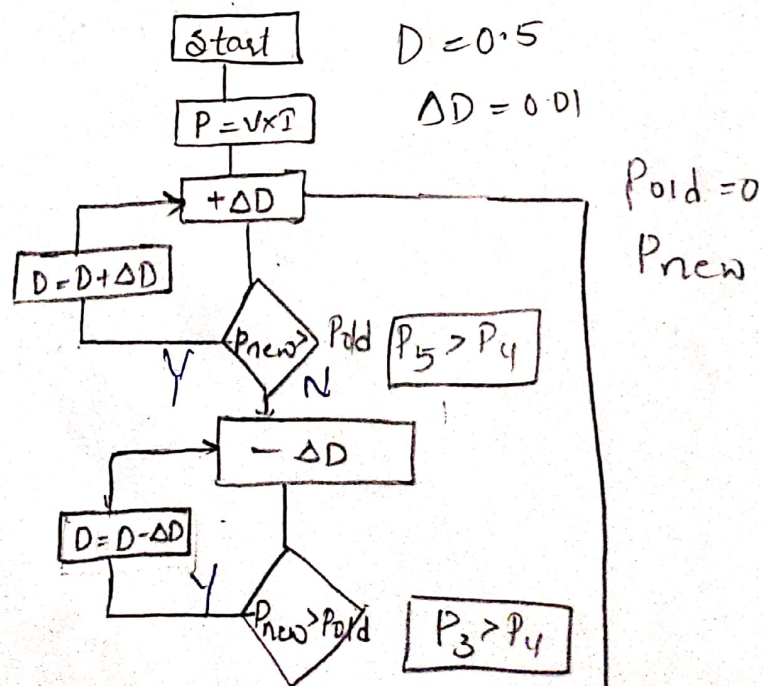


Perturb & observe Method (P&O): The perturb & observe Method is the one of maximum power point tracking Technique it is operated along with MPPT device. It is used to track Maximum Power point i.e. the point at which Load characteristics & Source Characteristics are intersect. It is operated by an algorithm by changing the duty Ratio of MPPT the maximum point is achieved.

Algorithm:



$$P = VI$$



Perturbations:-

$$P_1 > P_0 \rightarrow D + \Delta D$$

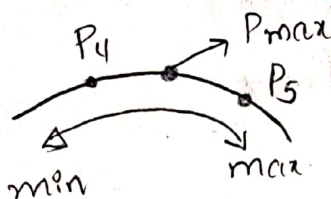
$$P_2 > P_1 \rightarrow D + \Delta D$$

$$P_3 > P_2 \rightarrow D + \Delta D$$

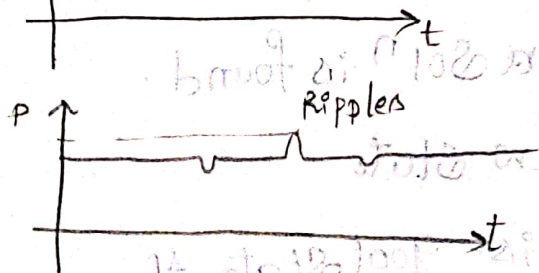
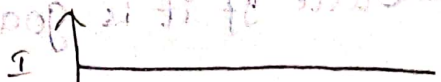
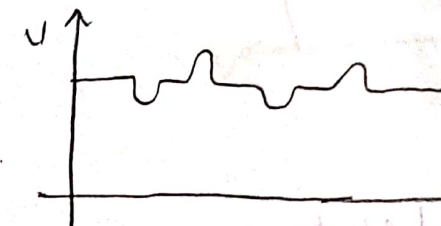
$$P_4 > P_3 \rightarrow D + \Delta D$$

$$I \rightarrow P_5 > P_4 \rightarrow D - \Delta D$$

$$II \rightarrow P_3 > P_4 \rightarrow D + \Delta D$$

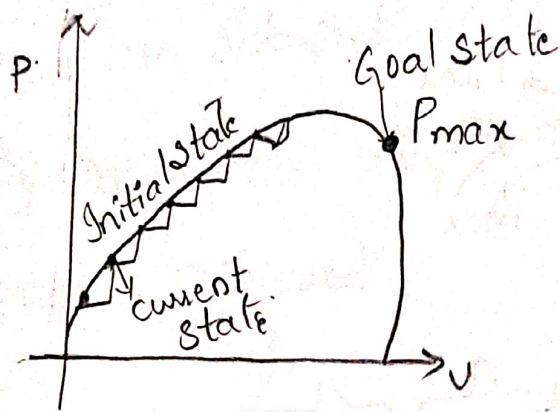


Waveforms:



- Smaller $\Delta D \rightarrow$ Quality of o/p iterations are more.
- greater $\Delta D \rightarrow$ Ripples are present but iterations are less.

Hill climbing Technique: To avoid the main drawback of Perturb & observe method HCT is used. It is one of MPPT Method. The main drawback of P&O method is there is no Return point & it takes longer time to achieve the maximum power Point.



- 1) Evaluate the Initial state. If it is goal state then return & quit.
- 2) Loop until a Solⁿ is found.
- 3) Evaluate new state
 - a) If it is goal state then quit
 - b) If it is better than Current state then make new Current state
 - c) If it is not better than current state go to Step - 2.

Balance of System Components:

- Battery Charge Controllers.
- Battery fuses
- lightning arresters
- Junction boxes
- Wires
- Distribution panels.