PERFORMANCE OF A GRID CONNECT SOLAR PV SYSTEM WITH DIFFERENT MODULE MOUNTING CONFIGURATION

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Master of Technology

Energy Systems

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CERTIFICATE

This is to certify that the work contained in this thesis titled **"PERFORMANCE OF A GRID CONNECT SOLAR PV SYSTEM WITH DIFFERENT MODULE MOUNTING CONFIGURATIONS"** has been carried out by Mr. S. M. Giridharan under my supervision and has not been submitted elsewhere for a degree.

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Nomenclature:

I = Output current

I_{ph} = Photo generated current

I_D = Diode current

I_{RP} = Shunt resistance

I_o = Reverse saturated current

n = Diode ideality factor

q = Elementary charge

K = Boltzmann's constant

T = Absolute temperature

V_{mpp} = Maximum power point voltage

I_{mpp} = Maximum power point current

V_{oc} = Open circuit voltage

I_{sc} = Short circuit current

P_{in} = Input power

V = Cell voltage

V_T = Thermal voltage

θ = Tilt of the angle

α = Function of latitude of installation

L = Length (Portrait)

W = Width (Landscape)

n = Number of panels.

ABSTRACT:

The recent scenario is in the demand of PV system is due to no negative impact on the environment while producing the electrical power by directly converting solar radiation. However the solar radiation is not constant it changes throughout the day. In this thesis by the use of software called PVsyst we can design at any capacity by both the way of installation called portrait mode and also landscape mode. By using this software it helps to identify the energy yield per annum, per month and also by hourly data for various capacities. According to the requirement of vendors PVsyst software gives the optimum pitch distances for a particular area. By using this software it is effectual to find out that which mode is most optimize for installing solar panel in various cities of India.

Chapter-1

Introduction

Energy crisis

Energy is any great bottleneck in the supply of energy sources to an economy. India is a developing country and has a great increase in the global demand for energy in recent past years as a result of great increase in industrial development and population growth. So energy in India is far less than the actual needs.

India has highly depend on fossil fuel mainly depends on coal, gas, nuclear etc. Today, the country like India has greatest effective use of renewable energy. Increased in the energy cost and the break, we are forced to switch the alternative energy production to meet our energy needs. The best option is renewable energy especially solar power. The sun is free of cost and this is largely available for the country like India so we should make use of it.

The main reason that solar energy is such a great idea to have found is one of the only renewable energy sources, which supply sufficient energy. Solar energy can be produced in large quantities, thus generating more energy than can be used. Lot of research is going on based on the solar energy to improve the needs of energy. Solar is basically a renewable energy so it never ends. One of the main advantage is it is not creating any negative impact to the environment; there are no any harmful gases while producing the energy. In the future however it is clear that the oil price is increasing and creating an outrage and strike all over the India so best option is to switch to renewable energy.

1.2 IMPORTANCE OF SOLAR

Before starting to the importance of solar first we can see why we chosen the solar energy. With the impending scarcity of many valuable resources people are now starting to thinking and considering the other resources like solar, wind, water etc... when we talk about the conventional energy sources like coal, gas, nuclear based power plant not only it is generating power but it also contributes negative to the environment. The gases that are emitting from the power plant causes harmful effect on our environment that we are now facing a big problem called "global warming"

To stop all these issues it's the time to utilize energy from the sun. Solar energy is free of cost so that anyone can make advantage of it. Solar energy is readily available energy it does not belong to anybody. By using the free solar energy we are reducing the green house gas emission that is the big issue in our country now a day. The only issue regarding the solar energy is the cost but when we compare with the last 20 years the cost has been reduced grammatically so that is the good sign for us to use the solar energy.

India is of the few countries with long day and plenty of sunshine. India is now facing the scarcity of electricity so that we can make use of solar energy to meet our electricity requirement. By knowing the importance of solar the Indian Renewable Energy Development Agency and the Ministry of Non-Conventional Energy Sources are conducting a program to create a awareness based on global warming, solar energy.

Solar energy can be used in many applications like domestic lighting, street lighting, rural electrification, water pumping, cooking, heating, electricity power generation etc... where ever possible use solar energy it will reduce the non-renewable energy sources and also the clean environment.

Solar energy availability

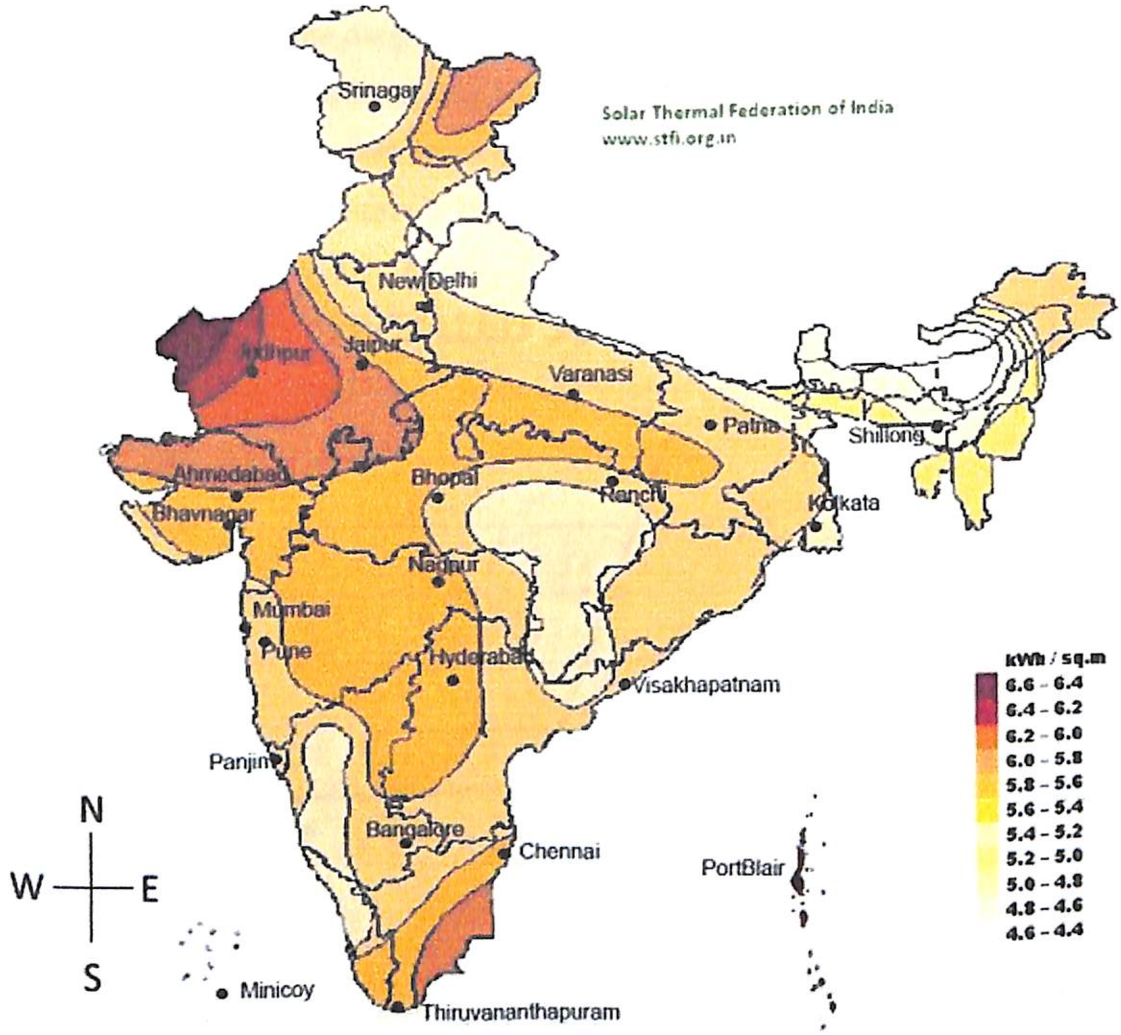


Fig 1.1 SOLAR RADIATION MAP OF INDIA **(Ref: www.econserve.in)**

When we compare with all renewable sources solar is the most prominent for the country having geographical sites like India where we are getting more than 300 days of sun shine. By seeing the picture Fig 1.1 we came to know that India has high level of solar radiation. The very important point is we can place at any location so that transmission and distribution losses are reduced.

1.3 INCREASING PV SYSTEM IN INDIA

Solar PV sector is the fast growing sector in India and around the world because of many advantages. From the diagram Fig 1.2 denotes that at the year 2009 the PV industry growth was 3MWp but at present it is 1045MWp from this we can see the rapid growth of increasing solar PV system. Due to easy construction and decreasing the solar panel cost the production of solar PV system in India is increasing.

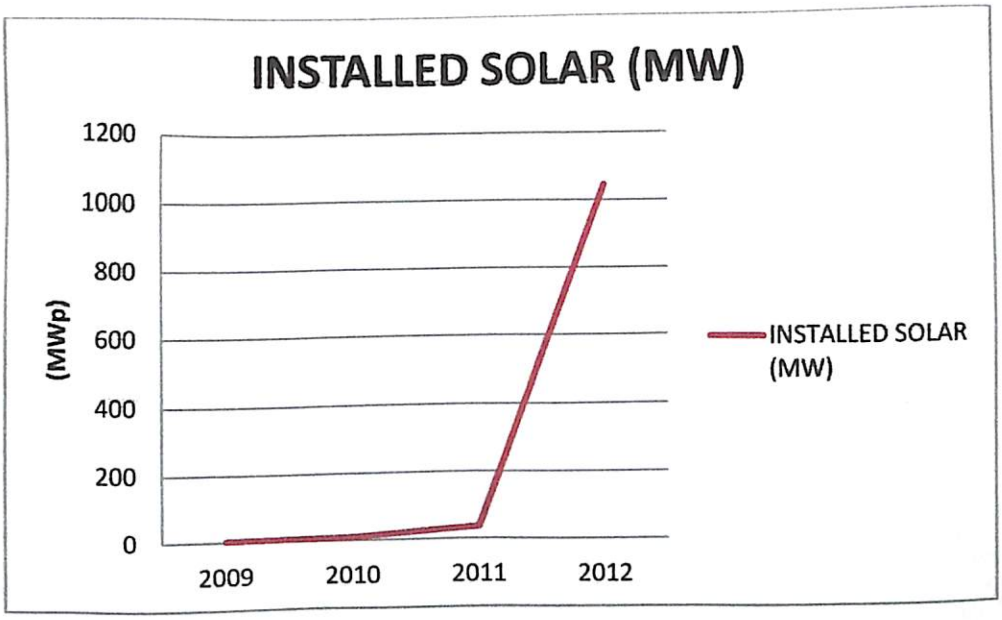


Fig 1.2 INCREASING ENERGY YIELD IN INDIA

India has more than 300 days of sun shine hence the gap of power availability will reduce by installing the PV systems.

Some of the largest capacity solar power parks in India are

1. Charanka Solar Park – Gujarat - 240MW
2. Bitta Solar Power Plant – Gujarat - 40 MW

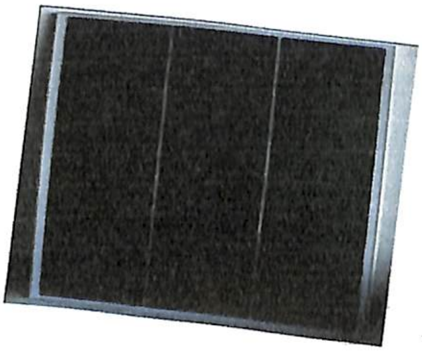
India receives an average 4-7 KWh/m2 of solar energy daily with average of 250 – 300 days. In which Gujarat and Rajasthan has an average 6-7 KWh/m2 is the most.

1.4 SILICON BAND SOLAR CELL IS DOMINANT

Solar cells are electronic devices that convert energy light directly into electricity by the photovoltaic effects. Solar cell are often electrically connected and encapsulated as a module. Above the module a sheet of glass is placed on the front side, it will allows the light to pass through it while protecting the semiconductor wafers from abrasion and rain, hail etc. Solar cells are often connected in serious to multiply the voltage for our purposes.

There are different types of solar cell. Silicon based solar cell (Si), Copper indium gallium Selenide based solar cell (CIS), cadmium telluride (CdTE) in which Silicon based solar cell is dominating.

(Mono-crystalline Silicon)



(CIS solar cell)

(CdTE solar cell)

Fig 1.3 DIFFERENT TYPES OF SOLAR CELLS **(Ref: solarstere.co.kr)**

Different types of silicon based solar cell are mono-crystalline silicon (C-si), poly-crystalline (p-si), and Amorphous silicon thin film (a-si).

Why silicon?

1. Non- toxic
2. Abundant
3. Relatively cheap
4. More efficiency than others.
5. 20-25 years of life span.
6. Inherited from VLSI.

Mono-Crystalline is otherwise known as the Single-Crystalline silicon and it is the base material for the industries to manufacture the solar cells. The technology for producing the single crystalline is Czochralski(CZ) method. A single crystalline seed is dipped into the molten mass after some time when the seed is pulled slowly from the melt the single crystalline silicon is formed. Then it should be sawed into thin wafers and that has to be polished, doped, coated, interconnected and assembled into modules and arrays.

Thin film technology is the recent technology but the main disadvantage is the efficiency is less but the manufacturing is easy. But its pros were low cost substrate and fabrication process but it not stable. Another most advanced technology is amorphous thin film technology but its main disadvantage is initial 20-40% loss in efficiency.

CHAPTER-2

2.1 BASICS OF SOLAR CELL, MODULES AND SYSTEMS

Solar cell is otherwise known as "Photovoltaic cell" is an electrical device which converts light energy into electricity by "Photovoltaic effect" when it is exposed to light without any external voltage source it can generate and support an electrical current.

The operation of PV cell requires 3 basic attributes

1. The absorption of light, generating electron-hole pairs.
2. The separation of charge carriers of opposite types.
3. The separate extraction of those carriers to an external circuit.

Working principle:

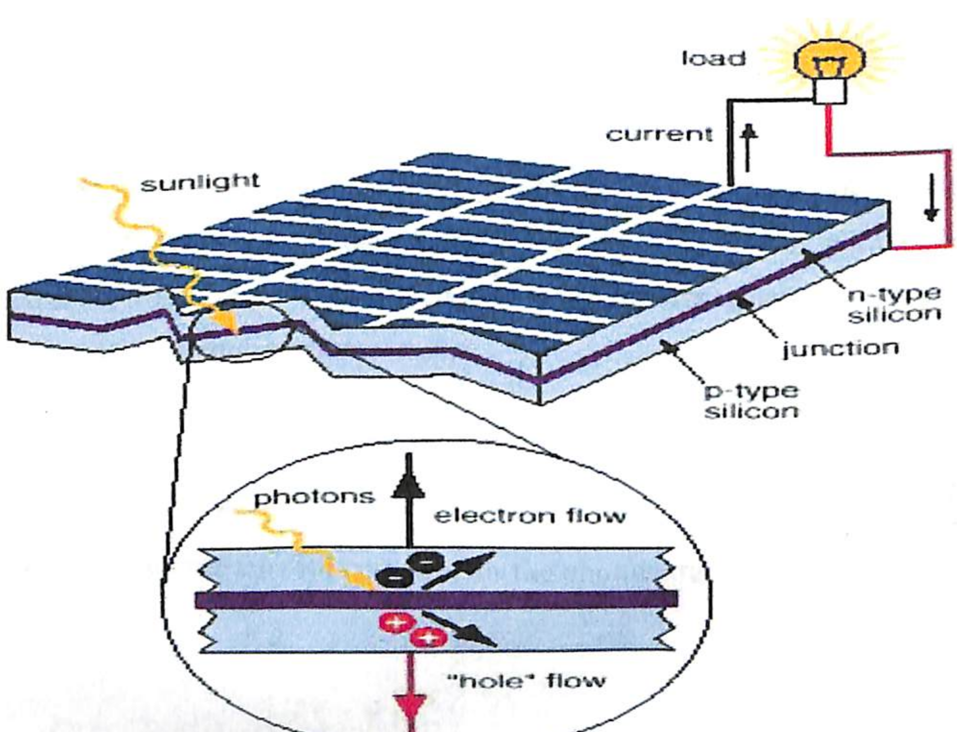


Fig 2.1: SCHEMATIC DIAGRAM OF SILICON SOLAR CELL **(Ref: www.solarpower2day.net)**

From the picture Fig 2.1 the solar cells are essentially semiconductor junction under illumination. It has two types of layer one is P-type (holes as majority charge carriers) and another one is N-type (electrons) as shown in Fig 1. When light passed to the semiconductor device it generates electron-hole pairs on both side of the junction. After generating the electron-hole pairs are diffused into the junction and are swept away by the electric field and thus produce the electric current across the devices (refer Fig 2.1).

2.1.2 Characteristics of PV Cell:

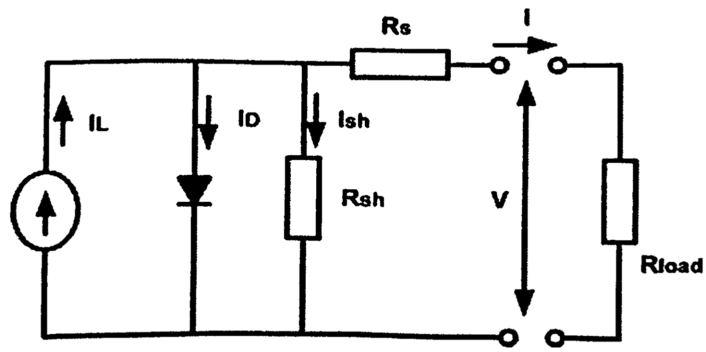


Fig 2.2 SINGLE DIODE MODULE PV CELL **(Ref: www.sciencedirect.net)**

From the picture Fig 2.2 it consists of current source, diode, series and parallel resistance and the load. In which current source, diode and parallel resistance are connected in parallel. Rs are the intrinsic series resistance whose value is very small when compare to the Rsh equivalent resistance.

Applying Kirchhoff's law to the node

$$I_{ph} = I_D + I_{RP} + I \quad \text{(i)}$$

Now we got the current equation for the photovoltaic

$$I = I_{Ph} - I_D - I_{RP} \quad \text{(ii)}$$

$$I = I_{Ph} - I_o \left[e\left(\frac{V + IR_s}{V_T}\right) - 1 - \left(\frac{V + IR_s}{R_P}\right)\right] \quad \text{(iii)}$$

Where,

$$V_T = \left(\frac{KT}{q}\right)$$

2.1.3 I-V CHARACTERISTICS CURVE:

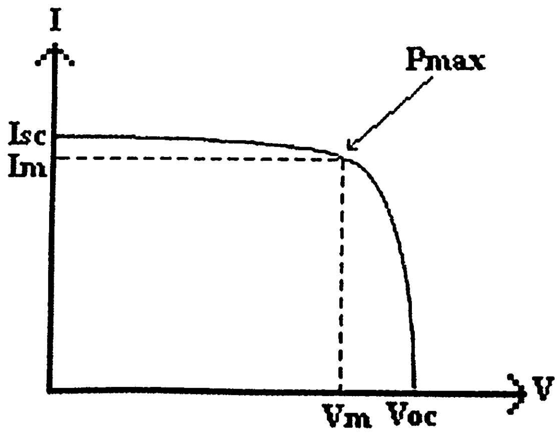


Fig 2.3 CHARACTERISTICS CURVE **(Ref: www.sciencedirect.net)**

Where,

P_{max} = maximum power

I_m = maximum current

V_m = maximum voltage

2.1.4 EFFICIENCY OF PV CELL:

The efficiency of PV cell defined as the ratio of peak power to the input solar power.

$$Efficiency = \frac{V_{mpp} \times I_{mpp}}{Area \times P_{in}} \quad (iv)$$

The efficiency of PV cell will increase if we track the maximum power with different conditions like solar radiation, temperature by using different methods like maximum power point tracking.

2.1.5 FILL FACTOR:

Fill factor is defined as the ratio of maximum obtained power to the product of open circuit voltage and short circuit current.

$$FF = \frac{V_{mpp} \times I_{mpp}}{V_{oc} \times I_{sc}} \quad (v)$$

2.2 PV MODULE INSTALLATION

Our aim is to maximizing the efficiency of solar panel installation so for a particular area how much of panel we can install. Often the question will be raised whether to installed in portrait mode or landscape mode. In the present scenario there are two types of installation. There are

1. Portrait.
2. Landscape.

2.2.1 NUMBER OF PANELS CAN BE INSTALLED IN A GIVEN LENGTH:

First we can see how many numbers of panels can be installed in the given length. By seeing the below picture Fig 1.4 we can difference in the number of panels that can be installed.

