SOLAR PHOTOVOLTAIC-SIMULATION AND DESIGNING

A business case report of engineering procurement to set up roof-top solarPV project at Noida, Uttar Pradesh

Report for Vardhan Consulting Engineers Group

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Acknowledgements

This report is authored by Millend Roy, a junior year student pursuing Bachelor of Technology in Electrical Engineering from Indian Institute of Technology (Indian School of Mines) Dhanbad.

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Executive Summary

With the escalation of energy demands all over and terror of draining conventional fossil fuels, the assimilation of distributed generation networks to centralized traditional networks was introduced. Distributed generation (DG) refers to the production of electricity near the consumption place through renewable energy resources especially wind, solar, tides, biomass, geo-thermal heat and so on. The heightened perforation of DG, renewable energy application, and the installation of micro-grid concept have changed the architecture of conventional electric power networks. A micro-grid operates in grid connected mode or standalone mode. In the grid connected mode, the main utility network is authoritative for effortless operation in masterminding with the protection and control units, while in standalone mode, the micro-grid operates as a self-reliant and self-sufficient power island that is electrically disconnected from the main utility network.

Therefore, this report is all about a business case problem contract which a client of the Techvardhan Power Private Limited received for engineering procurement and construction of 100 kW rooftop Solar PV project in Noida, Uttar Pradesh.

Hence the designing and simulation for the project has to be done using PVSyst, visualizing which the real-time investment will be made in the future for the same. A detailed Solar Resource Assessment, analysis report and a detailed losses report of the project has been prepared that will help the client while planning for the real construction and building.

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Abbreviations

DG: - Distributed generation
T&D: - Transmission and Distribution
DER: - Distributed Energy Resources
IPDN: - Integrated Power Distribution Network
PCC: - Point of Common Coupling
PV: - Photovoltaic
GW: - Giga watts
DISCOMS: - Distribution Companies

1| Introduction

1.1| Background

Power grid architectonics have emerged remarkably since previous decades, from an unidirectional centralized management approach to a rational and decentralised doctrine which allocate autonomous solutions in administering today's amplifying demand complications. The notion of decarbonizing while boosting electrifications have bricked way for DG technologies to knock the existing power grids, affording a substitute power generation that is more handy to consumers. Hence DG is a term that refers to the production of electricity near the consumption place. Solar power generators, wind generators, gas turbines and micro-generators such as fuel cells, micro turbines and so on are all examples of distributed generators. Hence it can be addressed that conventional power distribution systems are passive networks, where electrical energy at the distribution level is invariably outfitted to the customers from power resources which are associated to the bulk transmission scheme.

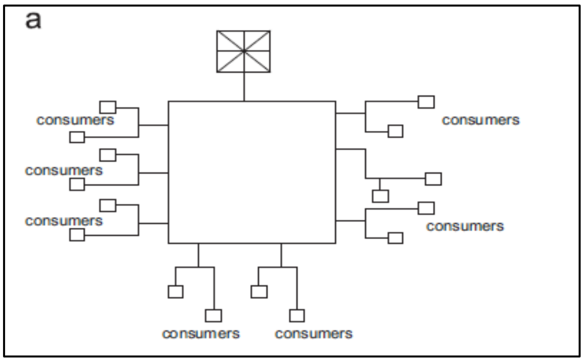


Figure1 Conventional centralized power distribution system

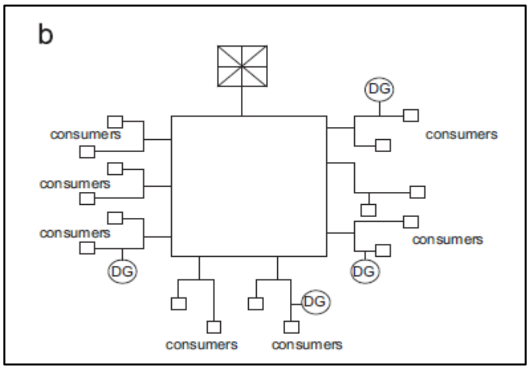


Figure2 Micro-grid network consisting of DG sources

Advantages of integration of DG resources include substantial environmental profits, enlarged adaptability, restraint of transmission and distribution (T&D) capacity promotion, abbreviated T&D line losses, re-modeling power quality, providing better voltage support and so on. However diverse problems need to be tackled before the DG units are applied to the networks. These problems include voltage stabilization, frequency ballast, intermittency of the renewable resources and power quality controversies. Such technical challenges are being resolved by professional engineers and researchers using advanced technologies and power economics.

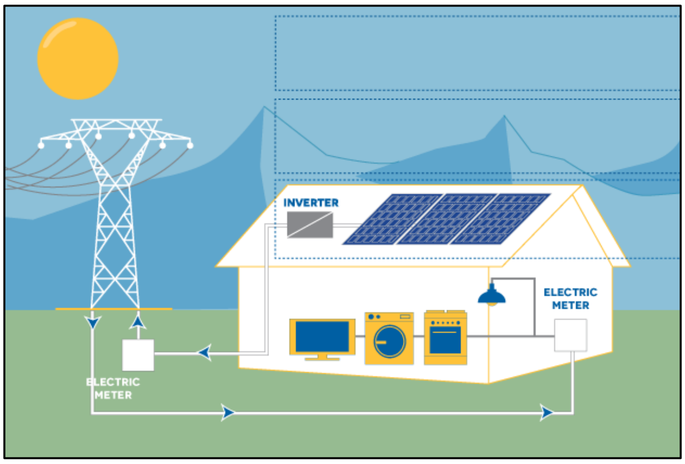


Figure3 Grid-tied solar PV physical diagram

1.2| Introduction to solar cells

The earth intercepts a lot of solar power of around 1,73,000 tera Watts i.e. 173 X 10^5 Watts. This amount is approximately 10,000 times more power than the total planet's population uses. So is it possible that one day the world could be completely reliant on solar energy?

To answer the above, one needs to understand how solar panels convert solar energy to electrical energy. Solar panels are made up of smaller units called solar cells which are of Silicon (a semiconductor that is the second most abundant element on the Earth).

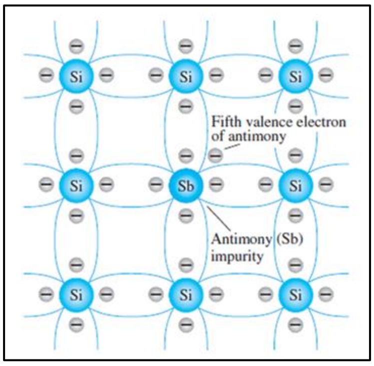


Figure4 Si-atomic structure with impurity

Each Si atom is connected to its neighbors by 4 strong bonds which keep the electrons in place and hence no current flows.

In a solar cell, crystalline Si is sandwiched between conductive layers. Two different types of impurities are injected in the Si module and hence n-type and p-type layers are formed within. N-type has excess of electrons and p-type has excess of holes. When the photons strike the Si cell with enough energy; it knocks an electron from its bond leaving a hole; the negatively charged electron and location of the positively charged hole are now free to move around. But because of the electric field $\vec{E}$ at the pn junction, they move in one way:- electrons to the n side and holes to the p side. The mobile electrons are collected by thin metal fingers at the top of the cell. From there, they flow through an external circuit doing electrical work like powering a light bulb, before returning through the conductive Aluminium sheet.

Each Si cell puts out only half a volt, but when stringed together in modules output power increases. Electrons are the only moving parts in a solar cell; and they all go back where they came from. There is nothing to get worn out or used up, so solar cells last for decades.

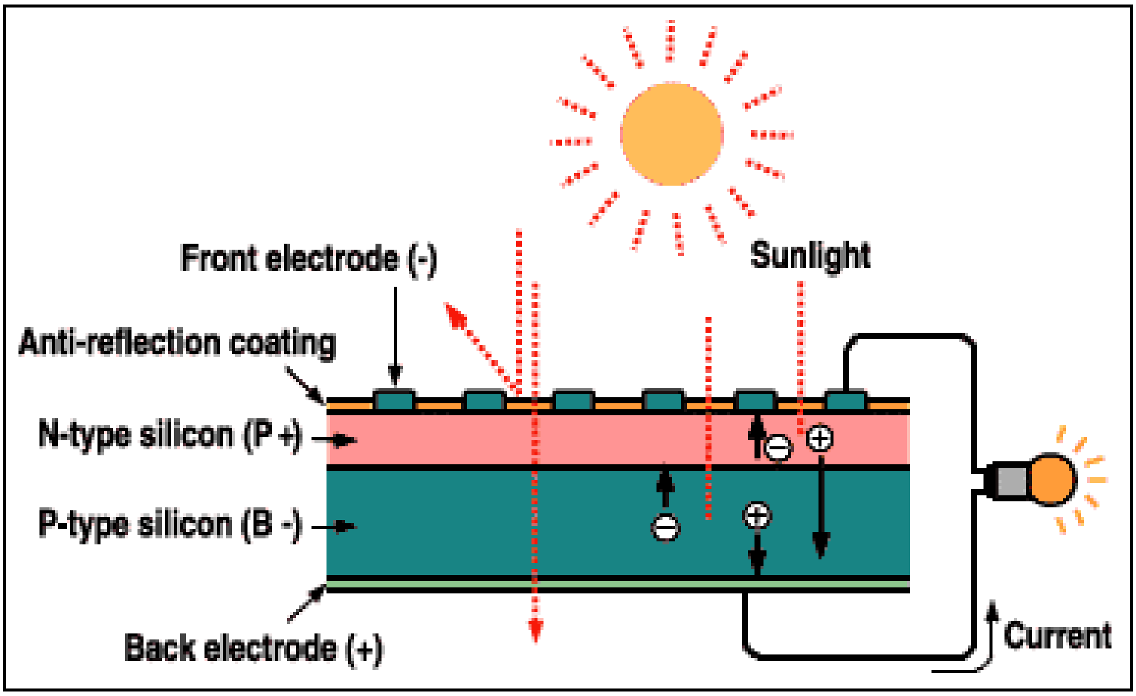


Figure5 Working of Solar cell

But there are some physical and logistical challenges:-

1. Solar energy is most unevenly distributed across the planet. Some areas are sunnier than others. It is also inconsistent i.e. less solar energy is available on cloudy days or at night. So a total reliance would require efficient ways to get electricity from sunny spots to cloudy ones and effective storage of energy.
2. If sunlight is reflected instead of absorption or if dislodged electrons fall back to holes before going through the external circuit, the photon's energy is lost. The most efficient solar cell still only converts 46% of the available sunlight to electricity and most of the commercial systems are currently 15-20% efficient.

Inspite of this limitations, it is actually possible to power the entire world with today's solar technology if proper funding required to build the infrastructure is provided and good deal of space is available.

1.3 | Different sources of Renewable Energy

Due to the limited availability of coal and petroleum, there is a considerable international effort in the development of alternative clean sources of energy. Hence, given below are the different types of renewable energy that our government has been trying to invest in since the beginning of the present decade.

- **Solar: -** The average incident solar energy received on earth's surface is nearly 600 W/m^2 but the existent figure varies considerably. It has the facilities of non- exhaustible, being free of cost, and pollution-free. On the other hand, it has many disadvantages - energy density per unit area is very less, available for only a part of the day, foggy and cloudy atmospheric conditions reduces the energy received immensely. Solar power potential is unlimited, however total capacity of about 34.404GW is being planned to date in India.

- **Wind: -** Winds are essentially created by solar heating of the atmosphere. As a power source, it is abundant, non-polluting, inexhaustible, and doesn't impose unnecessary heat burden on the environment. Unfortunately, it is not steady and undependable. Control equipment has been devised to start the wind power plant whenever the wind speed reaches 30km/hr. To harness electricity from wind energy, turbines are required to operate generators which then feed electricity into the National Grid. The theoretical power in the wind stream is given by- P=0.5pAV3 Watts, p=density of air at NTP, A= swept area, V=mean air velocity. The total installed wind power capacity in India is 37.669GW.