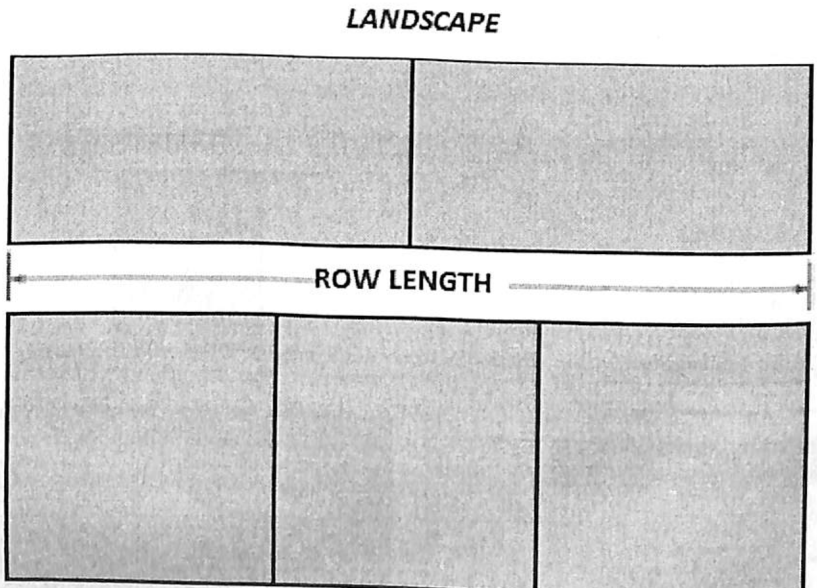


Fig 2.4 INSTALLING POR VS LAND LENGTHWISE **(Ref: article.pub.article.com)**

From the picture Fig 1.4 shows we can fit more portrait panels with in a give length. Because the width of the portrait panels is less when compare to landscape.

2.2.2 NUMBER OF PANELS CAN BE INSTALLED IN A GIVEN HEIGHT:

By knowing this the primary consideration is the shading distance is the minimum distance allowed between the rows, this will know the total number of rows available and also the minimum row spacing.

To calculate the shading distance

$$D = Sin\,(\alpha + \theta) \times \frac{H}{Sin\,\alpha} \qquad \text{(i)}$$

By this equation we can determine the distance between the front edges of the panel to the front edge of the next panel. So by calculating the (D) we find out the row spacing that dependent on the height of the panel and the tilt. So to find with installation will give the better efficiency. To do this we want to determine the number of panels that can fit in the given area.

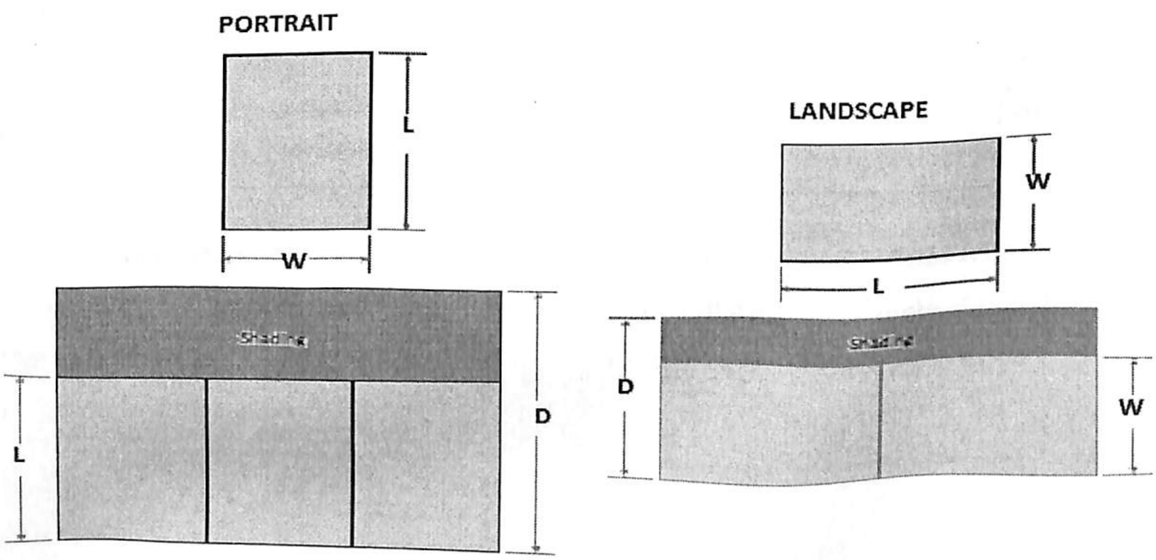


Fig 2.5 PORTRAIT VS LANDSCAPE **(Ref: article.pub.article.com)**

So first we want to find the row spacing and replacing the previous equation by (L) instead of H for the portrait and replacing (W) instead of H for landscape (refer Fig 1.5).

$$D = Sin(\alpha + \theta) \times \frac{L}{Sin\ \alpha} \text{ ------- Portrait} \qquad \text{(ii)}$$

$$D = Sin(\alpha + \theta) \times \frac{W}{Sin\ \alpha} \text{ -------- Landscape} \qquad \text{(iii)}$$

We want to find out how many number of panels (n) can be installed in the given area both for portrait and landscape. The equation are given below

$$n = \frac{A}{W \times D} \qquad \text{(iv)}$$

Combined equation (iv) and (ii) we get

$$n = \frac{A}{W \times Sin(\alpha + \theta) \times \frac{L}{Sin\ \alpha}} \qquad \text{(v)}$$

Combined equation (iv) and (iii) we get

$$n = \frac{A}{L \times Sin(\alpha + \theta) \times \frac{W}{Sin\ \alpha}} \qquad \text{(vi)}$$

By this detailed discussion panels can be installed in both the cases with no affect on the quantity of panels that can be installed. Installation of panels depends on the geographical sites.

2.3 EFFECTS OF PV INSTALLATION

The installation of photovoltaic module is the biggest issue and it depends on geographical sites. Mainly while installation the PV module we should consider the shadows and inter row gap that is the main effects. Two conditions are involved in the effects of shadows. The first issue is shadows involved in the longitudinal side of the panel and second issue is shadows involved in the latitudinal side of the panel and we can see the behavior of the installation in both portrait and landscape mode.

2.3.1 SHADOWS INVOLVED IN LATITUDINAL SIDE:

First we will go for the portrait mode when the issues of shadows involved in the latitudinal side of the panel it will affects the whole strings of the panel so that power generated from the panel will be reduced almost zero(refer Fig 1.6). Because if any one of the solar cell is affecting by the shadows it will affects the whole strings so automatically the power generated will be less.

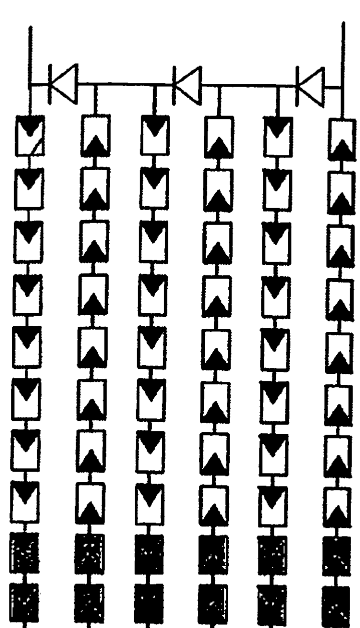


Fig 2.6 LATITUDINAL SHADOWS ON PORTRAIT MODE **(Ref: www.sciencedirect.net)**

But in case of landscape if shadows are involved it will affect only one row of the string and remaining strings will be operate without any disturbances so we will get full power(refer Fig 1.7). When we compare with power generation the landscape is the best option for this issues because it generate more power when compare to the portrait.

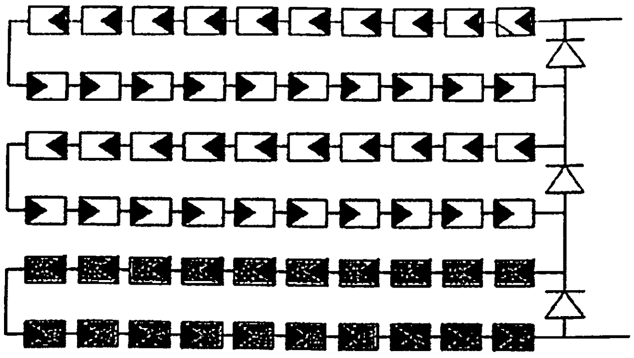


Fig 2.7 LATITUDINAL SHADOWS ON LANDSCAPE MODE **(Ref: www.sciencedirect.net)**

2.3.2 SHADOWS INVOLVED IN LONGITUDINAL SIDE:

First we will go for the landscape mode when the issues of shadows involved in the longitudinal side of the panel it will affects the each strings of the panel so that power generated from the panel will be reduced almost zero. Because if any one of the solar cell is affect by the shadows it will affects the whole strings (refer Fig 1.8).

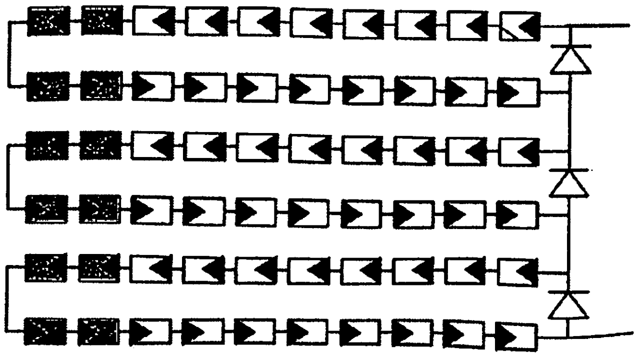


Fig 2.8 LONGITUDINAL SHADOWS ON LANDSCAPE MODE **(Ref: www.sciencedirect.net)**

But in case of portrait if shadows are involved it will affect only one row of the string and remaining strings will be operate without any disturbances so we will get full power. When we compare with power generation the portrait is the best option for this issues because it generate more power when compare to the portrait (refer Fig 1.9).

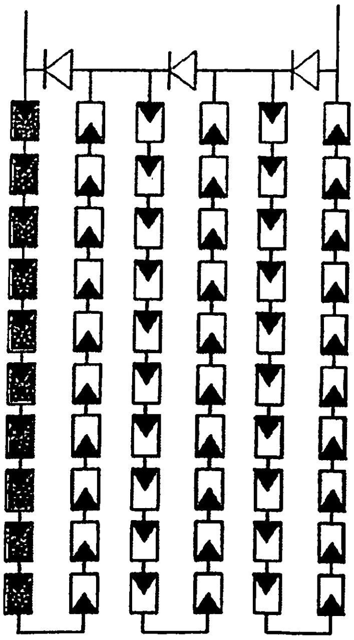


Fig 2.9 LONGITUDINAL SHADOWS ON PORTRAIT MODE **(Ref: www.sciencedirect.net)**

2.4 SOLAR PHOTOVOLTAIC MODULE

A photovoltaic system is a system which connects one or more panel to convert light energy to electrical energy. It consists of multiple panels which includes solar photovoltaic module, electrical and mechanical components and mounting. The PV cells are made up of semiconductor material such as silicon. The single cell which produces the power is not sufficient for any loads so the number of modules connected together to generate more power and used to power a load.

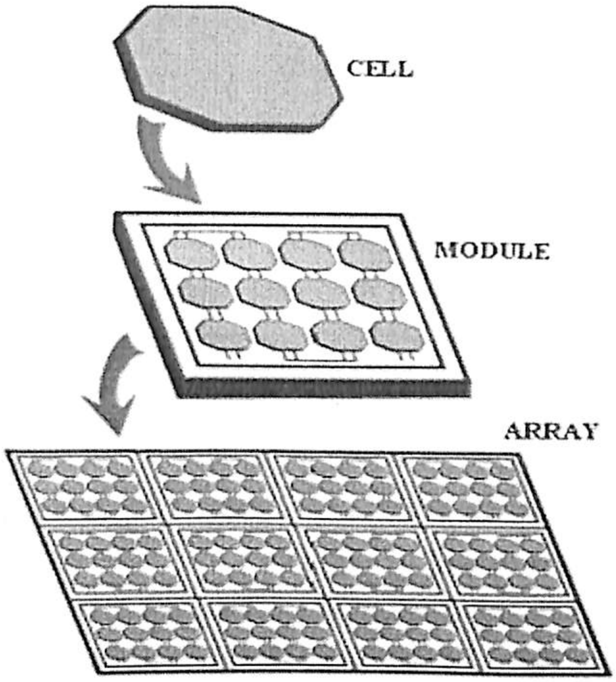


Fig 2.10 FORMATION OF SOLAR MODULE **(Ref: www.dailygreenpost.com)**

From the picture Fig 2.4 we can note that first it will be a single cell and then number of cell connected together to form a module and number of module connected together to form a array. Due to low voltage generated in a single cell typically around 0.6V of several cells connected together forms a module. When the cells are connected in series (for high voltage) and when it is connected in parallel (for high current). Diodes will be added for the cells to avoid reverse currents, in case of partial shaded or total shaded or during night time that we will discuss in the next chapter.

The power that produced from the single solar photovoltaic module is not sufficient to meet the requirement for homes or business. So number of modules connected together to form solar array (refer 2.4). The power that produced from the solar panel is DC current and that has to be converted into AC power through inverter. So the power can be used for the motors, lights, loads etc.

2.5 ROLE OF BYPASS DIODE

The bypass diodes are the standard addition for the solar panels. The function of bypass diode is to avoid the hotspot phenomenon which causes heating and even fire when the light is not diffused equally in the solar panels. Normally 20 cells will wire for one bypass diode.

When the module is connected in series with other modules if there is any partial shadings which may cause reverse voltage across the shaded area on the module. So the current generated will forced to the shaded area of the module. When the bypass diode is wired parallel with the PV cell strings, such a forced current will bypass through the diode so this will minimize the heating in the shaded potion which leads to hotspot, current loss and damage to the module.

Problem caused if the bypass diode is not connected

1. One single solar cell with shadows it will affects the whole sting it will kills the production of power.
2. Because of the overheating it may cause fire so that hotspot will create.

2.5.1 CASE 1: (NO BYPASS DIODE)

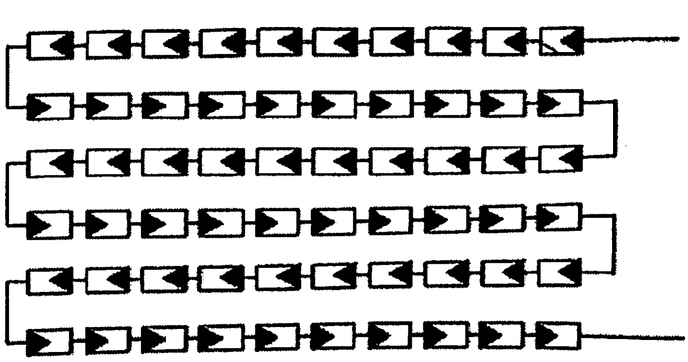


Fig 2.11 MODULE WITHOUT BYPASS DIODE **(Ref: www.sciencedirect.net)**

From the picture Fig 2.5 we can see that it has totally 60 cells which are connected in series and totally 6 strings are there that means 10 cells in each string without any bypass diode. If the modules are without any shadows then it will generate full power. If the modules are under partially shadows and has no bypass diode the current generated from the non shaded area will forced to the shaded areas the potential difference in these shaded potion of solar cell will be very high when the current passes through the high potential cell it will get heated and leads to hotspot phenomena (refer fig2.6), module will be damaged may be it leads to fire so to protect from this bypass diode is needed.

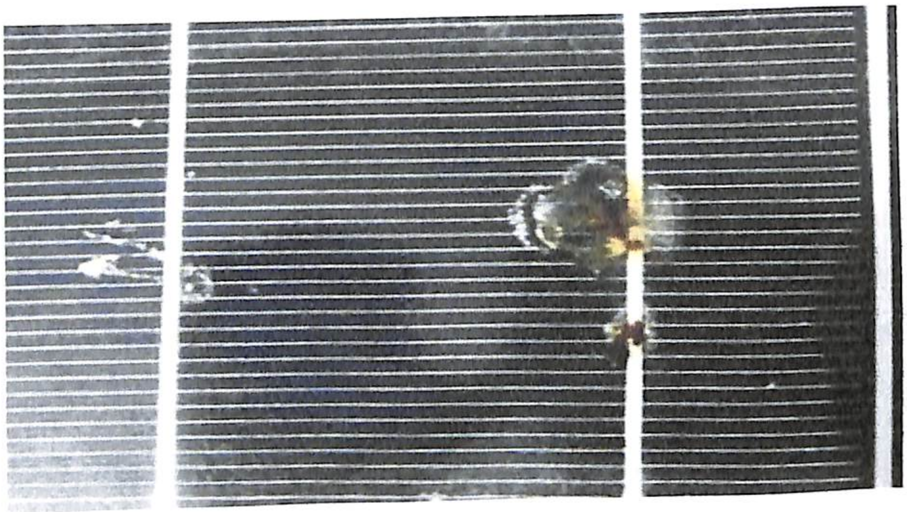


Fig 2.12 SOLAR MODULE WITH HOTSPOT **(Ref: www.sciencedirect.net)**

2.5.2 CASE-2: (WITH BYPASS DIODE)

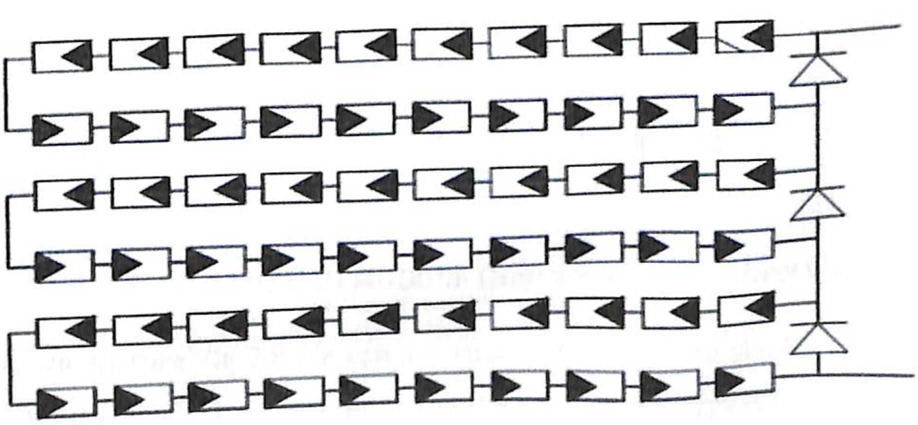


Fig 2.13 MODULES WITH BYPASS DIODES **(Ref: www.sciencedirect.net)**

From the picture Fig 2.7 we can see that 3 bypass diodes are connected parallel that means each diode will take care of 20 cells. If it is not shaded then it will generate full power at that time bypass diode is in reverse bias mode. If it is under partially shaded the current generated from the non shaded areas will forced to the shaded areas at that time the bypass diode will activate which has low potential difference when compare to the high potential difference involved in the shaded cell region. The current will always travel through the low potential difference side so the bypass diode will not allow the current to flow in the shaded region it will bypass the current at that time the bypass diode will be in forward bias. So this will avoid the hotspot, current loss and may be fire.

All the PV modules are fitted with internal bypass diode and are connected with junction box. Diode can be placed for every cell but it is very expensive and also the junction box will be very big that's the reason we are connected 20 cells for one bypass diode (refer Fig 2.7). If any bypass diodes are defective we can change the bypass diode in the junction box.

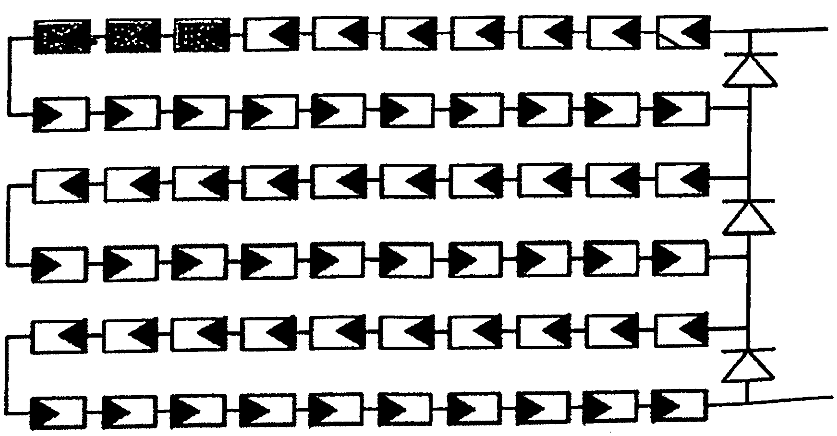


Fig 2.14 PARTIALLY SHADED MODULE **(Ref: www.sciencedirect.net)**

From the picture Fig 2.8 we can see that only 3 cells are shaded even though it is only 3 cells but it will affects the whole string the current will bypass through the diode but the power generates from the solar panel will be less. The remaining strings will generated the full power but comparatively we will get less power than the non shaded modules.

2.6 SOLAR PV SYSTEMS

Basically solar PV systems can be connected in two ways. The first method is the generated power can be stored in battery and then we can use whenever we needed and second method is the generated power can be directly connected to the grid. Both the systems are briefly explained below.

2.6.1 SOLAR GRID CONNECTED SYSTEM:

From the picture Fig 2.9 we can see the connection diagram first the power is generated in the PV array by the use of sunlight (refer Fig 2.1). The power produced from the PV array is the DC power but we require AC power so to convert DC to AC inverter is used. In between these two the DC side isolation switch is placed because if any fault occurs in the DC side then we should switch off for the further proceedings (refer Fig 2.9). The AC isolation switch is also separately placed. After that main fuse box is placed in case any fault occurs or over loaded this will activate to protect the other components then the AC power is directly connected to the grid.

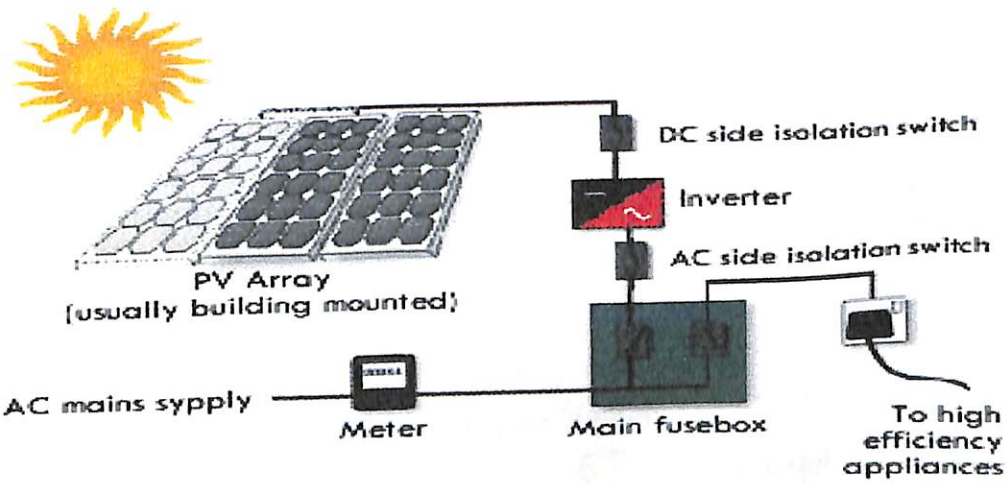


Fig 2.15 SOLAR PV GRID CONNECTED SYSTEM **(Ref:solarshop.co.uk)**

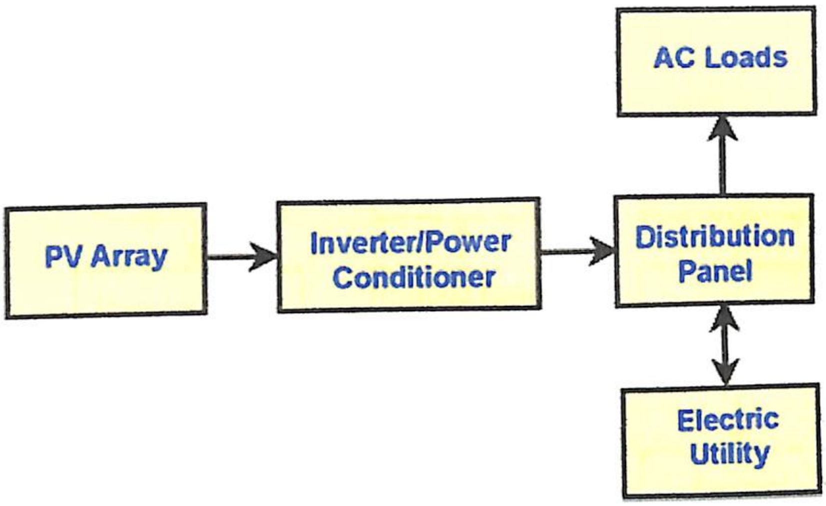


Fig 2.16 SOLAR PV GRID CIRCUIT DIAGRAM **(Ref: www.fsec.ucf.edu)**

2.6.2 SOLAR BATTEY BANK SYSTEM:

From the picture Fig 2.11 we can see the connection diagram first the power is generated in the PV array by the use of sunlight (refer Fig 2.1) that generated power will be stored in the battery. In between these two the charge controller is placed because the battery should not be over loaded and also under loaded so to restrict from this charge controller is placed. From the battery the power moves to the inverter the function of inverter is to convert DC to AC power. Then from the inverter the AC power can be used for the electrical appliances.

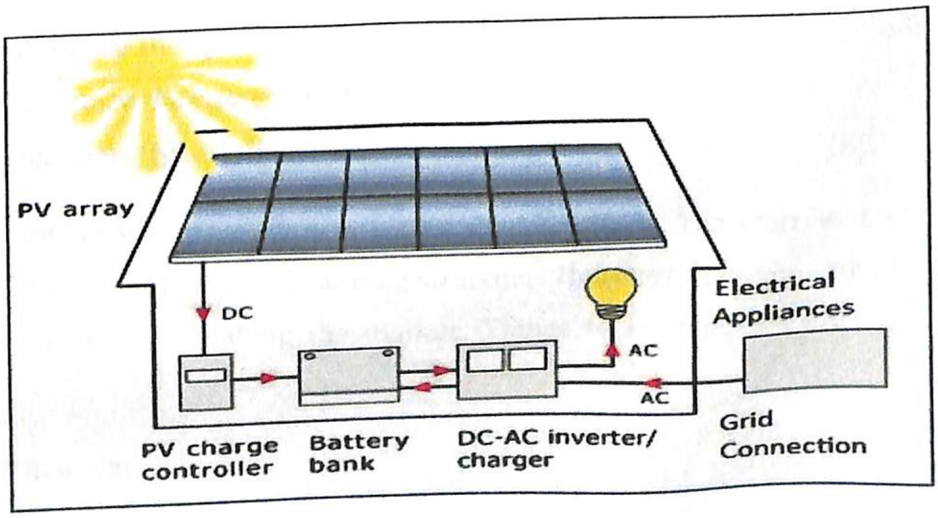


Fig 2.17 SOLAR PV BATTERY CONNECTED SYSTEM
(Ref: solarshop.co.uk)

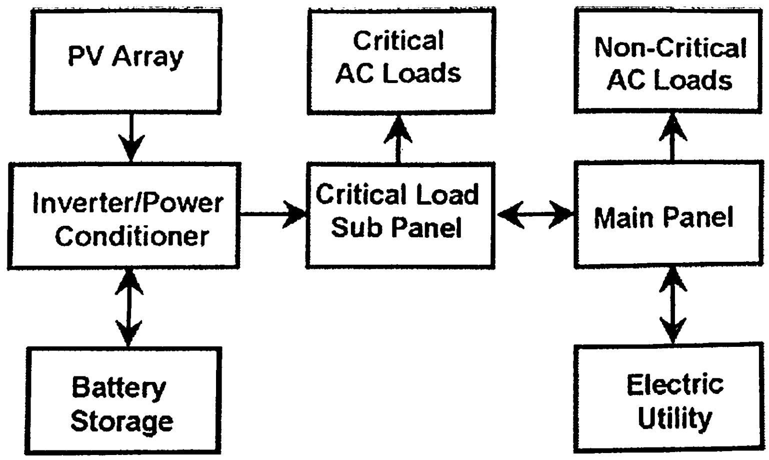


Fig 2.18 SOLAR PV BATTERY CIRCUIT DIAGRAM **(Ref: www.fsec.ucf.edu)**

2.7 MODULE MOUNTING SCHEME PLAYS AN IMPORTANT ROLE

If enough space is available then there is no specific issue to install the PV module. However, solar PV installations are increasing rapidly in highly populated urban areas. Most of the installations are rooftop. Therefore, it is highly desired to understand and optimize the way PV module are installed in order to,

1. Minimize the space required
2. Maximize the energy yield
3. High density installed

which will leads to increase the row – row shadow effects. Therefore to overcome these effects by the means of desired mounting structure. Therefore, mounting structure plays an important role while installing the module. Things to be consider while installing the module

1. Tilt angle
2. Geographical site
3. Pitch
4. Best utilization of available site.

TILT ANGLE:

Tilt angle plays an important role to optimize the maximum energy yield but it differs from different geographical location. To extract the maximum power from the solar panel we need to point them in the direction that capture the most sun. Tilt angle can be fixed or variable mode because it differs from climatic change. Solar panel always should face in the south direction if we are in the northern hemisphere and it should always face north direction if we are in the southern hemisphere. If latitude increases tilt angle will increase the example are given below (refer table 2.1)

LOCATION	LATITUDE	TILT ANGLE
COIMBATORE	11.01	10
PUNE	18.52	15
DELHI	29.01	25

Table 2.1 DIFFERENT TIL*T ANGLE FOR DIFFERNET LOCATION*

GEOGRAPHICAL SITE:

The power by which the solar panels extract that depends on the geographical site. The country like India has more than 300 days of sunshine in a year so we can extract maximum power from solar. India has high level of solar radiation and it receives an average 4-7 KWh/m2 of solar energy daily in which Gujarat and Rajasthan has an average 6-7 KWh/m2 is the most (refer Fig 1.1). Each geographical site has its own latitude and longitude and the tilt angle will depends on latitude and this will tells the energy yield of a particular site (refer table 2.2). The example of different geographical sites is listed below.

The example for 120KWp

LOCATION	LATITUDE	TILT ANGLE	ENERGY YIELD
DELHI	29.01	25	208.22
PUNE	18.52	15	192.06
BANGALORE	12.98	15	191.65
COIMBATORE	11.01	10	181.95

Table 2.2 ENERGY YIELD ARE DIFFERENT LOCATION

So from this table we can understand that Delhi has a high energy yield where as Coimbatore has less energy yield. So location plays an important role while mounting.

PITCH:

Pitch is defined as the distance between the mid of the two panels. Pitch is also depends on the latitude and longitude for the particular site. If the pitch distance is high then there will be any inter row shadows so that we can extract more power, but if we reduce the pitch distance to install more panel in the given area we should consider the row shadows otherwise the generated power will reduce.

BEST UTILIZATION OF GIVEN SITE:

Before installing the panel we should see how we can utilize the given site in a best way. Best utilization includes

1. Free of shadows
2. Maximum energy yield.

CASE -1:

For a particular given area we are installing the panels that too shadow free panels and we are installing 60KWp panels. We are getting the maximum performance ratio of 80% and we will get the energy. I am taking 300 numbers of days and I am extracting 72MWh/year.

CASE -2:

For the same given area which we taken in the case -1 somehow we are installing more panels and the capacity is of 100KWp. So the investment is more because of more panels and the performance ratio is reduced in this case it will be around 60%. I am taking same 300 numbers of days and I am extracting more energy than the previous case 90MWh/year.

So this depends on the customer if he is ready to invest more money then he will get more power. So in this way we can utilize our given area in the best manner.

3. RESULTS AND DISCUSSION

3.1 EFFECTS OF PV MODULE UNDER SHADOWS

Here we are going to see how the PV module behaves under shadow conditions both in portrait as well as landscape. Here the shadows are involved in longitudinal side of the panel. In the I-V graph it is represented in width, length and ideal condition. Width represents the portrait mode and length represents the landscape mode and ideal condition represents the no shadows. Now we will see the behavior of different conditions in terms of current, voltage and power.

3.1.1 IDEAL CONDITION:

In the ideal condition there is no any shadows involved so we will get the maximum current and power from the output (refer Fig 3.1).

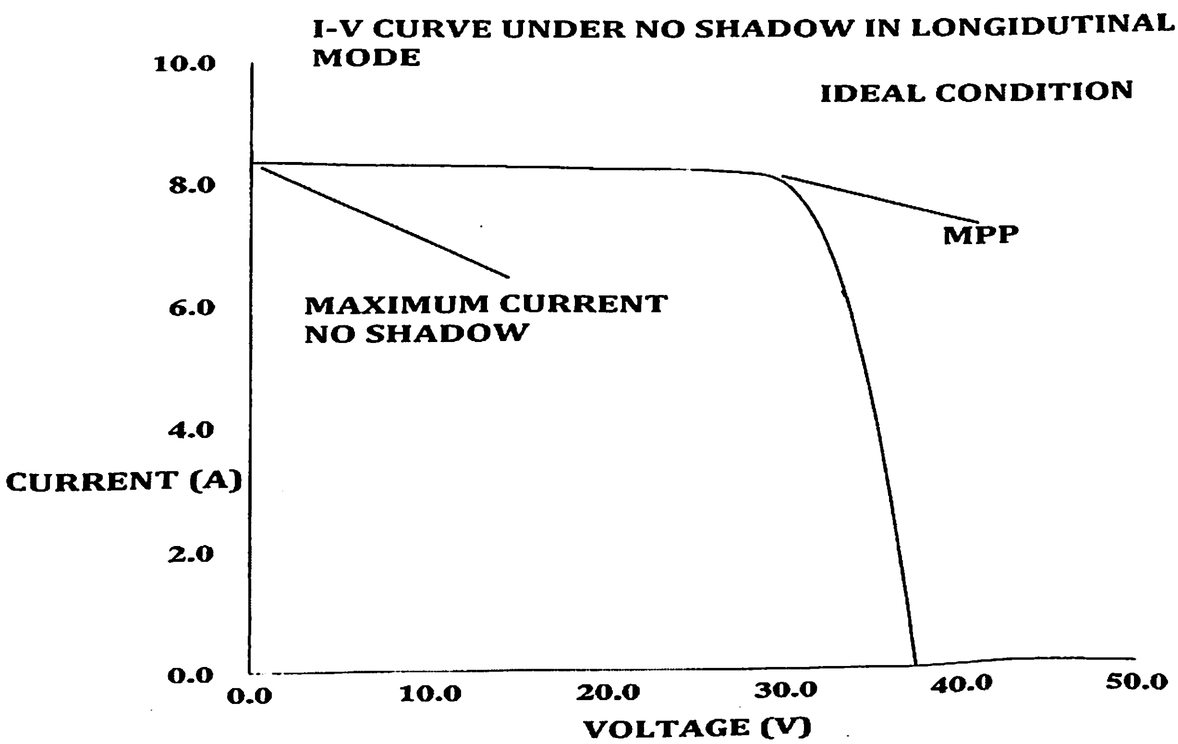


Fig 3.1 IDEAL CONDITION (NO SHADOWS)

$$I_{pm} = 7.864 \quad A$$

$$V_{pm} = 30.062 \quad V$$

$$P = 236.40 \quad W$$

If there are no shadows we will get the maximum current and power (refer Fig 3.1).

3.2 SHADOWS INVOLVED IN WIDTH (PORTRAIT)

15 % SHADOWS IN WIDTH:

In this condition shadows is affected by 15 % in width that means in portrait condition. Current will decreases when compare to the previous condition because of area of shadows increasing (refer Fig 3.2). Let's see how it behaves,

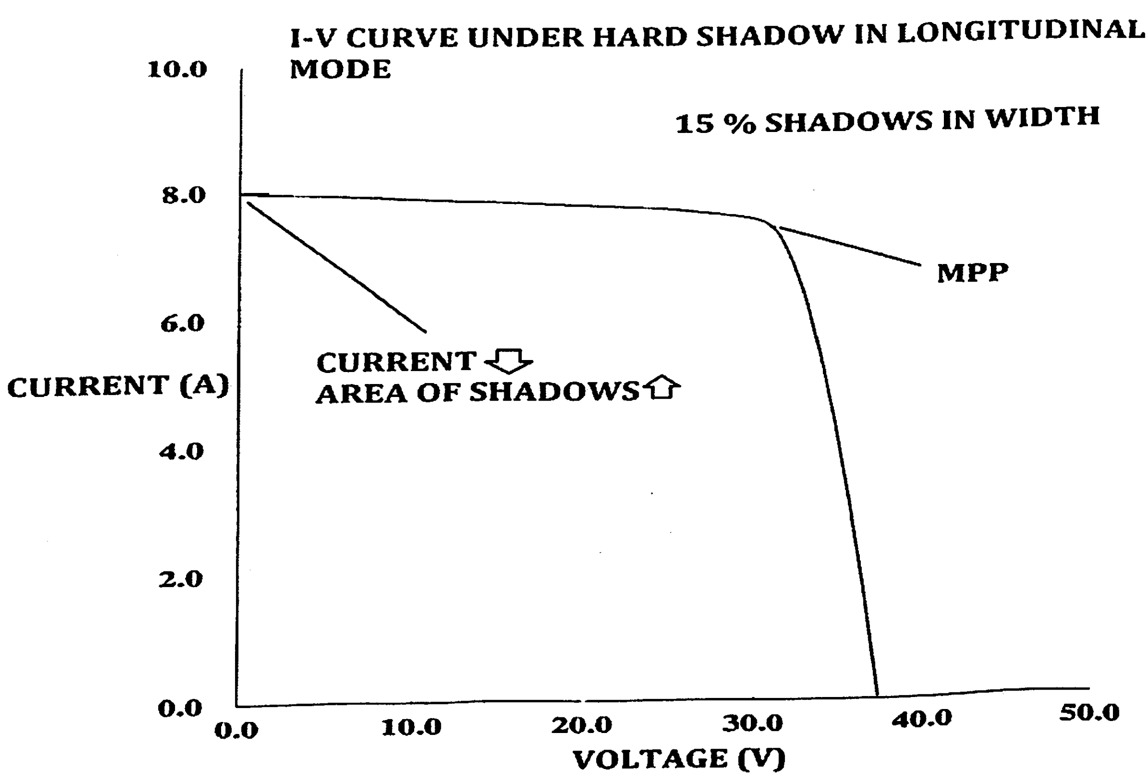


Fig 3.2 15 % SHADOWS IN WIDTH (PORTRAIT)

$$I_{pm} = 7.422 \quad A$$

$$V_{pm} = 30.806 \quad V$$

$$P = 228.64 \quad W$$

By this reading we can easily understand that when shadows increasing current is decreasing (7.864 to 7.422) and simultaneously the generated power is also decreasing (236.40 to 228.64).

30 % SHADOWS IN WIDTH:

In this condition shadows are affected by 30 % in width that means in portrait condition. The current is decreasing again from the previous cases because of area of shadows increasing. Let's see how it behaves,

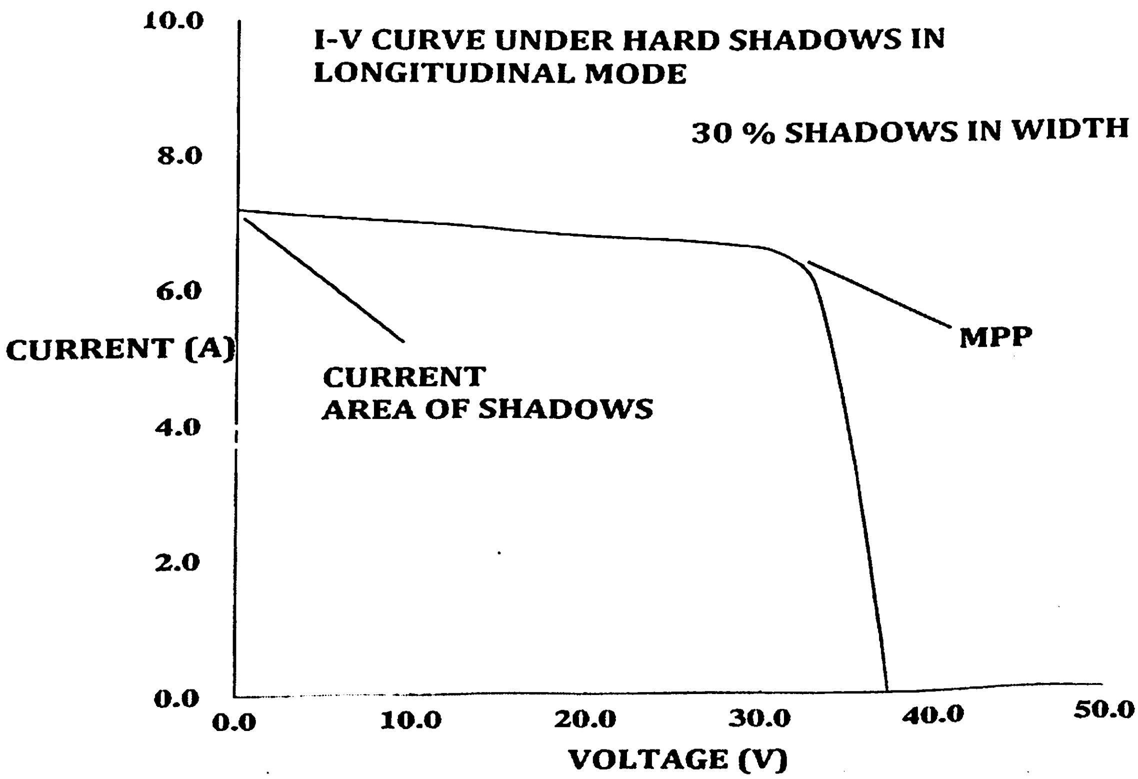


Fig 3.1.3 30 % SHADOWS IN WIDTH (PORTRAIT)

$I_{pm} = 6.328 \quad A$

$V_{pm} = 32.030 \quad V$

$P = 202.685 \quad W$

By this reading we can easily understand that when shadows increasing current is decreasing (7.422 to 6.328) and simultaneously the generated power is also decreasing (228.64 to 202.685).