- **Hydro: -** The oldest and cheapest method of power generation is that of utilizing the potential energy of water. But it necessitates high capital cost because of the heavy construction works involved. It also requires a long gestation period of 5 to 8 yrs. The total installed hydel power capacity in India is 44.594GW. Hydroelectric plants are capable of starting very quickly within 5 minutes. The rate of taking up load on the machines is up-to 20MW/min. Further, no losses are incurred at standstill. The power available from a hydropower plant is P=gpWH Watts, g=9.8m/s2, p=density 1000kg/m3, W= discharge m3/s through the turbine, H=head in m.

- **Tidal: -** This is another form of hydro energy that uses twice-daily tidal currents to drive turbine generators. Although tidal flow, unlike hydro energy sources, isn't constant, it can be highly predictable and therefore can compensate for the periods when the tide current will be less. The identified economic tidal power prospects in India is in the range of 8000-9000 MW.

- **Geothermal: -** By curbing the natural heat below the earth's surface, geothermal energy can be used in heating homes directly or generating electricity so that it can be fed to the grid. The estimated capability for geothermal energy in India is around 10000 MW.

- **Biomass: -** Biomass involves the conversion of solid fuel made from plant materials by burning organic materials to produce electricity. This is not burning wood, and nowadays this is a much cleaner and more energy-efficient process. By converting agricultural, industrial and domestic waste into solid, liquid and gas fuel, biomass generates power at a much lower economic and environmental cost. The estimated potential for biomass energy in India is about 10GW.

1.4| Process Flow of Solar PV Power Plant

PV solar generating power stations convert sunlight into electricity which is later fed into the grid. Any PV solar plant has subsequent basic structural components:

- ❖ The solar panels convert sunlight into electricity, generating a direct current (DC) with voltage rising up to 1500 V. The development of solar panels make use of lead- free, optically transparent, anti-reflective glass. Solar panels contain modules that are formed by the interconnection of individual cells.

- ❖ The solar panels are mounted on supporting structures and connected to successive chains. Supporting structures are prepared with Aluminium profiles and stainless-steel fasteners. Solar panels are also equipped with trackers —these are devices that track the movement of the sun and thus enable the maximization of the energy performance of the plant. The solar panels can reel to catch the foremost of daylight and be more efficient.

- The inverter system that transforms electricity (DC) into AC (AC) with the assistance of a transformer, to extend voltage and transmit electricity to the grid. Generally, there are three styles of inverters (inverter types):
  a. Central inverters usually monitor the most power of the solar panels. This type of system achieves 98.6% in performance efficiency.
  b. String inverters are smaller and possess less power, from 10 to 30 kW with 380 V of the output voltage. However, in terms of performance efficiency string inverters are completely comparable to the central ones, reaching a score of 98.2% — 98.6%.
  c. Micro-inverters convert generation from individual solar PV modules; the output of several micro-inverters is combined and sometimes fed into the electrical grid. A basic advantage of micro-inverters is that they isolate and tune the output of the panels individually, by reducing the results that shading or failure of any one (or more) module(s) has on the output of a complete array.

- The monitoring system controls and manages the plant. Features of the system are:-
  - ✓ Real-time monitoring of equipment's operation
  - ✓ Preparation of graphics-based reports
  - ✓ Analysis and comparison of individual grid units' operation
  - ✓ Emergency signalling for deviations from the norm and other extreme conditions
  - ✓ Interactive diagram display of PVS, including detailed information about the component location and enabling navigation and localization of any technical failures
  - ✓ Export of monitoring results, publishing of information on a web-server, and printing
  - ✓ Access to the monitoring system is sometimes granted via browser or mobile app.

- Finally, there's an external power system to which the plant is connected.

1.5| Solar Resource Assessment

Solar Resource Assessment (SRA) calls attention to the anatomization of a prospective solar power production site with the aim of the precise estimation of this facility's annual energy production (AEP). "SRA" is employed to conduct site-specific measurement campaigns in support of that goal which is, the systematic collection of "ground truth" meteorological data for the aim of lowering the uncertainty of the AEP estimate. Contrary to some short years ago, the routine collection of site-specific solar resource data has quickly become standard practice within the utility-scale solar PV industry, just as it is in wind. When properly installed and maintained, site-specific SRA campaigns provide an accurate context from which long-term satellite-derived irradiance data are often corrected. Together with this combination of short-term "ground truth" and long-term satellite-derived data provide all-time low possible uncertainty for your prospective project, making it the well-liked methodology by leading financial institutions. This precariousness reduction renders improved financial terms and faster return on investment.

Since the past few years, project developers use pyranometers to live the solar resource, typically mounted on a brief mast. Data from a range of other met sensors also are collected to assist characterize the resource, inform plant design decisions and estimate PV panel efficiency. Once installed, regular maintenance of the system is critical to provide meaningful resource assessment results. Most significantly, this entails cleaning pyranometers routinely (e.g., as frequently as a hebdomadal reckoning on the site).

1.6| Losses in a Solar PV project

- **Radiation losses: -** Solar radiation at the surface of Earth is composed of direct radiation (DNI) and diffuse radiation (GHI).The extra-terrestrial radiation at the higher altitudes of atmosphere, fortunately, loses chunks of these radiations before reaching the surface due to aerosols, water vapour and other particles in the atmosphere. Diffuse scattering helps in more splitting of the radiation and in the end, there is the so-called direct and diffuse radiation. The main determinants of the Solar Irradiance are as follows:-
  - ✓ Earth's orbital motion
  - ✓ Solar geometry
  - ✓ Atmospheric effects

- **Solar Panels (Conversion Loss): -** The basic function of the solar panel is to convert the sunlight into the DC electrical energy. Some fraction of the sunlight falling on the panels is either reflected back or gets dissipated as heat into the surroundings. In noontime and the clear sky, a solar panel of 1 m^2, lying flat on the earth's surface receives around 1,000 watts of solar power. It is able to convert a small percentage, say 18%, efficiency of solar panel, of the solar power into electrical power. The remaining 82% of the energy is either reflected back or dissipated as heat into the surroundings. This is called the conversion loss of energy.