50 % SHADOWS IN WIDTH:

In this condition shadows are affected by 50 % in width that means in portrait condition. The current is decreasing again from the previous cases because of area of shadows increasing. Let's see how it behaves,

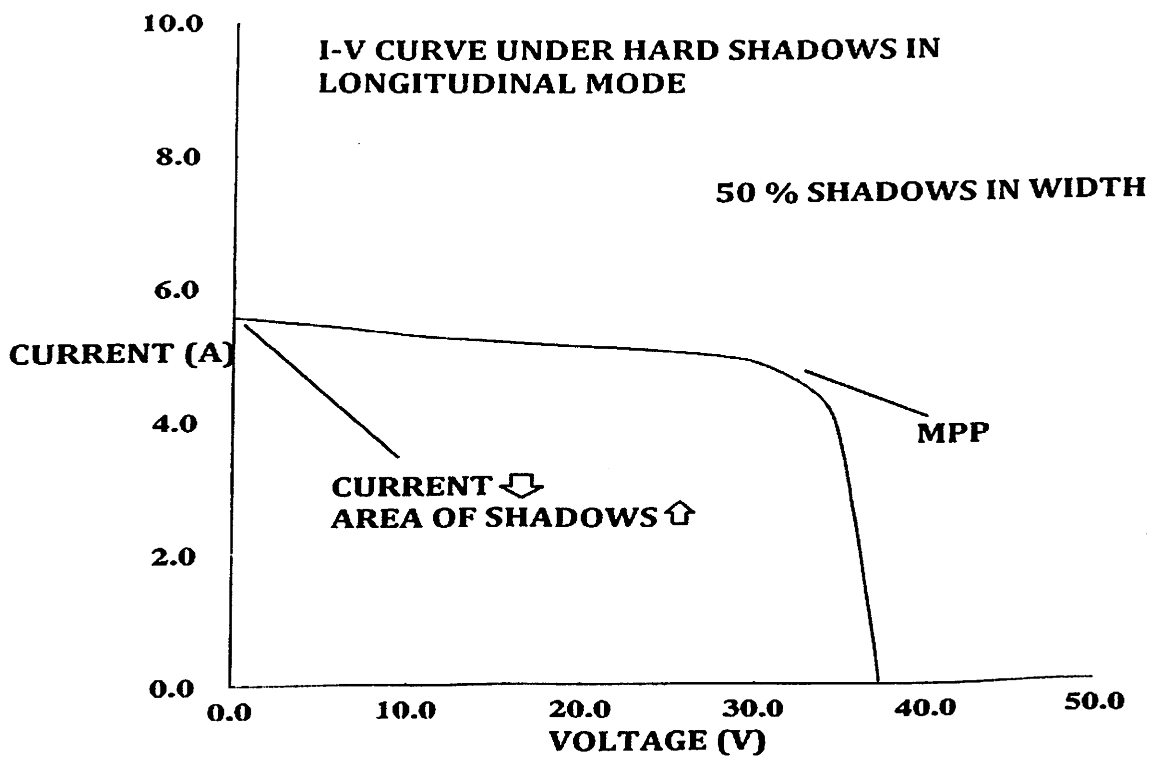


Fig 3.4 50 % SHADOWS IN WIDTH (PORTRAIT)

$I_{pm} = 4.626 \quad A$

$V_{pm} = 32.028 \quad V$

$P = 148.681 \quad W$

By this reading we can easily understand that when shadows increasing current is decreasing (6.328 to 4.626) and simultaneously the generated power is also decreasing (202.685 to 148.181).

75 % SHADOWS IN WIDTH:

In this condition shadows are affected by 75 % in width that means in portrait condition. The current is decreasing again from the previous cases because of area of shadows increasing. Let's see how it behaves,

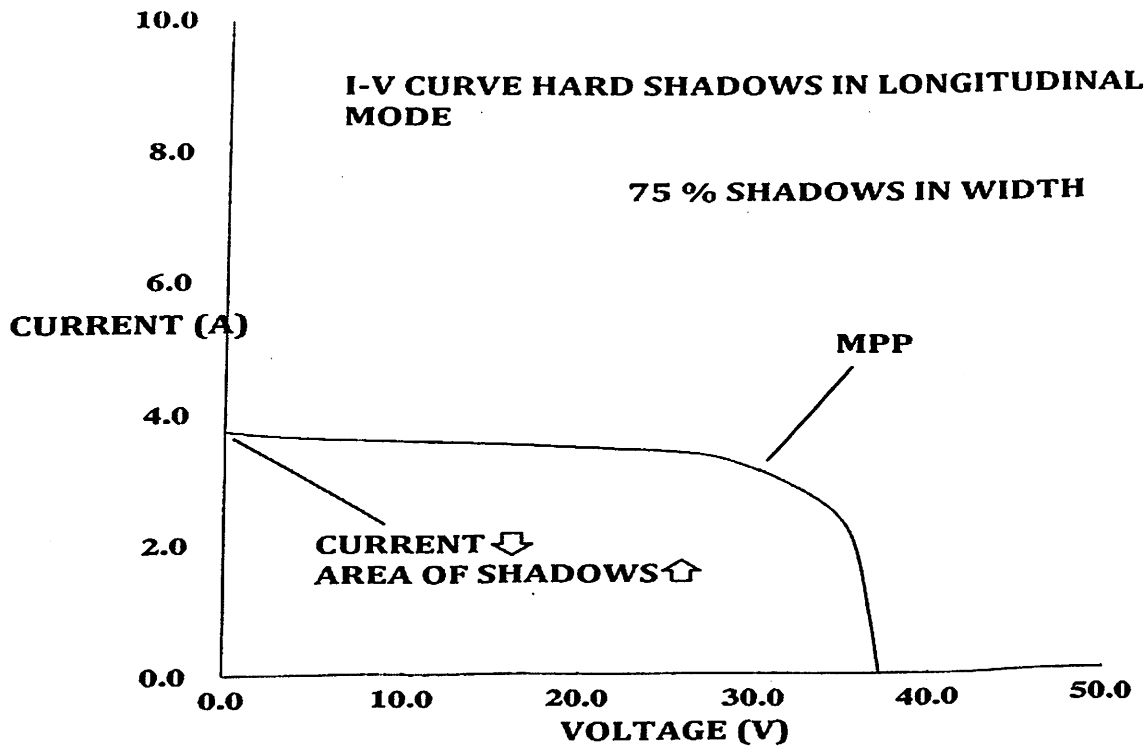


Fig 3.5 75 % SHADOWS IN WIDTH (PORTRAIT)

$I_{pm} = 3.120 \quad A$

$V_{pm} = 30.019 \quad V$

$P = 93.64 \quad W$

By this reading we can easily understand that when shadows increasing current is decreasing (4.626 to 3.120) and simultaneously the generated power is also decreasing (148.181 to 93.64).

100 % SHADOWS IN WIDTH:

In this condition shadows are affected by 100 % in width that means in portrait condition. The current is decreasing again from the previous cases because of area of shadows increasing. Let's see how it behaves,

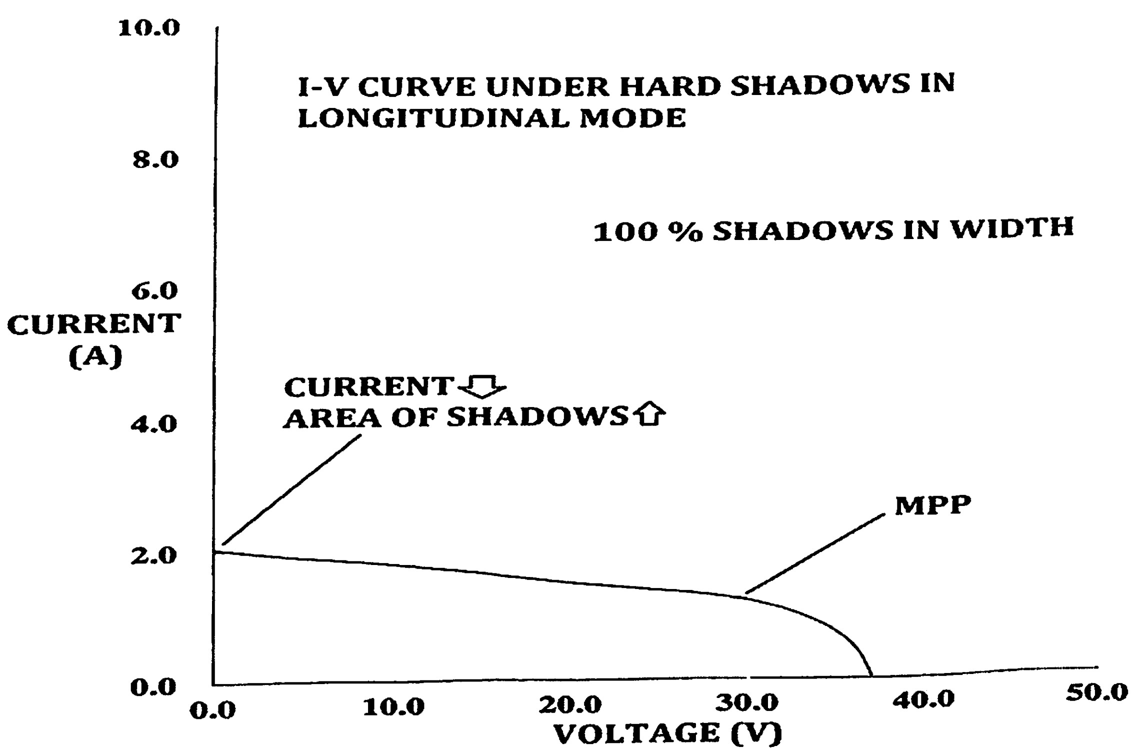


Fig 3.6 100 % SHADOWS IN WIDTH (PORTRAIT)

$$I_{pm} = 1.229 \quad A$$
$$V_{pm} = 29.306 \quad V$$
$$P = 36.01 \quad W$$

By this reading we can easily understand that when shadows increasing current is decreasing (3.120 to 1.229) and simultaneously the generated power is also decreasing (93.64 to 36.01).

3.2.1 I-V CHARACTERISTICS CURVE UNDER PORTRAIT SHADOWS:

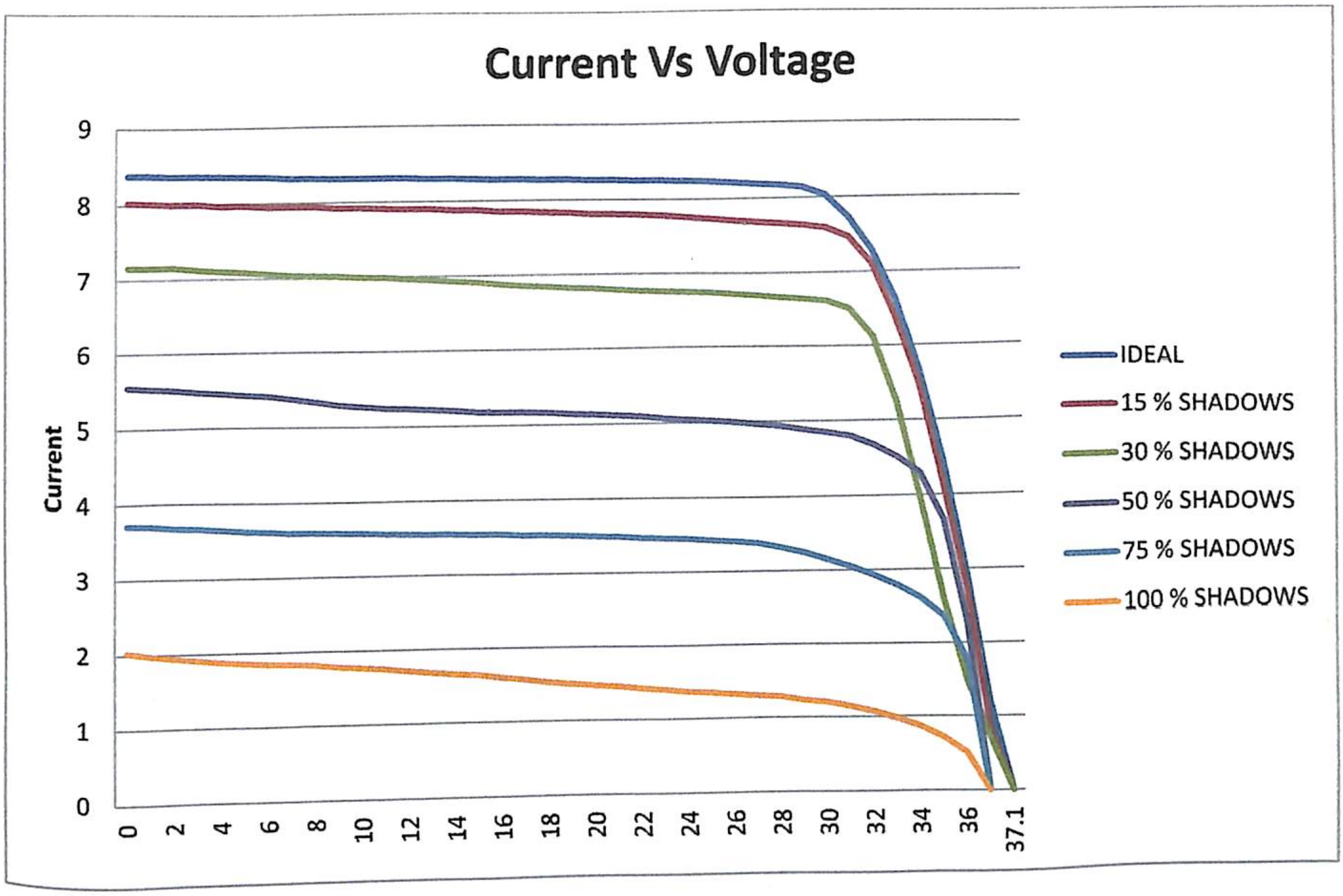


Fig 3.7 I-V CURVE UNDER HARD SHADOWS FOR PORTRAIT

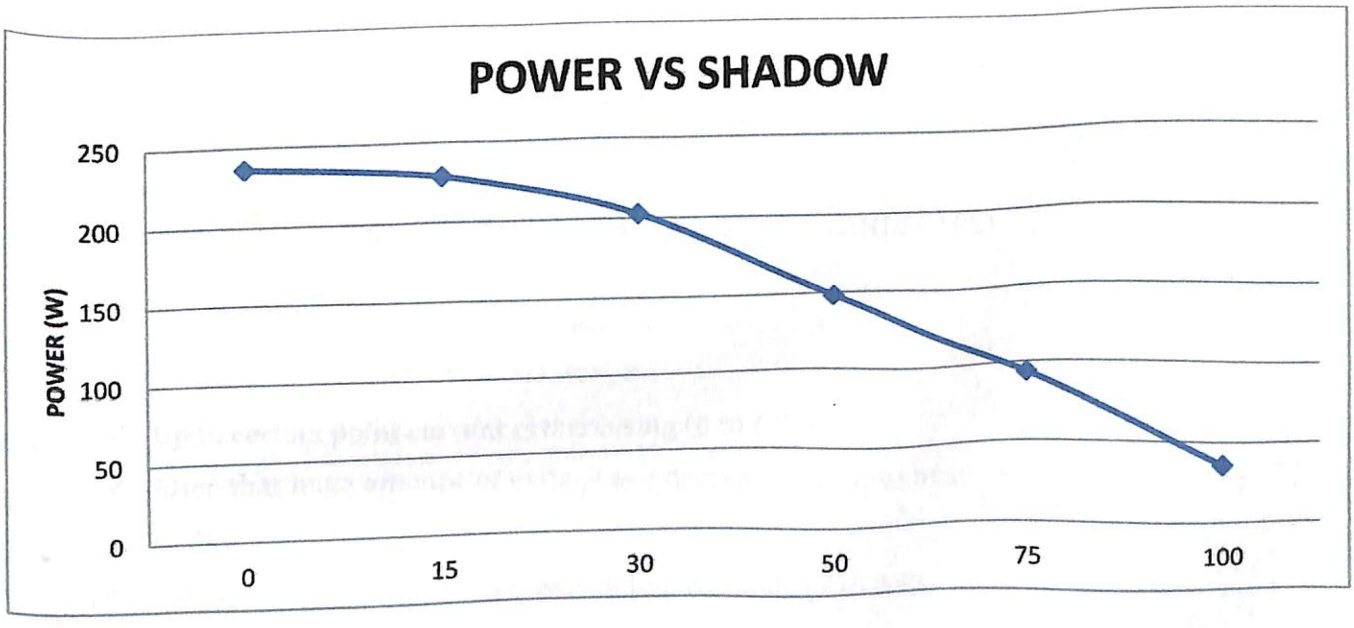


Fig 3.8 POWER VS SHADOW (PORTRAIT)

3.3 SHADOWS INVOLVED IN LENGTH (LANDSCAPE)

15 % SHADOWS IN LENGTH:

In this condition 15 % shadows are involved in length that means in landscape mode. Let's see how the current, voltage, power behaves,

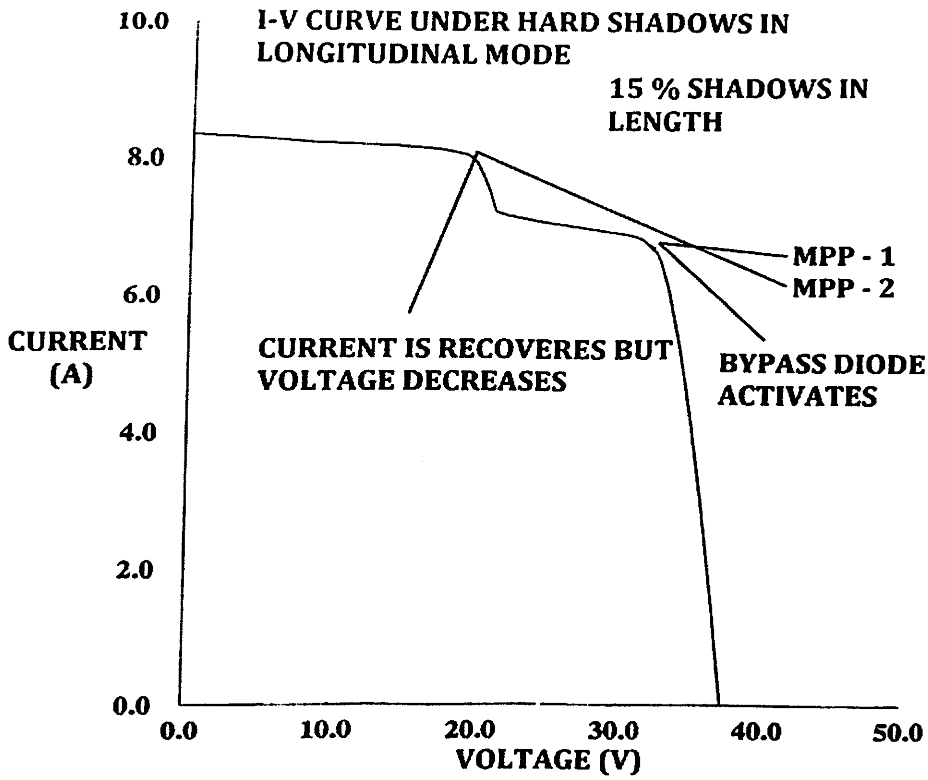


Fig 3.9 15 % SHADOWS IN LENGTH (LANDSCAPE)

$$I_{pm} = 6.756 \quad A$$

$$V_{pm} = 31.665 \quad V$$

$$P = 213.92 \quad W$$

- ✓ Up to certain point current is increasing (0 to 6.756).
- ✓ After that huge amount of voltage are decreases because of shadow effects (31.665 to 20).
- ✓ Current starts to recover because of bypass diode (7 to 8.4).

By this reading we can easily understand that when shadows increasing current is decreasing (7.864 to 6.756) and simultaneously the generated power is also decreasing (236.40 to 213.92).