- **Battery (Conversion Loss): -** When energy is not being used from the solar panels to run the electrical appliances, the energy gets stored in the solar batteries in the form of chemical energy which later on can be utilized to run the appliances, when there is no sunlight i.e. during the night. The battery provides energy by transforming the stored chemical energy into DC electrical energy and there occurs a loss in this conversion. If the battery is 85% efficient then it will convert 85% of its stored chemical energy into DC electrical energy.

- **Inverter (Conversion Loss): -** The energy after assimilating into DC electrical energy by the solar panels is passed through the inverter. The basic function of the inverter is to change a DC electrical energy into AC electrical energy. Suppose the inverter is 95% efficient, which means that it is able to convert 95% of the input DC electrical energy into AC electrical energy. 5% of the energy is lost as conversion loss into the system.

- **Wires (Transfer Loss): -** The energy that is received as the output from our electrical appliances, needs a medium to travel from one point to the other. This medium is provided through wires. The diverse units of the solar power system are linked through copper wires. When the energy travels through a wire, a part of it gets lost as heat into the surroundings. The longer the distance is, between the solar panel and your electrical appliance, the more is the wastage of energy as heat. Therefore, it is always recommended to keep minimum or optimum distance and the right sizing of the wires between the various components and the electrical load. If, suppose the wire losses are 1% of the DC electrical energy that is 1% of 180 watts or 1.8 watts are lost as heat. This is supposed to be the transfer loss, through the wire running between the components.

- **Environmental Losses**: -
  - ✓ Shading: - When your solar panels are placed under the shade, they get less sunlight and in turn, they produce less current. Therefore it is always recommended to install panels with no nearby high structure or tree. Because at one point in a day, the obstacle comes in between the sun and the panel in such a way that its shadow covers a portion of the panels and block the sunlight.
  - ✓ Temperature: - Panel efficiency decreases with the increase in temperature.
  - ✓ Dirt: - The moving air takes away dirt from the ground and leaves it over your panels. These dust particles form the thin layer on the panels, preventing the sunlight striking on their surface.

- **Design Loss: -** The panels perform to their maximum when the sunlight is falling perpendicular to their surface. But the sun rays to be every time normal to the surface is just impossible because the earth and the sun are always in the relative motion. Also, one cannot always keep on changing the tilt of the panel in order to make sunlight fall normal to it. Although solar trackers are used which keep on moving the panels from east to west in line with the sun's motion to get the maximum sunlight, the solar trackers are costly if we are considering a small solar power system. Therefore, it is best to find the most optimum tilt where one can fix the panels and get the maximum sunlight in the day. The tilt and the orientation depend on the location of the region where the system is built.

2| Success so far in India

India has set a path to achieve 100 GW power capacity through grid-connected solar energy, out of which 40 GW is targeted to come through rooftop solar installations by 2022. Till date, considerable efforts have been put in place to develop the rooftop solar photovoltaic sector in India by the government, regulatory commissions and concerned agencies. Basic framework now exists in the country and implementation of rooftop solar power plants has started in true sense. However, considering the targets committed by India including in the international forums with respect to rooftop solar photovoltaic plants, there is still huge scope for development of the market and addressing the barriers faced by the stakeholders in the sector.

The modular nature of solar PV systems makes them highly adaptable for use on vacant rooftops. The benefits associated with rooftop solar PV systems are multi-fold. For a developer, it includes reduced land and interconnection costs, higher tariffs due to increasing commercial and industrial tariffs, and increased profitability. Rooftop solar PV assists distribution companies (DISCOMs) by reducing the peak demand during daytime and decreases transmission and distribution (T&D) losses as the power is consumed at the point of generation. According to PwC analysis, more than 10,000 MU of electricity will be saved as avoidance of T&D losses alone in year 2022 alone if 40 GW rooftop PV is achieved. Further, commercial benefits in avoiding investments in transmission system are huge. Finally and most importantly, it reduces the dependence on grid power, diesel generators and is a long-term reliable power source for consumers.

The evolution of solar rooftops in India has witnessed a significant transformation to reach a phase where all but one Indian state has issued net metering guidelines to promote solar rooftops. In terms of technology, the quality of components has increased and there have been drastic reductions in costs. In fact, SECI rooftop bids got quotations as low as INR 53,000 per kW in Gujarat, Maharashtra and Tamil Nadu and a quotation of INR 45,100 for North-eastern special category states. The electricity tariffs under the Renewable Energy Service Company (RESCO) mode have similarly come down to Rs 4.5 per kWh in Rajasthan and Rs 3 per kWh in certain special category states. This comes just 7 years from the time when utility scale plants had signed agreement at tariffs of over Rs 17 per kWh, signifying an almost 75% reduction in tariff.

There are now around 1,000 rooftop installers in the country who have been certified as channel partners by the Ministry of New and Renewable Energy. These players have been classified under various categories based on their performance parameters. There are now multiple innovative mechanisms of rooftop implementation such as projects being financed by the Developer itself under the RESCO mode and then ownership being transferred to the site owner after a fixed number of years. Also, large players such as Tata Power and Hero Future Energies have established separate divisions that cater only to rooftops installation to gain an early entry into the massive 30 billion USD market in the project development space alone.

3| Methodology

3.1| Preliminary Design

First and foremost the most important aspect is to determine the location of our solar project as different places have different power outputs for the same plant.

The preliminary tab gives us basic step to go about modelling.