30 % SHADOWS IN LENGTH:

In this condition 30 % shadows are involved in length that means in landscape mode. Let's see how the current, voltage, power behaves,

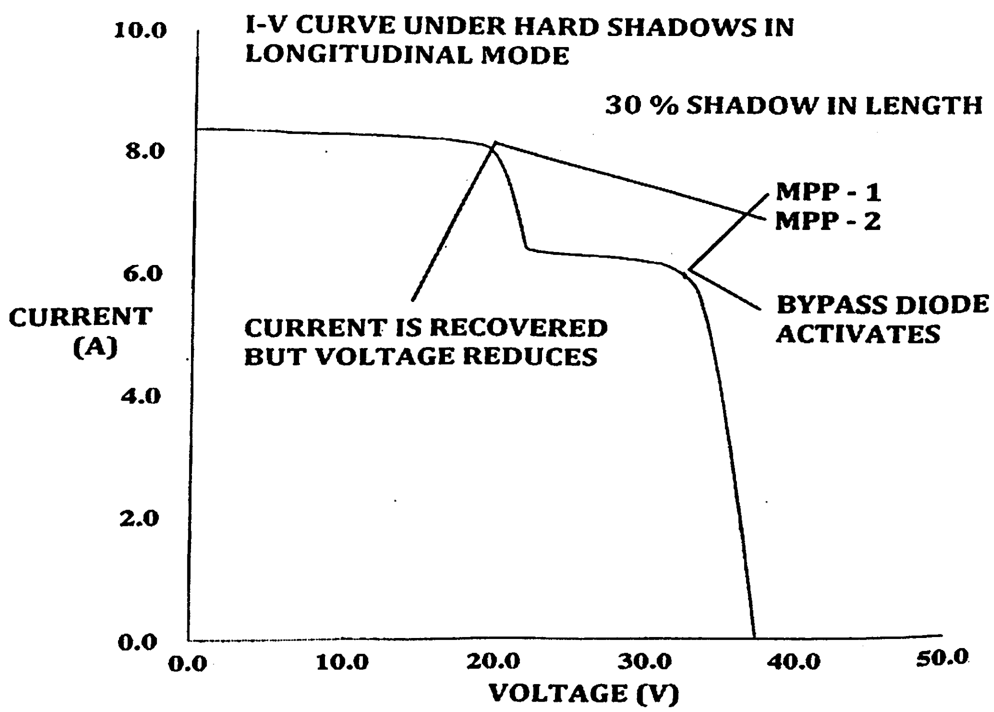


Fig 3.10 30 % SHADOWS IN LENGTH (LANDSCAPE)

$I_{pm} = 5.950 \quad A$

$V_{pm} = 32.036 \quad V$

$P = 190.61 \quad W$

- ✓ Up to certain point current is increasing (0 to 5.950).
- ✓ After that huge amount of voltage are decreases because of shadow effects (32.036 to 20).

✓ Current starts to recover because of bypass diode (6.2 to 8.4).

By this reading we can easily understand that when shadows increasing current is decreasing (6.756 to 5.950) and simultaneously the generated power is also decreasing (213.92 to 190.61).

50 % SHADOWS IN LENGTH:

In this condition 50 % shadows are involved in length that means in landscape mode. Let's see how the current, voltage, power behaves,

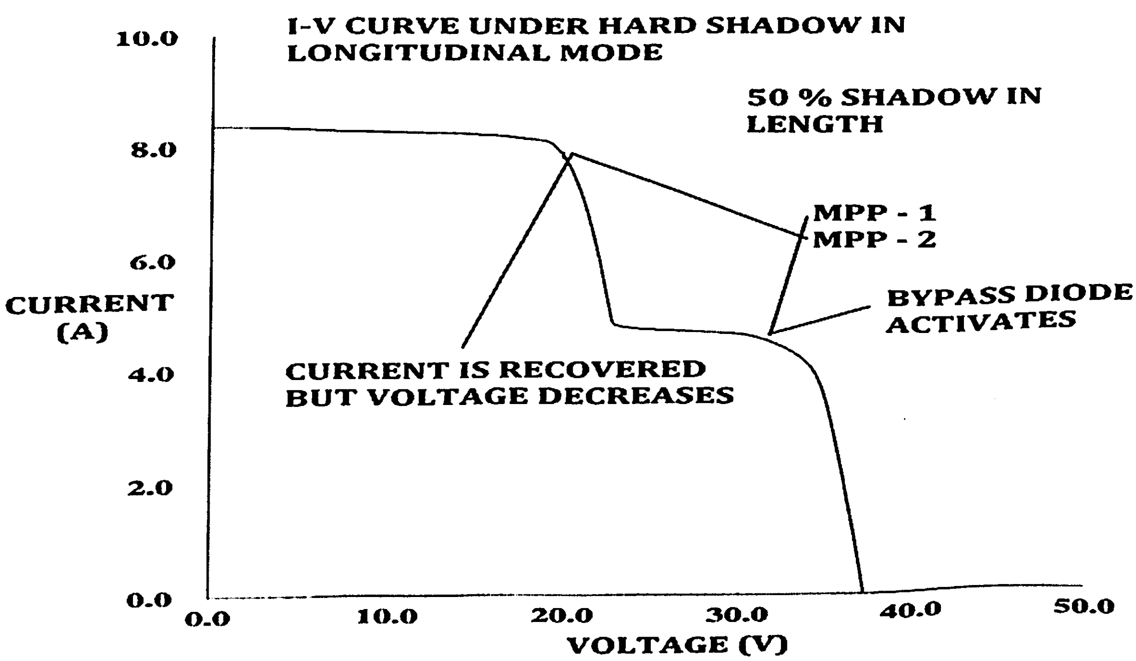


Fig 3.11 50 % SHADOWS IN LENGTH (LANDSCAPE)

$$I_{pm} = 7.893 \quad A$$

$$V_{pm} = 19.562 \quad V$$

$$P = 154.40 \quad W$$

✓ Up to certain point current is increasing (0 to 4).

✓ After that huge amount of voltage are decreases because of shadow effects (33 to 22).

✓ Current starts to recover because of bypass diode (4.2 to 8.4).

By this reading we can easily understand that when shadows increasing current is decreasing (5.950 to 4) and simultaneously the generated power is also decreasing (190.61 to 154.40).

75 % SHADOWS IN LENGTH:

In this condition 75 % shadows are involved in length that means in landscape mode. Let's see how the current, voltage, power behaves,

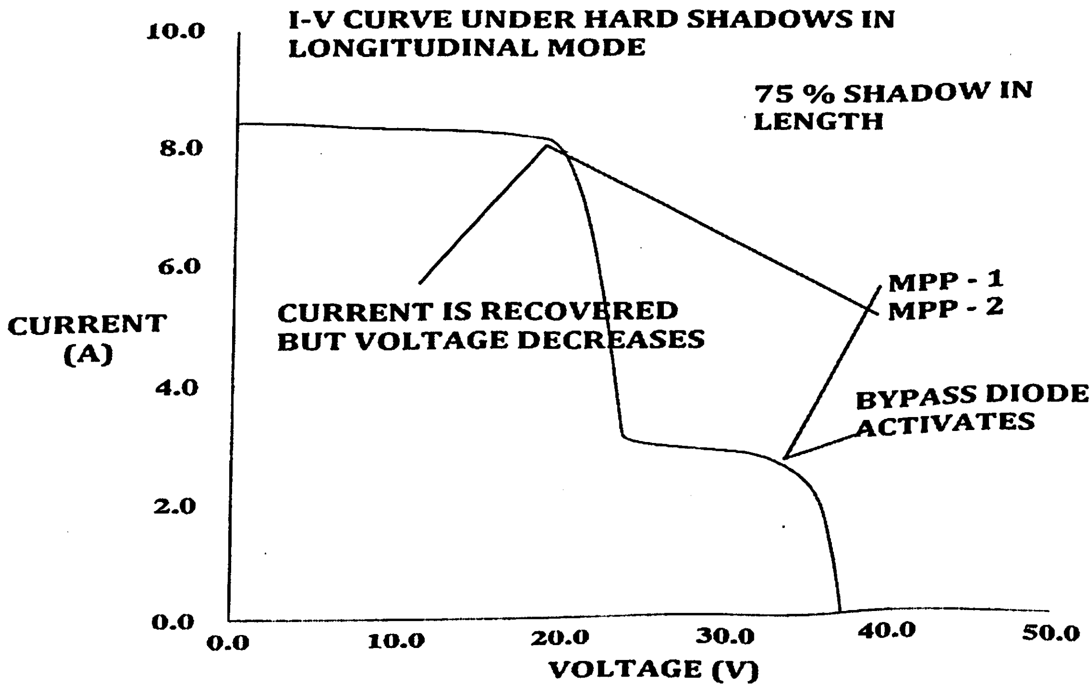


Fig 3.12 75 % SHADOWS IN LENGTH (LANDSCAPE)

$$I_{pm} = 7.909 \ A$$

$$V_{pm} = 19.528 \ V$$

$$P = 154.4 \ W$$

- ✓ Up to certain point current is increasing (0 to 2.3).
- ✓ After that huge amount of voltage are decreases because of shadow effects (33 to 22).
- ✓ Current starts to recover because of bypass diode (3 to 8.4).

By this reading we can easily understand that when shadows increasing current is decreasing (4.8 to 2.3), but the power generated in this condition is same. How? We can see it in later (refer 3.2.2).

100 % SHADOWS IN LENGTH:

In this condition 100 % shadows are involved in length that means in landscape mode. Let's see how the current, voltage, power behaves,

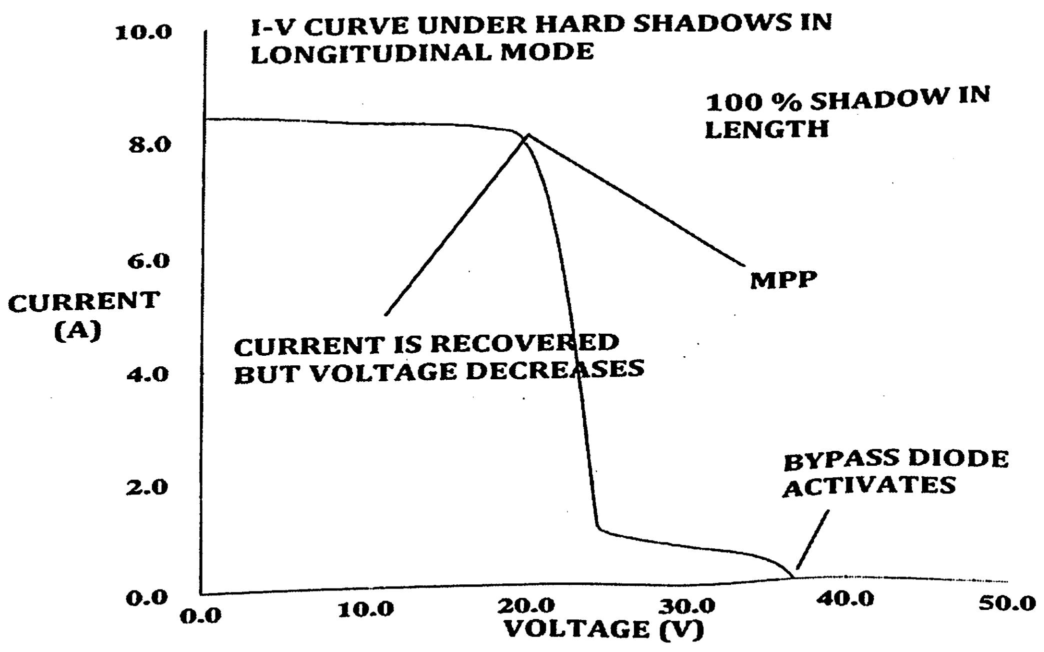


Fig 3.13 100 % SHADOWS IN LENGTH

$$I_{pm} = 7.9 \quad A$$

$$V_{pm} = 19.561 \quad V$$

$$P = 154.4 \quad W$$

- ✓ Because of 100 % shadows the bypass diode activates quickly and voltage started to decreases in the initial because voltage is fully dominated in the shadow region.
- ✓ Current starts to recover because of bypass diode (1 to 8.4).

By this reading we can easily understand that when shadows increasing current is decreasing, but the power generated in this condition is same. How? We can see it in later (refer 3.2.1).

3.3.1 I-V CHARACTERISTICS CURVE UNDER LANDSCAPE SHADOW:

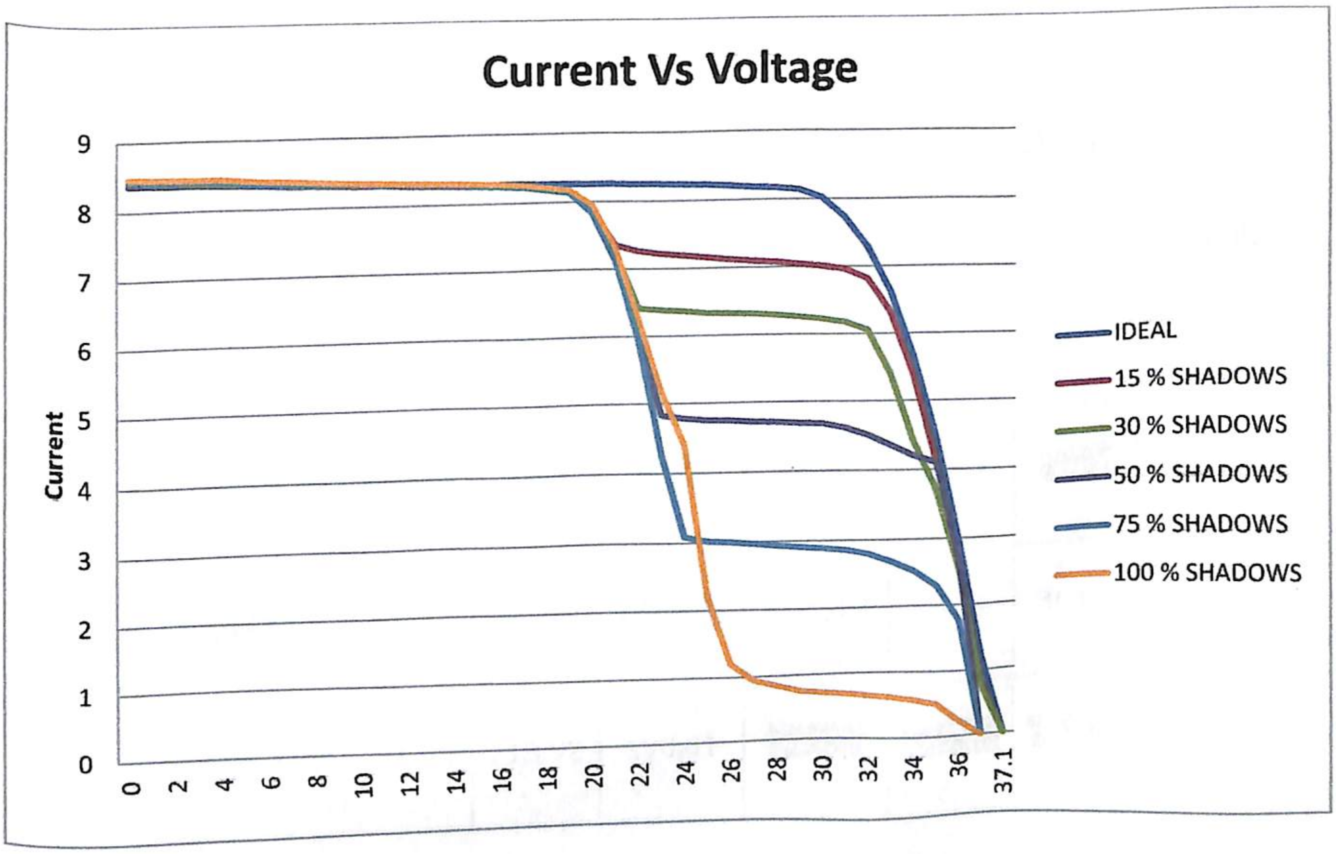


Fig 3.14 I-V CURVE UNDER HARD SHADOW OF LANDSCAPE MODE

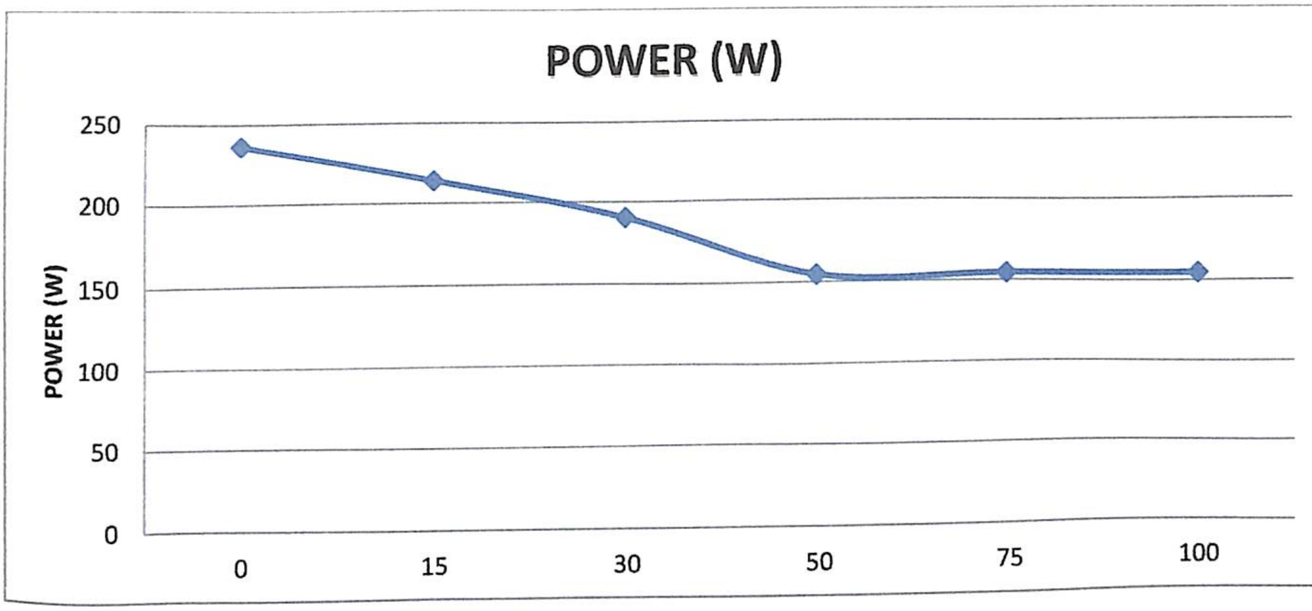


Fig 3.15 POWER VS SHADOW (LANDSCAPE)

3.4 EFFECTS OF POWER GENERATED UNDER SHADOWS:

Now we can see how much the power generated under shadows in both the conditions.

POWER (W)	IDEAL	15%	30%	50%	75%	100%
PORTRAIT	236.40	228.64	202.685	148.181	93.64	36.01
LANDSCAPE	236.40	213.92	190.61	154.40	154.40	154.40

Table 3.1 GENERATED POWERS UNDER SHADOWS

From the table (1.1) we can clearly under stood that the maximum power is generating under ideal condition because there is no any shadows involved at this condition. So we are getting the maximum power (refer Fig 3.1).

3.4.1 SHADOWS UNDER LANDSCAPE MODE:

When we see in the table (1.1) I have clearly noted that at 50%, 75%, and 100 % of shadows we are getting maximum power when compare to the portrait. But during the time of 15% and 30% shadows 10 cells are involved under shadow out of 60 cells so more power is lost (refer Fig 3.16). During at this time the bypass diode will be in reverse bias, but at the time of 50%, 75% and 100% shadows we are getting almost equal power, because during the time of 50% shadow the bypass diode will activate because of high potential difference in the solar cell so the current will pass through the bypass diode so we will lose almost 2 strings from the module. Similarly the same conditions for 75% and 100% because the same 2 strings will be lost during this condition. So we are getting almost the same power from the remaining cells.