❖ SITE AND METEO:

The location of our concern here is Noida, Uttar Pradesh, so we can either pull the metrological data from existing database but if the data of the specified place isn't available we can very well create our new site and data from different sources :-

Figure6 Step1 of preliminary design

❖ HORIZON:

- **Sun path diagrams:** It gives us an approximate idea about when a sun rises and sets in a particular location. It represents data in both Cartesian and polar format and shows the data of sun time in monthly durations. The lines marled as 1, 2, 3 etc. represent the monthly durations and the path length of those lines show the hours of sun time. Additionally we can get the diffuse factors to incorporate any of the other reasons for which we might not be able to get proper solar energy.

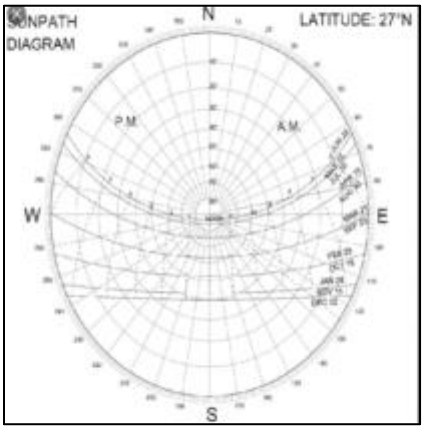


Figure7 Solar Path_1 in polar co-ordinates

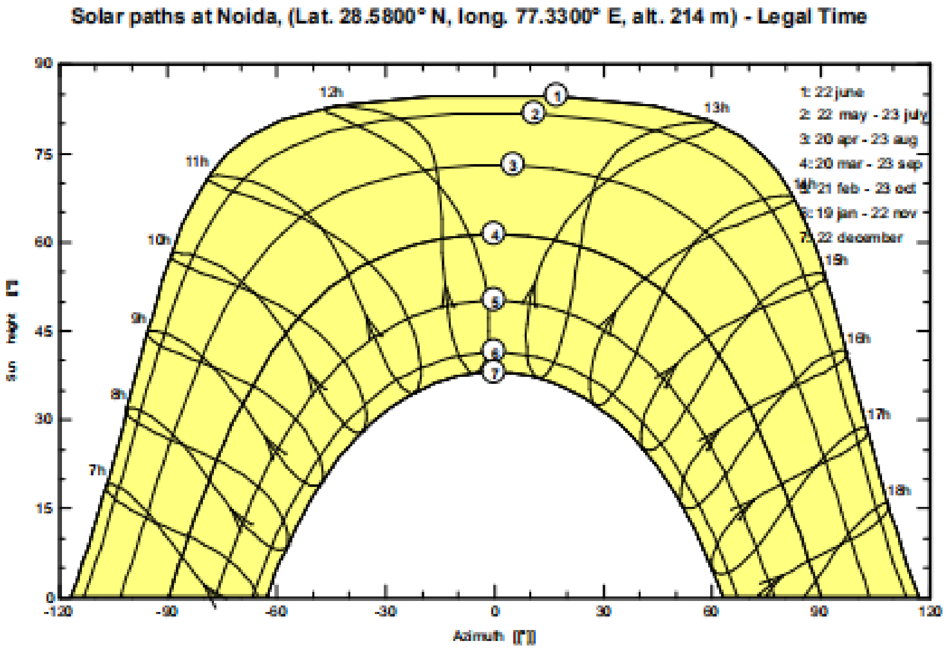


Figure8 Solar Path_2 in legal time

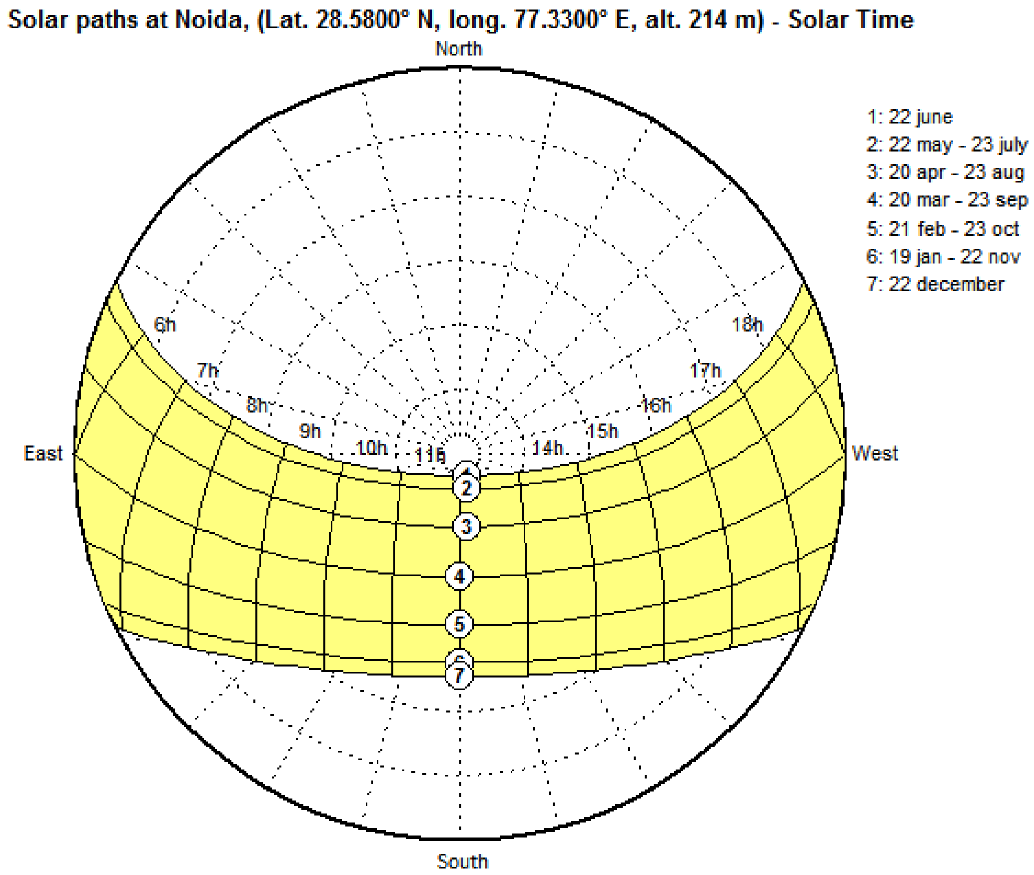


Fig:- Polar Coordinates solar path of Noida

Figure9 Solar Path_3 in polar co-ordinates

❖ **SYSTEM SPECIFICATIONS:** Next thing is **system specifications** ,

- here first we need to give the basis of our **PV ARRAY designing** :
  - Total active area
  - Nominal area
  - Target annual yield