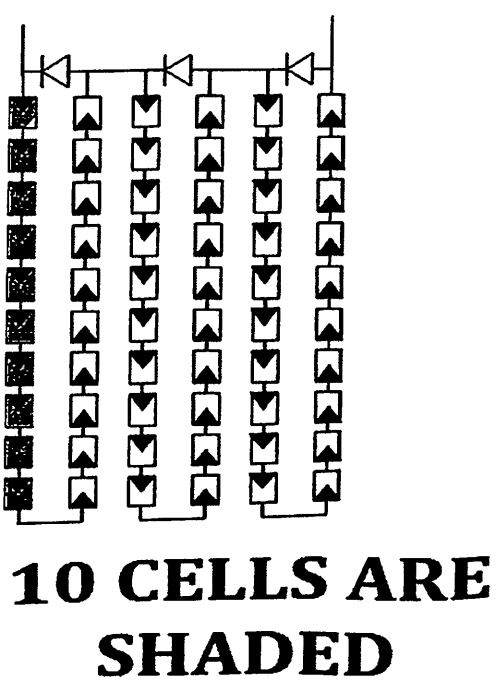
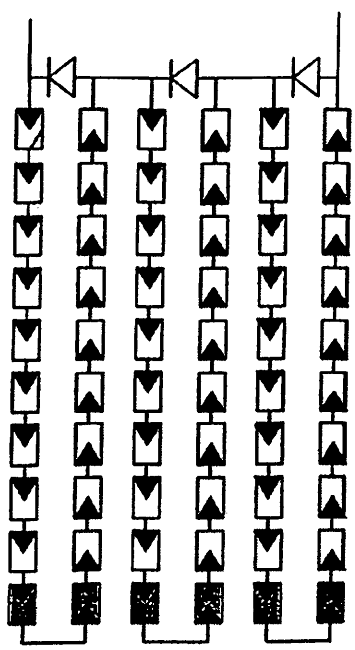


Fig 3.16 LONGITUDINAL SHADOW (LANDSCAPE)

3.4.2 SHADOWS UNDER PORTRAIT MODE:

When we see in the table (1.1) I have clearly noted that at 15% and 30% of shadows we are getting maximum power when compare to the landscape. Because 60 cells are there in which only 6 cells are under shadows so we are getting more power than the landscape (refer Fig 3.17). During at this time the bypass diode will be in reverse bias and it will not activate. But at the time of 50%, 75% and 100% shadows the bypass diode will activate and voltage is dominated by the shaded region and also has high potential difference so the current will pass through the lower potential difference that means through the diode so simultaneously the power also reduced.



6 CELLS ARE SHADED

Fig 3.17 LONGITUDINAL SHADOW (PORTRAIT)

3.5 PORTRAIT VS LANDSCAPE FOR DIFFERENT GEOGRAPHICAL SITES (ENERGY YIELD)

Now we are going to see the energy yield for different geographical site in terms of portrait and landscape mode. The energy yield will not constant for all the sites because each site has their own latitude, longitude, solar radiation etc... Energy yield will differ from all these parameters which are mention. The latitude and longitude for different cities are mention below. The different cities are

1. Delhi
2. Raipur
3. Chennai
4. Coimbatore
5. Bangalore
6. Pune
7. Gandhinagar

From this study we are going to find out

1. Maximum energy production for a particular site.
2. Optimum pitch distance for a particular site.
3. Energy production for different pitch distance.

The design part is done with the software called "PVsyst". The design is for 100KWp.

Each panel	=	250Wp
Total panel installed	=	400
Each inverter	=	20KW
Total inverter used	=	5
Data Source	=	NASA-SSE SATELITE
NOCT	=	46

Mismatch	=	1%
Ohmic losses	=	1%
Soiling losses	=	1%
Summer oper.Temp	=	50
Winter oper.Temp	=	20

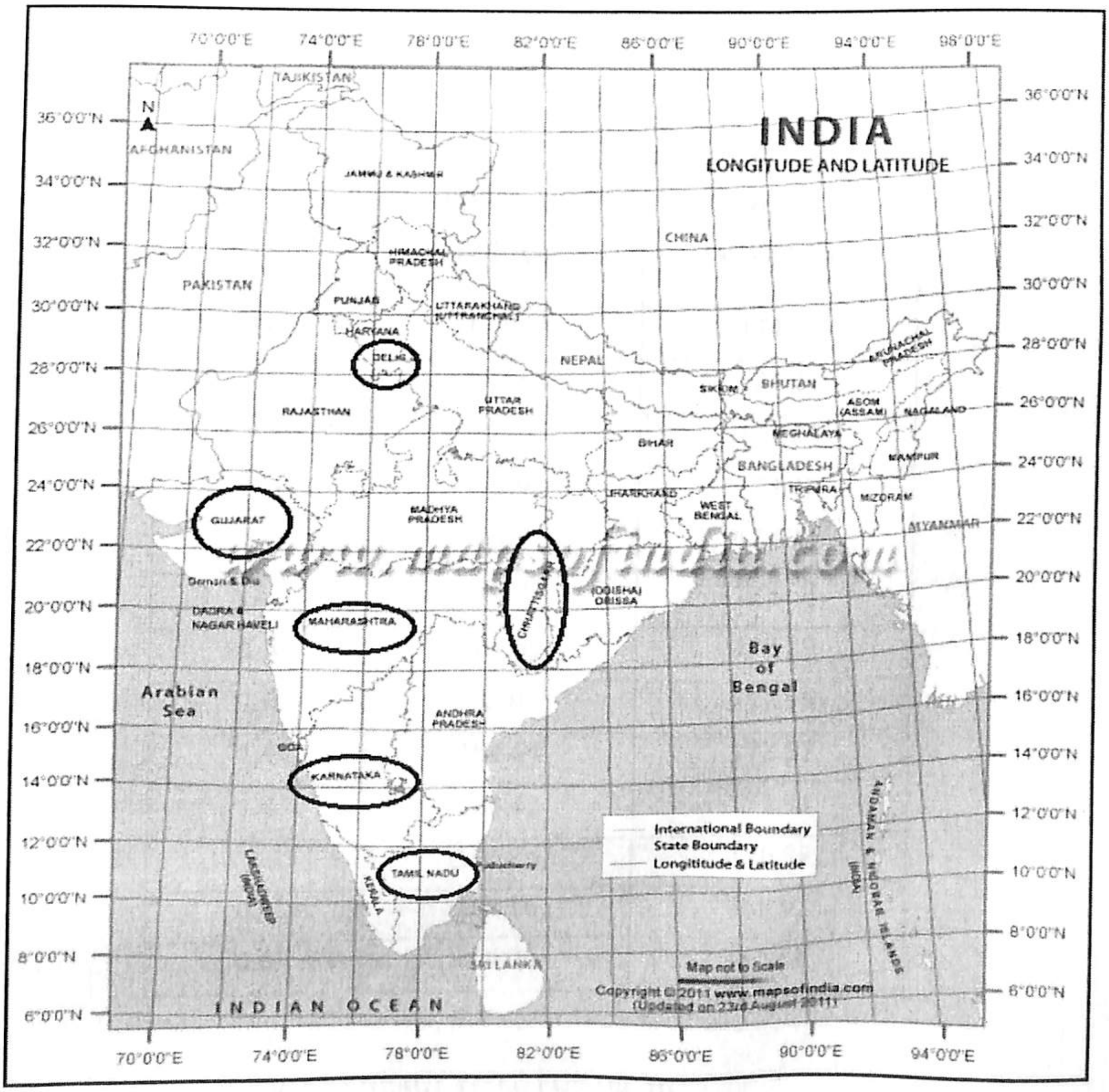


Fig 3.18 LATITUDE AND LONGITUDE FOR DIFFERENT CITIES

3.5.1 CASE-1 (DELHI):

Latitude = 29.01

Longitude = 77.38

Altitude = 600 M

Tilt angle = 25

Initial pitch = 3.34+3 = 6.4 m

PITCH (m)	PORTRAIT (MWh/year)	LANDSCAPE (MWh/year)
3	172.97	174.32
2.8	172.68	174.21
2.6	172.3	174.08
2.4	171.91	173.93
2.2	171.31	173.75
2	170.72	173.53
1.8	169.69	173.29
1.6	168	172.95
1.4	164.64	172.51
1.2	160.42	171.91
1	156.84	170.95
0.8	153.16	168.87
0.6	149.05	165.88

Table 3.2 ENERGY YIELD FOR DELHI

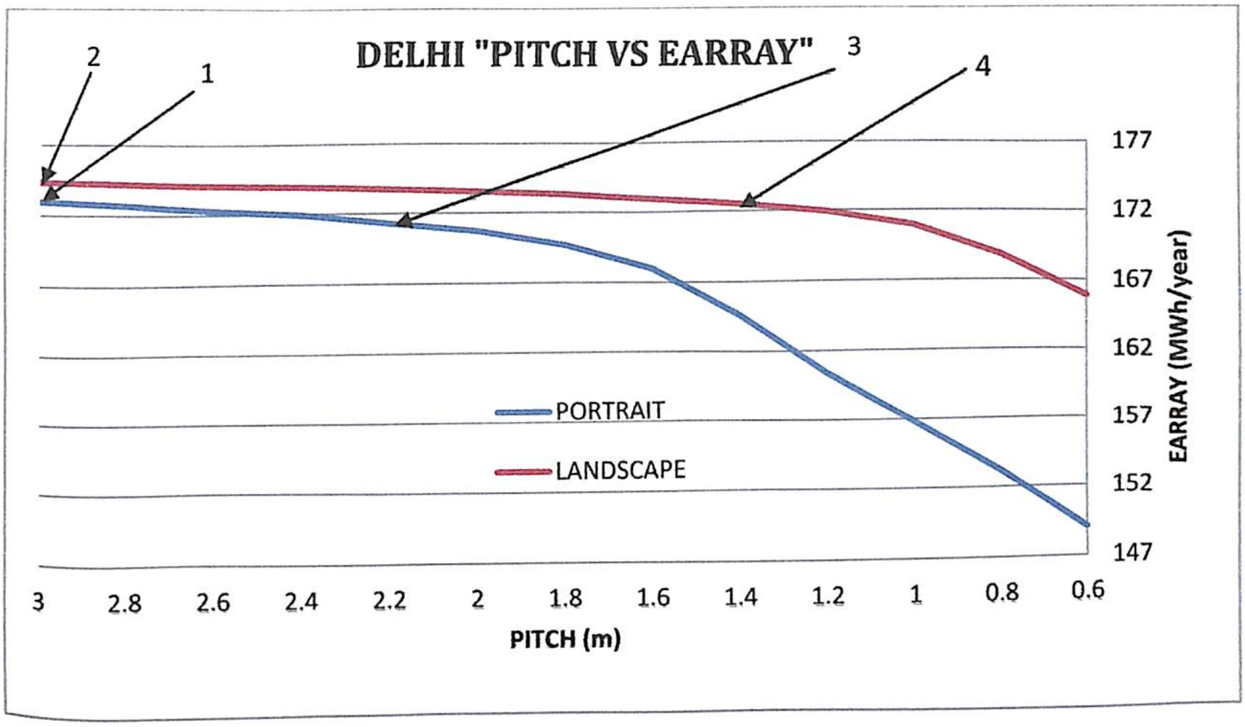


Fig 3.19 PITCH VS EARRAY FOR DELHI

1 Maximum energy yield in portrait mode (3m)= 172.97 MWh/year
2 Maximum energy yield in landscape mode (3m)= 174.32 MWh/year
3 The optimum pitch for portrait mode is = 2.2 m
4 The optimum pitch for landscape mode is = 1.4 m

From this graph we can note that after a certain pitch distance the value of portrait mode is reducing quickly when compare to the landscape mode (refer Fig 3.19). Because when we reduce the pitch distance the shadow of one shed will affects the other shed so if it is connected in portrait mode it will affects the whole string of the module that's why the value of energy yield in portrait mode is reducing much. When we take the landscape mode only one string will affect so the remaining strings will generate the power that's why energy yield is high in this case.

3.5.2 CASE-2 (BANGALORE):

Latitude = 12.98

Longitude = 77.58

Altitude = 920 M

Tilt angle = 15

Initial pitch = 3.34+3 = 6.4 m

PITCH (m)	PORTRAIT (MWh/year)	LANDSCAPE (MWh/year)
3	159.71	160.13
2.8	159.65	160.09
2.6	159.58	160.04
2.4	159.49	160
2.2	159.39	159.94
2	159.28	159.86
1.8	159.13	159.76
1.6	158.9	159.66
1.4	158.65	159.51
1.2	158.27	159.34
1	157.71	159.08
0.8	156.9	158.73
0.6	155.01	158.14

Table 3.3 ENERGY YIELD FOR BANGALORE

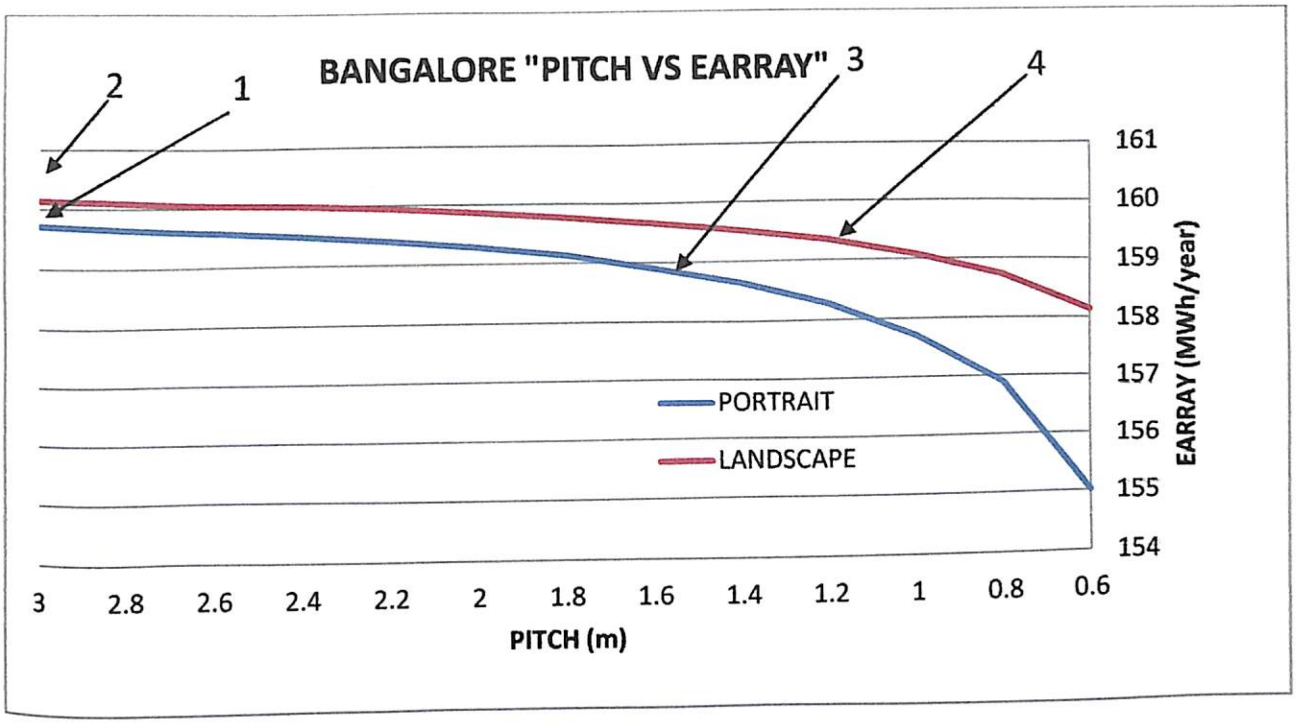


Fig 3.20 PITCH VS EARRAY FOR BANGALORE

1. Maximum energy yield in portrait mode (3m)= 159.71 MWh/year
2. Maximum energy yield in landscape mode (3m) = 160.13 MWh/year
3. The optimum pitch for portrait mode is = 1.6 m
4. The optimum pitch for landscape mode is = 1.2 m

After a certain point the value of portrait mode is reducing much when compare to the landscape (refer case-1).

3.5.3 CASE- 3 (CHENNAI):

Latitude = 13.08

Longitude = 80.27

Altitude = 7 M

Tilt angle = 20

Initial pitch = 3.34+3 = 6.4 m

PITCH (m)	PORTRAIT (MWh/year)	LANDSCAPE (MWh/year)
3	153.67	154.33
2.8	153.53	154.26
2.6	153.41	154.18
2.4	153.26	154.08
2.2	153.08	153.98
2	152.88	153.87
1.8	152.65	153.72
1.6	152.39	153.53
1.4	152.01	153.3
1.2	151.39	153.02
1	150.67	152.64
0.8	149.37	152.11
0.6	146.07	151.29

Table 3.4 ENERGY YIELD FOR CHENNAI

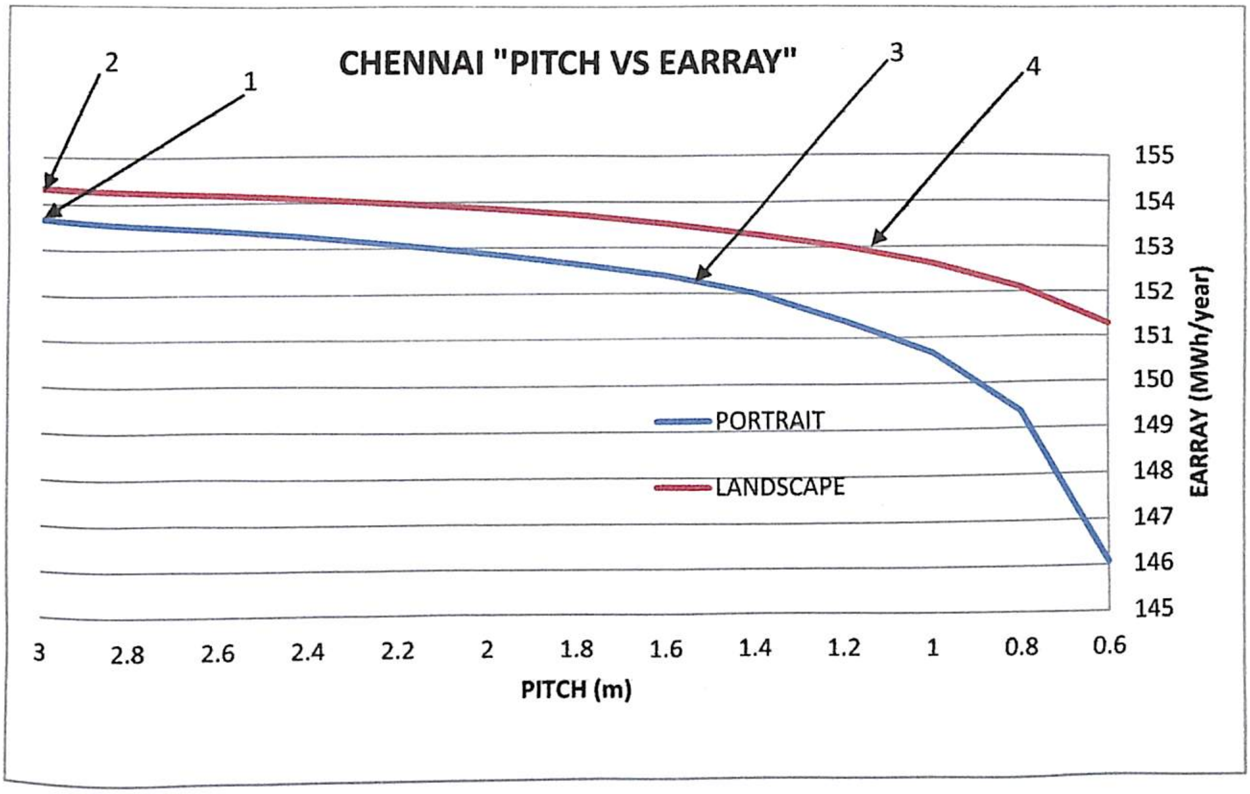


Fig 3.21 PITCH VS EARRAY FOR CHENNAI

1. Maximum energy yield in portrait mode (3m)= 153.67 MWh/year
2. Maximum energy yield in landscape mode (3m)= 154.33 MWh/year
3. The optimum pitch for portrait mode is = 1.6 m
4. The optimum pitch for landscape mode is = 1.2 m

After a certain point the value of portrait mode is reducing much when compare to the landscape (refer case-1).