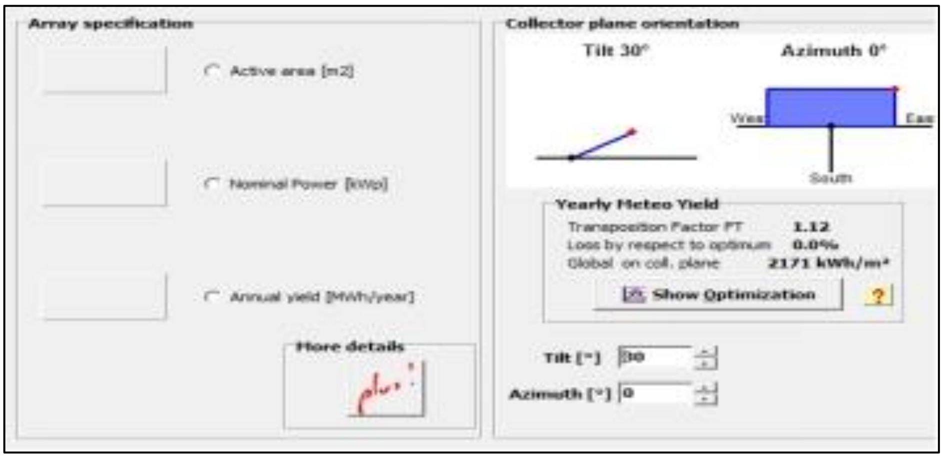


Figure10 Step3 of preliminary design

- Next we need to find out the optimum **tilt angle,** it basically specifies how our panel should be oriented in order we get the maximum global on collector plate and minimum loss

- Further we need to specify **our PV array technicalities**:
  1. Module type
  2. Technology
  3. Mounting disposition
  4. Ventilation property

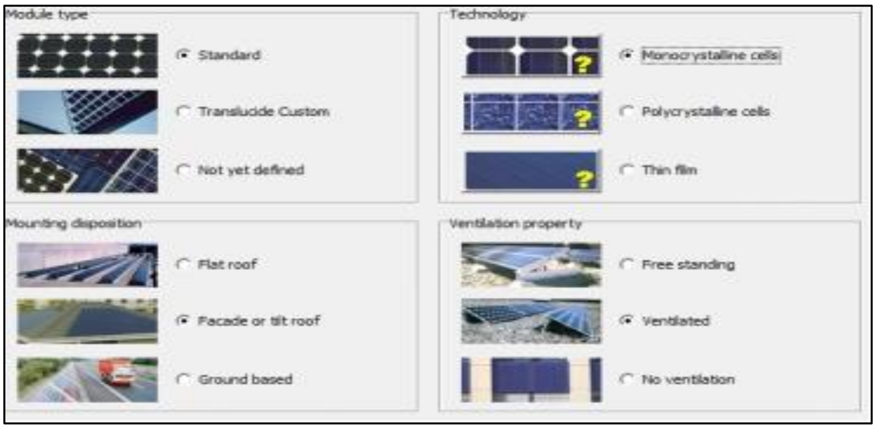


Figure13 Step4 of preliminary design

3.2| Project Design

Sizing the inverters with respect to panel voltage

It is most important that we do array sizing of our solar module with the inverter available. Typically solar module have operating voltage between 36-40 V and inverters might have some operating voltage range of 400-800V in these cases they are made compatible to each other by connecting solar modules in series in this way PV module voltage increases whilst current remaining same.

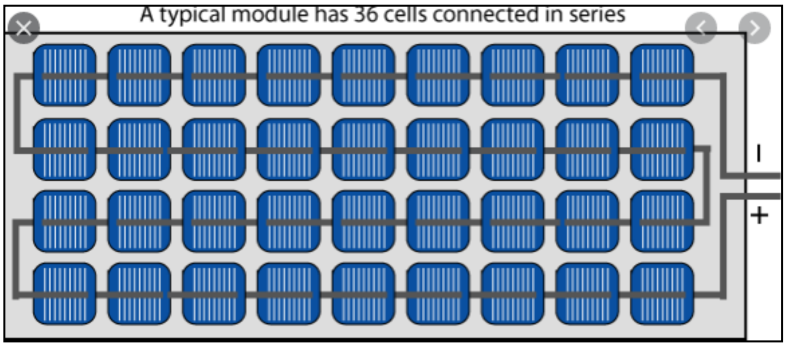


Figure12 Sizing of Inverters

Type of inverters:

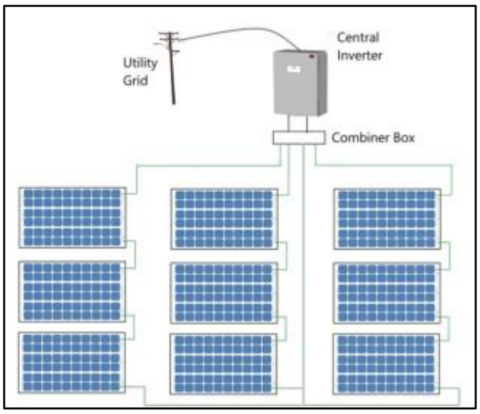


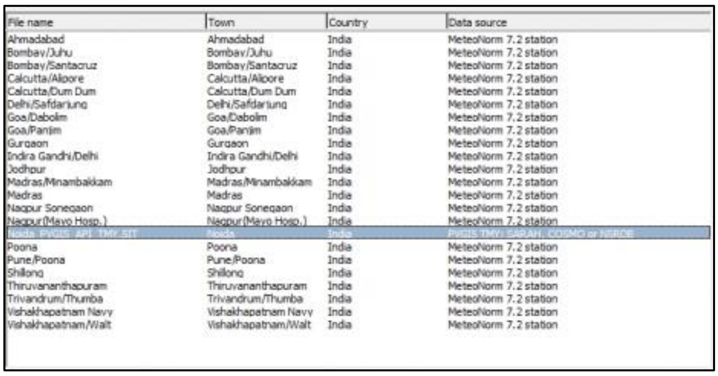
Figure13 Inverter types

1. **Central inverters:**
It has an overall capacity more than 100kVA and the string connection with respect to inverter is shown. The parallel strings are directly connected to inverter. One major disadvantage is ,if one the strings is shaded from insolation the voltage of that pv array decrease and consequently it affects the other panels connected in that branch. This is used for grid connected system as it has higher voltage capability.

2. **String inverters:**
These have a capacity less than 100kVA and every string or group of string of PV panels is connected in series is connected to a different inverter. So whatever shading effect of one panel don't affect the working voltage of other panels.

3.2.1| Step-wise Procedure

- **Step 1: -** choosing site



File name	Town	Country	Data source
Ahmadabad	Ahmadabad	India	MeteoNorm 7.2 station
Bombay/Juhu	Bombay/Juhu	India	MeteoNorm 7.2 station
Bombay/Santacruz	Bombay/Santacruz	India	MeteoNorm 7.2 station
Calcutta/Alipore	Calcutta/Alipore	India	MeteoNorm 7.2 station
Calcutta/Dum Dum	Calcutta/Dum Dum	India	MeteoNorm 7.2 station
Delhi/Safdarjung	Delhi/Safdarjung	India	MeteoNorm 7.2 station
Goa/Dabolim	Goa/Dabolim	India	MeteoNorm 7.2 station
Goa/Panjim	Goa/Panjim	India	MeteoNorm 7.2 station
Gurgaon	Gurgaon	India	MeteoNorm 7.2 station
Indira Gandhi/Delhi	Indira Gandhi/Delhi	India	MeteoNorm 7.2 station
Jodhpur	Jodhpur	India	MeteoNorm 7.2 station
Madras/Minambakkam	Madras/Minambakkam	India	MeteoNorm 7.2 station
Madras	Madras	India	MeteoNorm 7.2 station
Nagpur Sonegaon	Nagpur Sonegaon	India	MeteoNorm 7.2 station
Nagpur(Mayo Hosp.)	Nagpur(Mayo Hosp.)	India	MeteoNorm 7.2 station
Noida_PVGIS_API_TMY.SIT	Noida	India	PVGIS TMY: SARAH, COSMO or NSRDB
Poona	Poona	India	MeteoNorm 7.2 station
Pune/Poona	Pune/Poona	India	MeteoNorm 7.2 station
Shillong	Shillong	India	MeteoNorm 7.2 station
Thiruvananthapuram	Thiruvananthapuram	India	MeteoNorm 7.2 station
Trivandrum/Thumba	Trivandrum/Thumba	India	MeteoNorm 7.2 station
Vishakhapatnam Navy	Vishakhapatnam Navy	India	MeteoNorm 7.2 station
Vishakhapatnam/Walt	Vishakhapatnam/Walt	India	MeteoNorm 7.2 station

Figure14 choosing site

- **Step 2**: - specify project settings

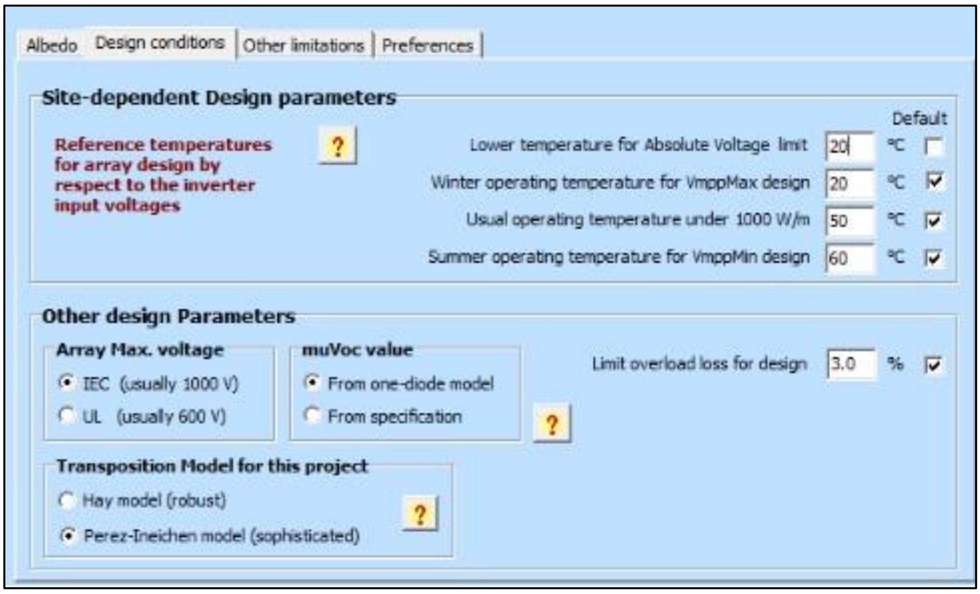


Figure15 specify project settings

- **Step3:** - give orientation

Here various orientations are possible, we can have various orientations for doifferernt subarrays as well as with seasonal variations. Here we can have tracking oof panels wrt different axes as well as decide the distance between 2 solar panels