3.5.4 CASE- 4 (COIMBATORE):

Latitude = 11.01

Longitude = 76.97

Altitude = 40 M

Tilt angle = 10

Initial pitch = 3.34+3 = 6.4 m

PITCH (m)	PORTRAIT (MWh/year)	LANDSCAPE (MWh/year)
3	151.59	151.74
2.8	151.56	151.73
2.6	151.53	151.72
2.4	151.48	151.69
2.2	151.41	151.66
2	151.34	151.63
1.8	151.27	151.59
1.6	151.18	151.54
1.4	151.07	151.48
1.2	150.94	151.38
1	150.71	151.27
0.8	150.3	151.09
0.6	149.56	150.81

Table 3.5 ENERGY YIELD FOR COIMBATORE

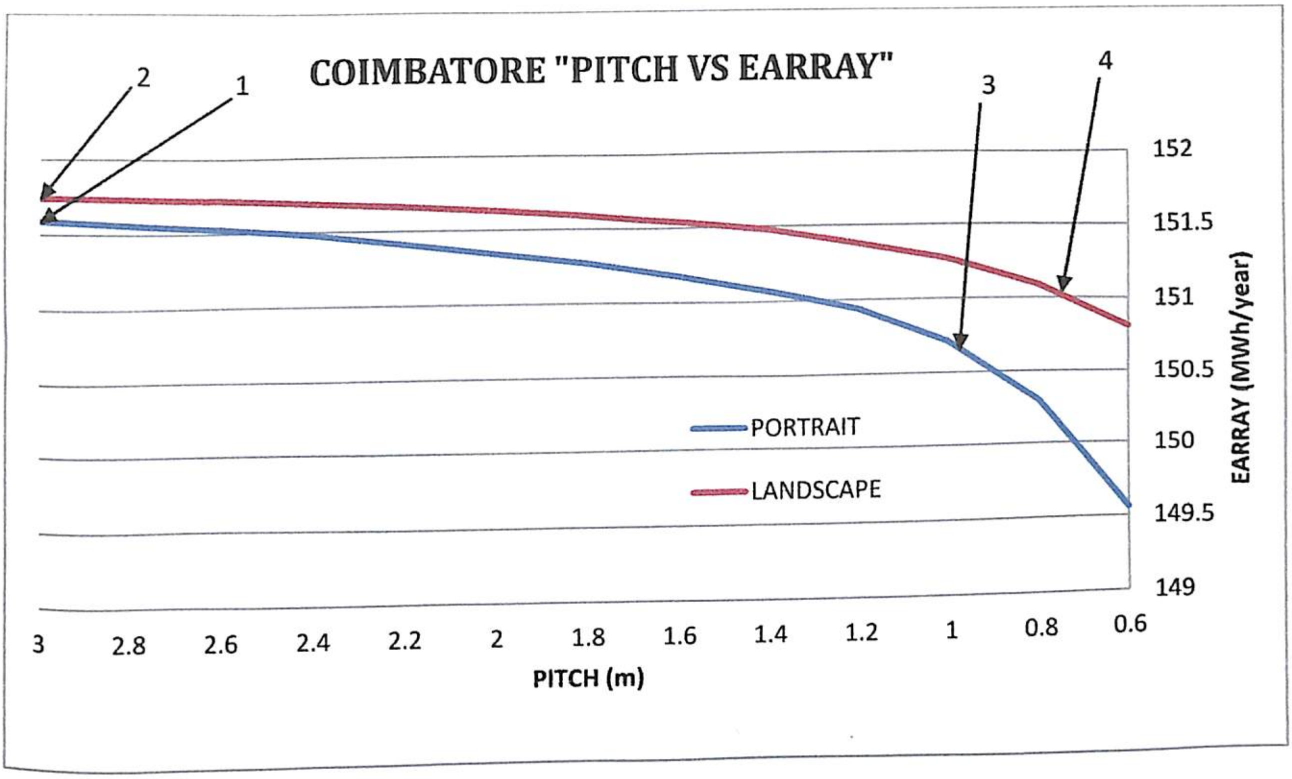


Fig 3.22 PITCH VS EARRAY FOR COIMBATORE

1. Maximum energy yield in portrait mode (3m)= 151.59 MWh/year
2. Maximum energy yield in landscape mode (3m)= 151.74 MWh/year
3. The optimum pitch for portrait mode is = 1 m
4. The optimum pitch for landscape mode is = 0.8 m

After a certain point the value of portrait mode is reducing much when compare to the landscape (refer case-1).

3.5.5 CASE- 5 (RAIPUR):

Latitude = 21.14

Longitude = 81.38

Altitude = 297 M

Tilt angle = 15

Initial pitch = 3.34+3 = 6.4 m

PITCH (m)	PORTRAIT (MWh/year)	LANDSCAPE (MWh/year)
3	158.97	159.5
2.8	158.9	159.46
2.6	158.83	159.42
2.4	158.73	159.36
2.2	158.62	159.29
2	158.49	159.2
1.8	158.34	159.1
1.6	158.17	159.98
1.4	157.68	158.83
1.2	157	158.63
1	156.29	158.38
0.8	154.17	157.94
0.6	147.85	157.21

Table 3.6 ENERGY YIELD FOR RAIPUR

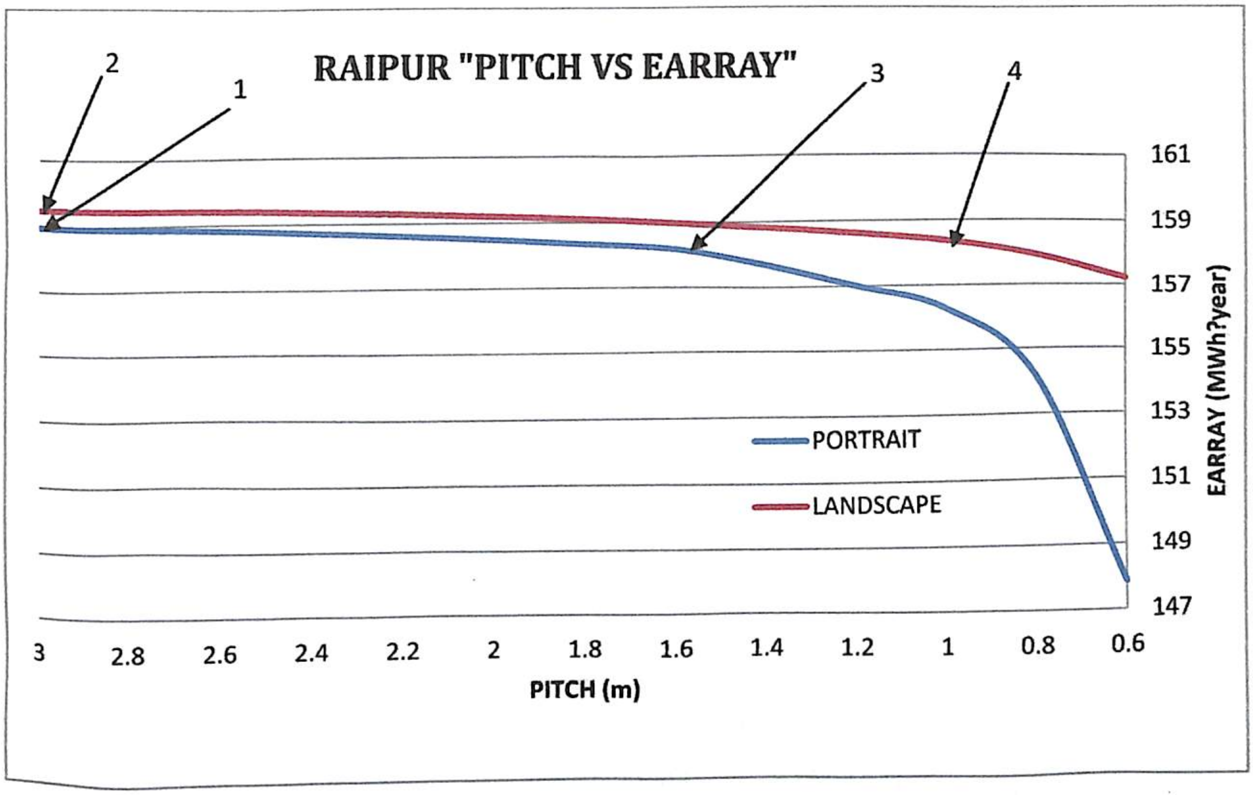


Fig 3.23 PITCH VS EARRAY FOR RAIPUR

1. Maximum energy yield in portrait mode (3m)= 158.97 MWh/year
2. Maximum energy yield in landscape mode (3m)= 159.5 MWh/year
3. The optimum pitch for portrait mode is = 1.4 m
4. The optimum pitch for landscape mode is = 1 m

After a certain point the value of portrait mode is reducing much when compare to the landscape (refer case-1).

3.5.6 CASE- 6 (PUNE):

Latitude = 28.52

Longitude = 73.84

Altitude = 560 M

Tilt angle = 15

Initial pitch = 3.34+3 = 6.4 m

PITCH (m)	PORTRAIT (MWh/year)	LANDSCAPE (MWh/year)
3	160.67	160.41
2.8	160.01	160.37
2.6	159.95	160.33
2.4	159.87	160.29
2.2	159.77	160.24
2	159.62	160.17
1.8	159.33	160.09
1.6	159	159.99
1.4	158.69	159.87
1.2	158.33	159.69
1	157.62	159.4
0.8	156.09	159.01
0.6	151.4	158.41

Table 3.7 ENERGY YIELD FOR PUNE

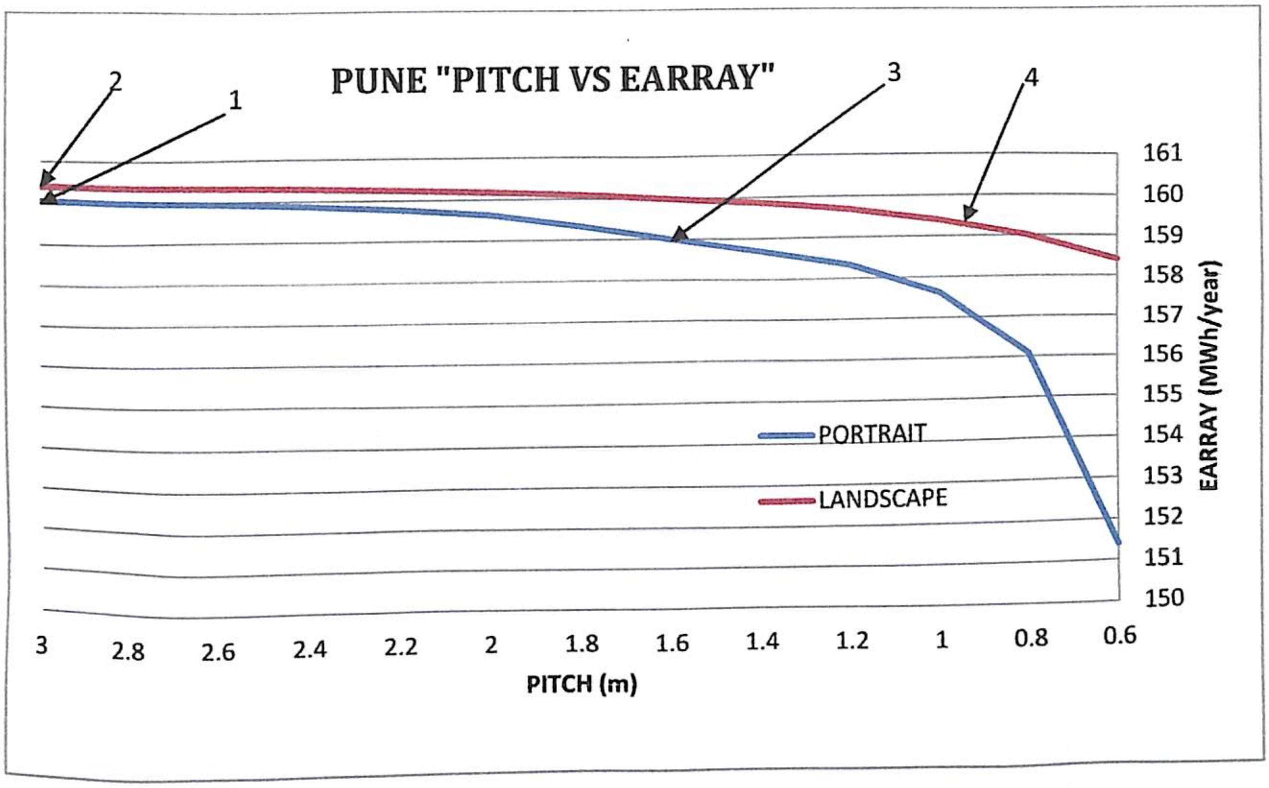


Fig 3.24 PITCH VS EARRAY FOR PUNE

1. Maximum energy yield in portrait mode (3m)= 160.07 MWh/year
2. Maximum energy yield in landscape mode (3m)= 160.41 MWh/year
3. The optimum pitch for portrait mode is = 1.4 m
4. The optimum pitch for landscape mode is = 1 m

After a certain point the value of portrait mode is reducing much when compare to the landscape (refer case-1).

3.5.7 CASE- 7 (GANDHINAGAR):

Latitude = 23.22

Longitude = 72.68

Altitude = 80 M

Tilt angle = 25

Initial pitch = 3.34+3 = 6.4 m

PITCH (m)	PORTRAIT (MWh/year)	LANDSCAPE (MWh/year)
3	160.03	164.35
2.8	162.83	164.24
2.6	162.64	164.12
2.4	162.41	163.99
2.2	162.15	163.84
2	161.75	163.62
1.8	161.05	163.36
1.6	160.2	163.08
1.4	159.05	162.76
1.2	156.63	162.27
1	151.5	161.55
0.8	146.67	160.49
0.6	142.11	157.97

Table 3.8 ENERGY YIELD FOR GANDHINAGAR

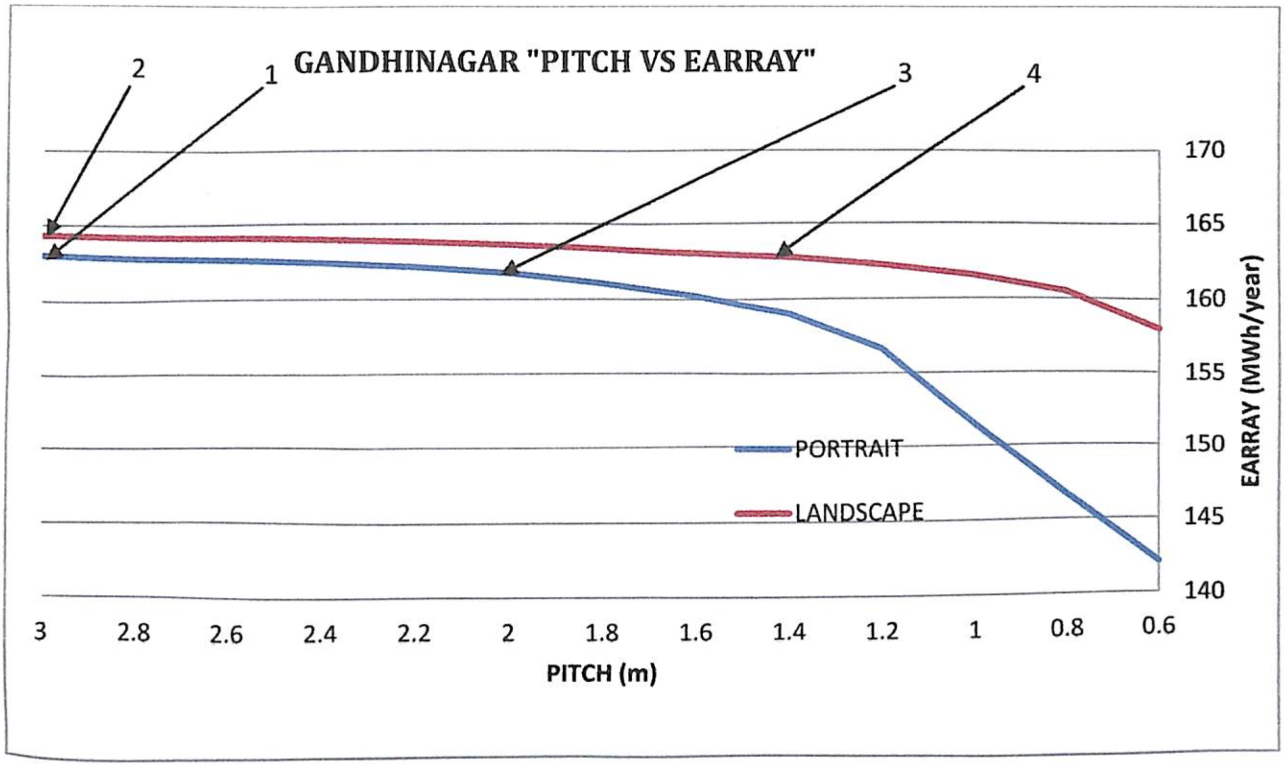


Fig 3.25 PITCH VS EARRAY FOR GANDHINAGAR

1. Maximum energy yield in portrait mode (3m)= 163.03 MWh/year
2. Maximum energy yield in landscape mode(3m) = 164.35 MWh/year
3. The optimum pitch for portrait mode is = 2 m
4. The optimum pitch for landscape mode is = 1.4 m

After a certain point the value of portrait mode is reducing much when compare to the landscape (refer case-1).

3.5.8 PITCH VS EARRAY FOR DIFFERENT CITIES:

This is the combined graph of pitch VS Earray for different cities. From the graph we can see that initially the value are similar for both landscape and portrait (refer Fig 3.25), but after a certain point when we keep on reducing the pitch the value of portrait is reducing much for all the cities (refer case-1).

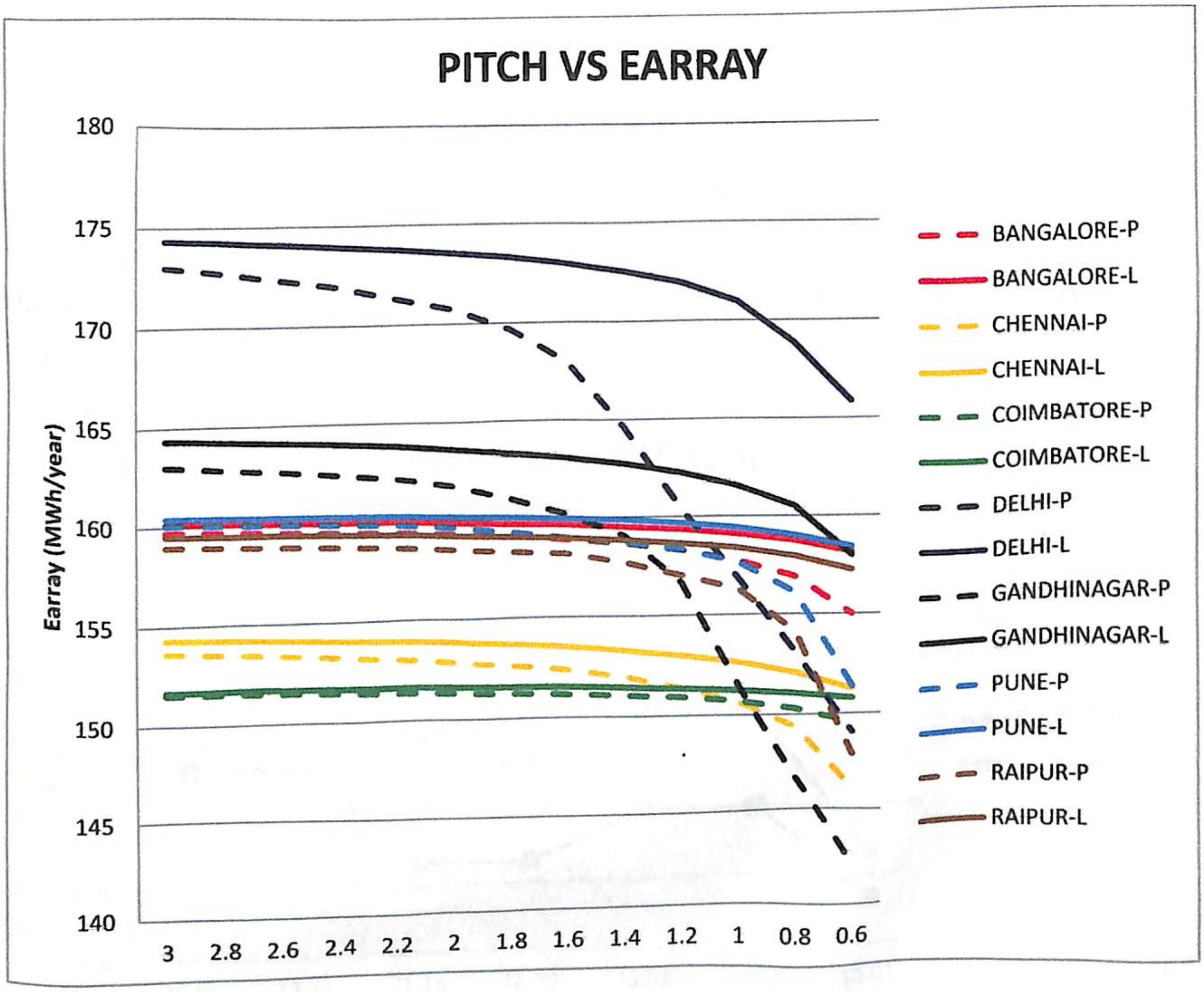


Fig 3.26 COMBINED GRAPH OF PITCH VS EARRAY

3.5.9 OPTIMUM PITCH VALUE FOR DIFFERENT CITIES:

SITE	PORTRAIT	LANDSCAPE
DELHI	2.2	1.4
GANDHINAGAR	2	1.4
BANGALORE	1.6	1.2
CHENNAI	1.6	1.2
PUNE	1.4	1
RAIPUR	1.4	1
COIMBATORE	1	0.8

Table 3.9 OPTIMUM PITCH VALUE

In the table we can see the optimum pitch distance for different cities. Up to the certain pitch distance which is mention in the table (refer table 3.9), we will get optimum energy value but when we go behind the certain pitch the value of energy will be reduced (refer case- 1).

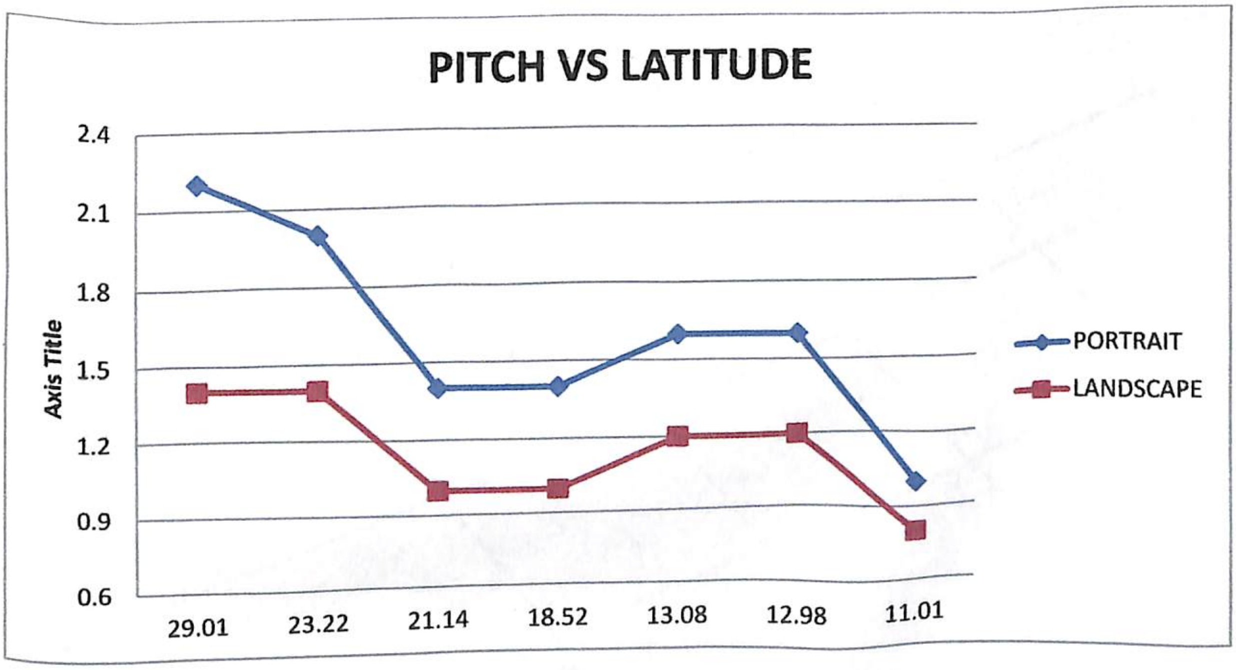
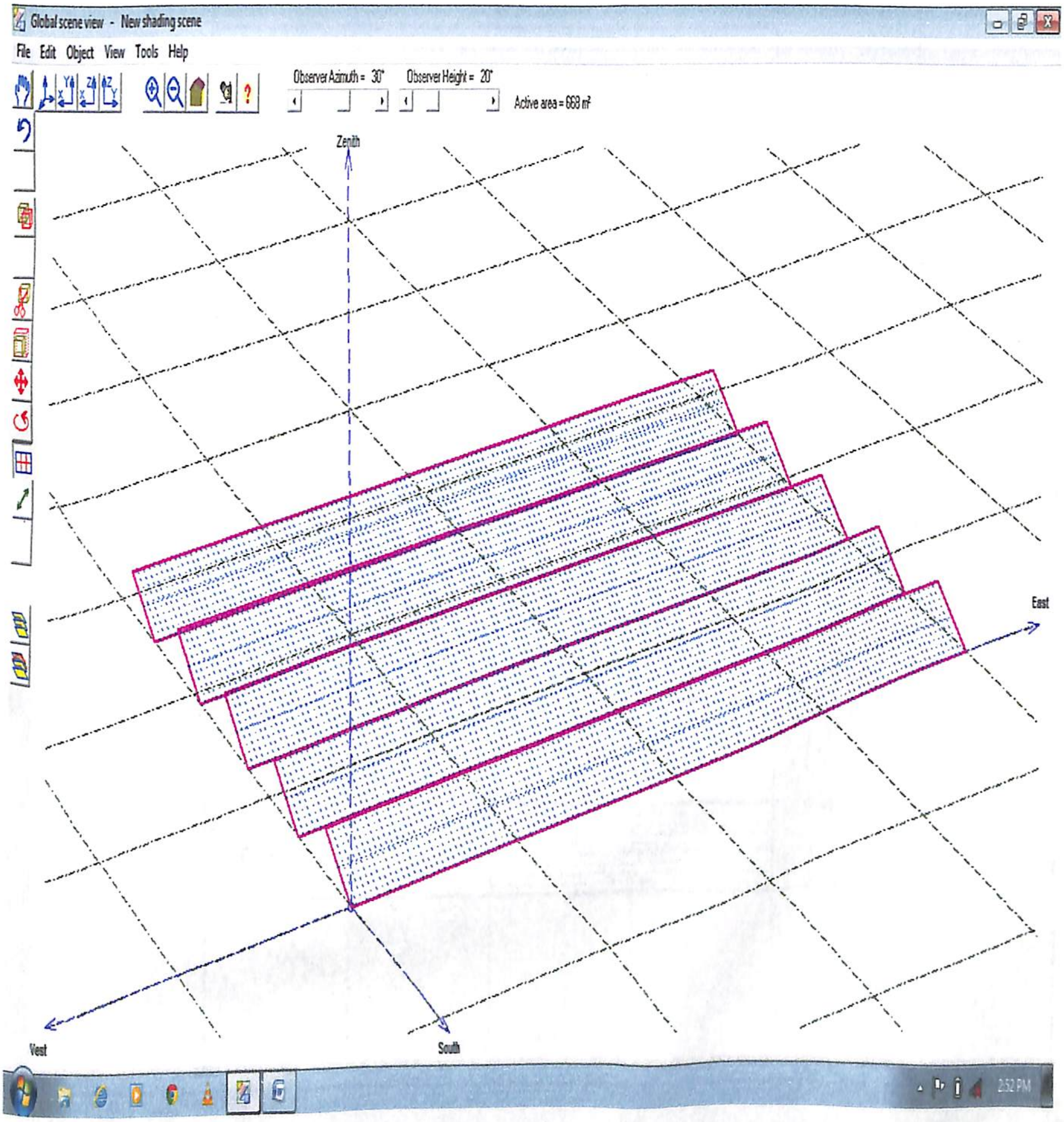


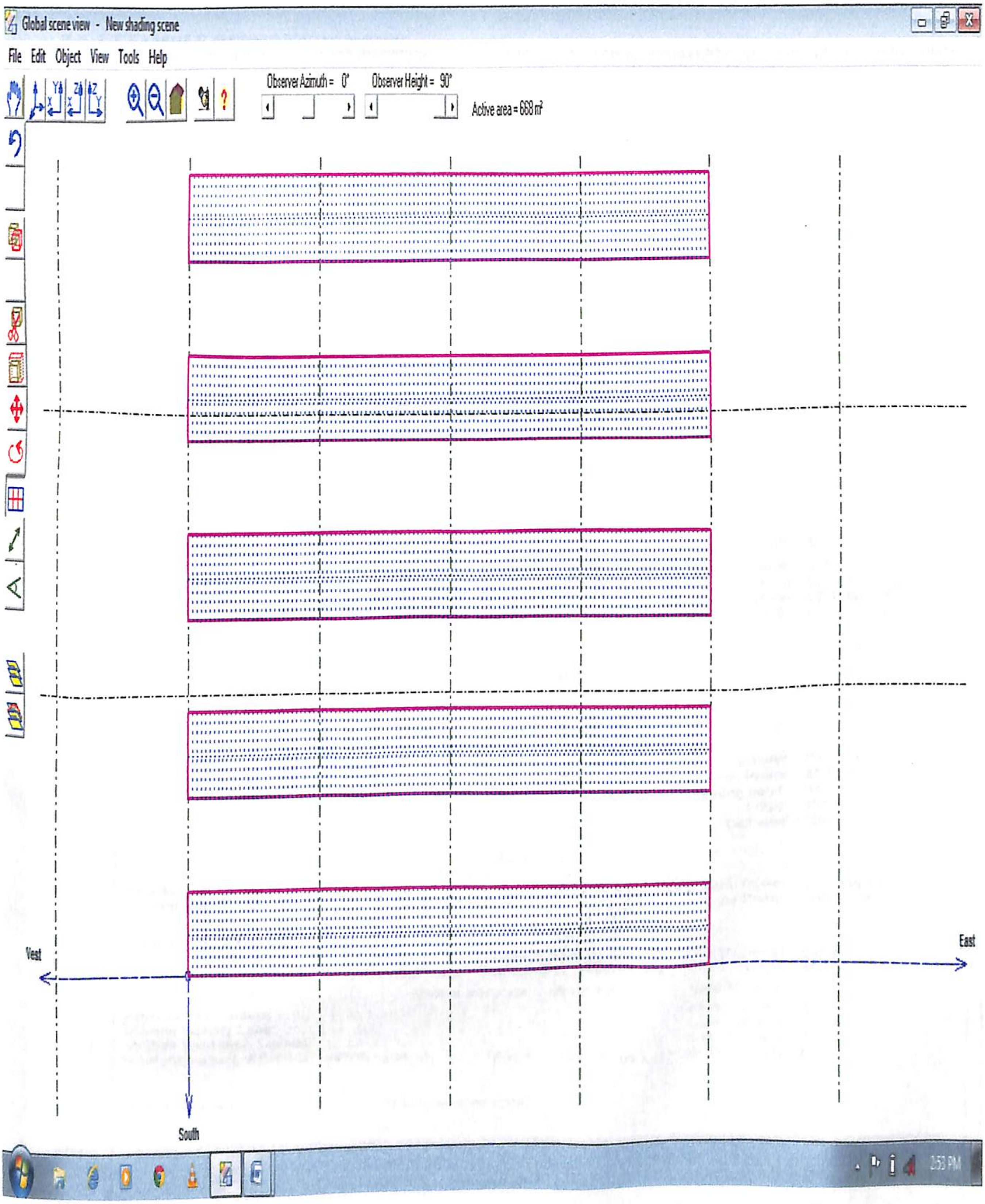
Fig 3.27 OPTIMUM PITCH VALUES

3.6 DESIGN PART FOR 100KWp

The design which is mention below is 3d view of 100KWp.Totally we have 5 sheds in which each shed consist of 80 modules. So totally 80 * 5 = 400 modules.



2D view of 100KWp:



3.6.1 EXAMPLE REPORT FOR DELHI:

This is for the pitch distance of 3m in portrait mode. In this report majorly it will show the no of module, no of inverter, inverter losses, energy production in yearly basis, collector losses, system losses etc....

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Grid-Connected System: Simulation parameters

Project :	**delhi.city.**			
Geographical Site	**Delhi.**		**Country**	**India**
Situation	Latitude	29.0°N	Longitude	77.4°E
Time defined as	Legal Time	Time zone UT+6	Altitude	600 m
	Albedo	0.20		
Meteo data :	Delhi., Synthetic Hourly data			

Simulation variant :	**New simulation variant**			
	Simulation date	16/04/13 12h55		

Simulation parameters

Collector Plane Orientation	Tilt	25°	Azimuth	0°
5Sheds	Pitch	6.34 m	Collector width	3.34 m
Inactive band	Top	0.00 m	Bottom	0.00 m
Shading limit angle	Gamma	23.08 °	Occupation Ratio	52.7 %
Shadings electrical effect	Cell size	15.6cm	Strings in width	2
Horizon	Free Horizon			
Near Shadings	Mutual shadings of sheds	Electrical effect		

PV Array Characteristics

PV module	Si-poly	Model	**TP250**		
		Manufacturer	Tata Power Solar		
Number of PV modules		In series	20 modules	In parallel	20 strings
Total number of PV modules		Nb. modules	400	Unit Nom. Power	250 Wp
Array global power		Nominal (STC)	**100 kWp**	At operating cond.	94.2 kWp (40°C)
Array operating characteristics (50°C)		U mpp	571 V	I mpp	165 A
Total area		Module area	**667 m²**	Cell area	584 m²
Inverter		Model	**xyz**		
		Manufacturer	abc		
Characteristics		Operating Voltage	350-800 V	Unit Nom. Power	20.0 kW AC
Inverter pack		Number of inverter	5 units	Total Power	100.0 kW AC

PV Array loss factors				
Thermal Loss factor	Uc (const)	27.7 W/m²K	Uv (wind)	0.0 W/m²K / m/s
=> Nominal Oper. Coll. Temp. (G=800 W/m², Tamb=20°C, Wind=1 m/s.)			NOCT	46 °C
Wiring Ohmic Loss	Global array res.	56 mOhm	Loss Fraction	1.5 % at STC
Array Soiling Losses			Loss Fraction	1.0 %
Module Quality Loss			Loss Fraction	1.0 %
Module Mismatch Losses			Loss Fraction	1.0 % at MPP
Incidence effect, ASHRAE parametrization	IAM =	1 - bo (1/cos i - 1)	bo Parameter	0.05

User's needs :	Unlimited load (grid)

Grid-Connected System: Main results

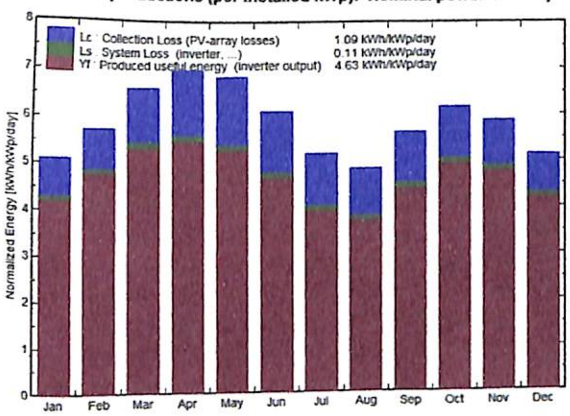
Project : **delhi.city.**

Simulation variant : **New simulation variant**

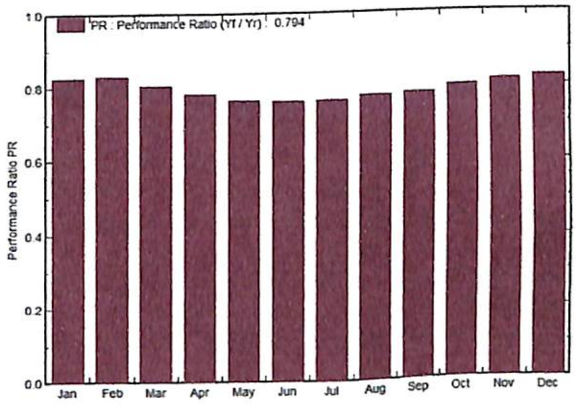
Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	Sheds disposition, tilt	25°	azimuth	0°
PV modules	Model	TP250	Pnom	250 Wp
PV Array	Nb. of modules	400	Pnom total	**100 kWp**
Inverter	Model	xyz	Pnom	20.00 kW ac
Inverter pack	Nb. of units	5.0	Pnom total	**100 kW ac**
User's needs	Unlimited load (grid)			

Main simulation results				
System Production	**Produced Energy**	**169.0 MWh/year**	Specific prod.	1690 kWh/kWp/year
	Performance Ratio PR	79.4 %		

Normalized productions (per installed kWp): Nominal power 100 kWp



Performance Ratio PR



New simulation variant

Balances and main results

	GlobHor kWh/m²	T Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	EffArrR %	EffSysR %
January	114.1	12.40	158.0	148.7	13.34	13.04	12.67	12.38
February	127.7	15.40	160.2	153.3	13.58	13.28	12.72	12.44
March	179.8	21.10	204.1	195.4	16.81	16.44	12.35	12.08
April	205.2	26.40	209.3	200.1	16.73	16.35	11.99	11.72
May	226.6	29.40	211.6	201.5	16.61	16.24	11.78	11.51
June	201.3	30.00	182.3	172.9	14.27	13.93	11.74	11.46
July	172.7	27.80	160.0	151.1	12.58	12.27	11.80	11.50
August	152.8	26.60	149.7	141.6	11.92	11.64	11.95	11.66
September	157.5	25.00	168.3	160.3	13.53	13.22	12.06	11.78
October	156.6	22.10	190.6	182.3	15.64	15.29	12.30	12.03
November	127.8	17.90	175.8	167.1	14.63	14.30	12.48	12.20
December	109.7	13.70	158.3	148.9	13.32	13.02	12.62	12.34
Year	1931.8	22.35	2128.0	2023.2	172.97	169.03	12.19	11.91

Legends:

GlobHor	Horizontal global irradiation	EArray	Effective energy at the output of the array
T Amb	Ambient Temperature	E_Grid	Energy injected into grid
GlobInc	Global incident in coll. plane	EffArrR	Effic. Eout array / rough area
GlobEff	Effective Global, corr. for IAM and shadings	EffSysR	Effic. Eout system / rough area

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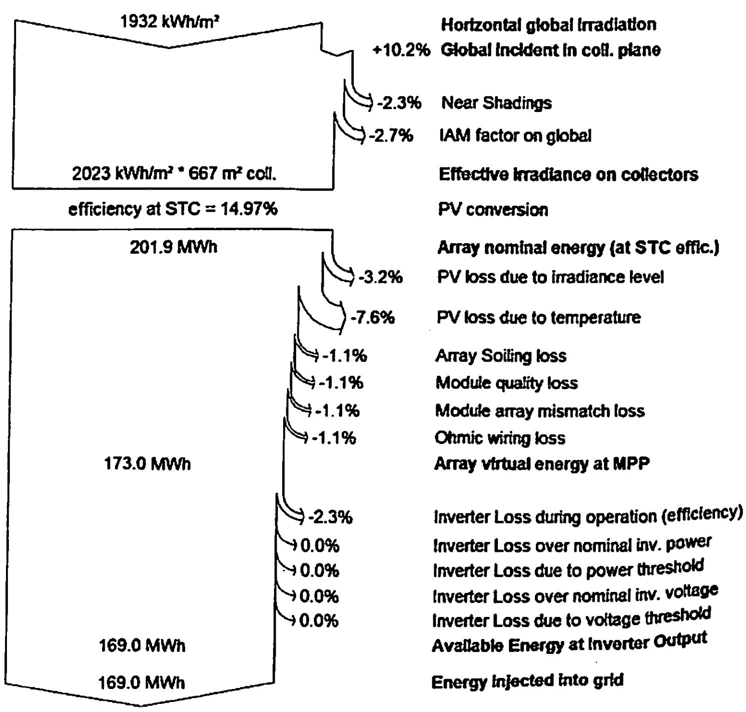
Grid-Connected System: Loss diagram

Project : **delhi.city.**

Simulation variant : **New simulation variant**

Main system parameters	System type	**Grid-Connected**			
PV Field Orientation	Sheds disposition, tilt	25°	azimuth	0°	
PV modules	Model	TP250	Pnom	250 Wp	
PV Array	Nb. of modules	400	Pnom total	**100 kWp**	
Inverter	Model	xyz	Pnom	20.00 kW ac	
Inverter pack	Nb. of units	5.0	Pnom total	**100 kW ac**	
User's needs	Unlimited load (grid)				

Loss diagram over the whole year



3.7 CONCLUSION

This paper investigated to obtain the maximum possible power output for a particular site, to find the optimum pitch distance for a same site and also the different shading effects of the panel. Solar energy is the best option for the country like India which has more than 300 days of sun shine. Energy is free of cost but the only issue is initial cost but the government of India has giving lot of subsidy that is the good sign for us to switch to solar energy.

In this thesis I have discussed about the shading issues of the panel, from the study the portrait mode installation is best for the longitudinal side of the shadows and landscape installation is best for the latitudinal side of the shadows. Connecting with the bypass diode is the best option mainly to avoid the hotspot phenomena. Energy yield for a particular area is depends on the geographical site like latitude, longitude, altitude etc... From the study we can note that the same capacity installation for different areas the output of energy yield differs. The energy yield for different cities have been observed, from the seven different cases the Delhi has high energy yield because of high latitude and tilt angle where as Coimbatore has less energy yield because of less latitude and less tilt angle.

Tilt angle plays an important role while the installation, if we change the pitch distance of high tilt angle like Delhi the energy yield is reducing frequently where as less tilt angle there is no much reducing in the energy yield. From the study the energy yield of portrait mode is reduced after a particular point because the whole string is affected by the other sheds where as in landscape only one string will affects. So while installing the solar panel we should consider the tilt angle, row to row gap, whether to install in portrait mode or landscape mode that depends on the area installing.

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