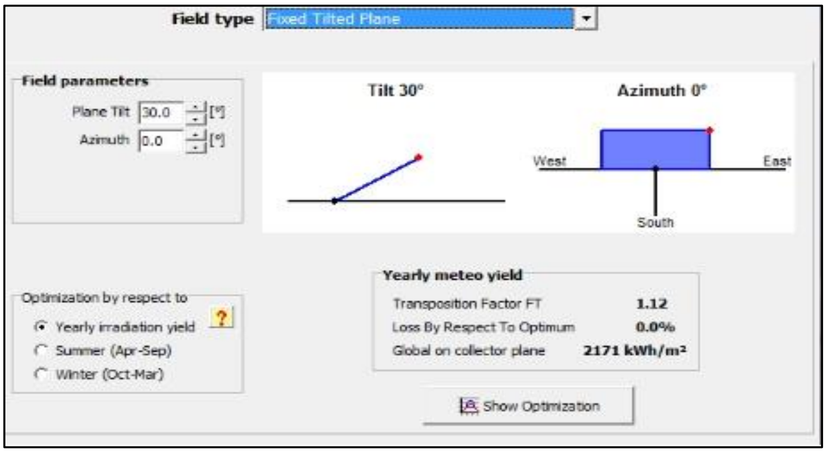


Figure16 Orientation

- **Step4: -** now specify the system:

Choose the peak power of the plant as well as select the specifications of the pv modules. Now we need to do array sizing
Power output of each solar panel =250W
Maximum voltage of pv panel: 38.1 V
Minimum voltage of pv panel: 25.5V
Maximum voltage of inverter: 1000V
Minimum voltage of string: 520 V

<u>PANELS IN SERIES TO ACHIEVE THE POWER</u>:

1000/38.1 =26

=>480/25.5=19

Panels in series = 26, we always choose the higher limit as if the voltage goes below threshold limit inverter wont operate

<u>POWER OUTPUT OF A STRING</u>:

(POWER OUTPUT OF A PANEL)*NO. OF PANELS IN A STRING = 26*250=6500W=6.5kW per string (at STANDARD TESTING CONDITIONS)

TARGET POWER OF EACH INVERTER CHOSEN =20 kW

- Now insolation conditions are not always at STC so we choose a load factor = 1.2 ;
  Each inverter capacity (practical) =1.2*20=24 kW
- No. Of stings practically required for each inverter = 24/6.5 =4 strings
- Load ratio=1.2 to 1.3

Now let there be 5 inverters, so total no. of strings 5*4= 20 strings

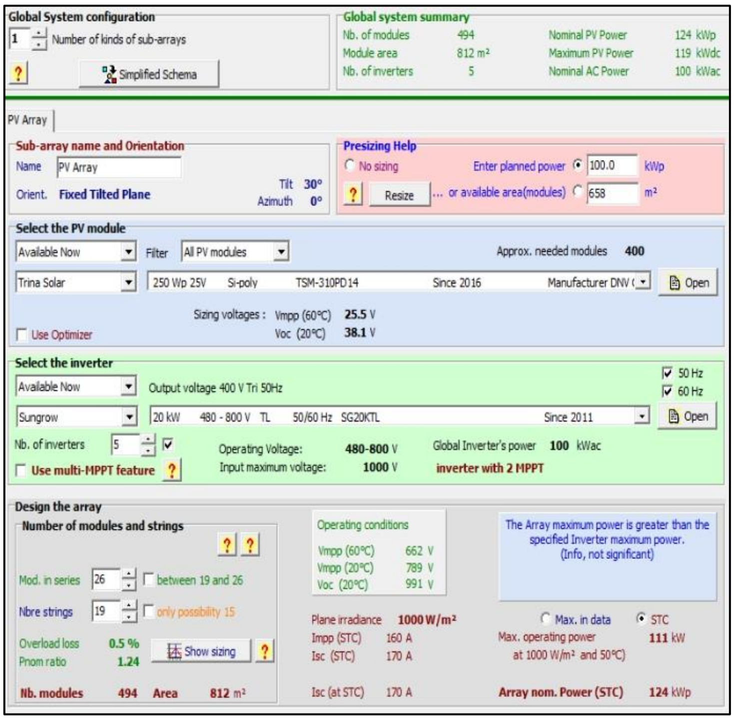


Figure17 PVSyst ORIGINAL SYSTEM CONFIGURATION SPECIFICATIONS

- **Step 5: -** detailed losses

  ✓ **NOCT: nominal operating cell temperature: -** As per mounting structure whatever solar energy falls on our panels it will go up to a temperature. If we choose free mounted with air circulation the NOCT ~45 deg C and thus loss in minimum.

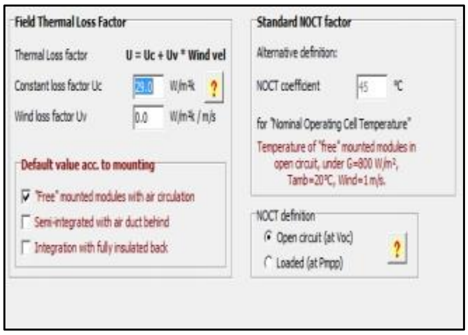


Figure18 nominal operating cell temperature

  ✓ **Ohmic losses:** Loss incurred as current flows through our cables.

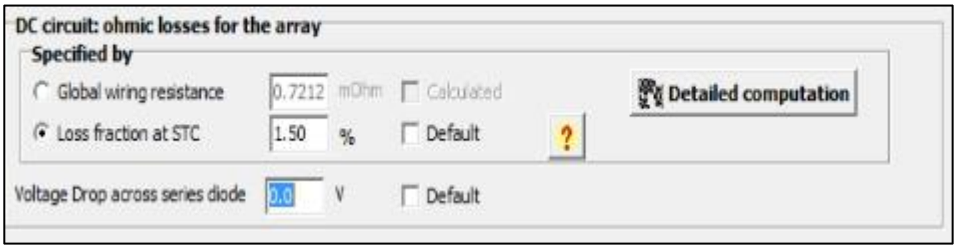


Figure19 Ohmic losses

  ✓ **Module quality loss:** the manufacturing company produces us with a certain tolerance our yield is affected by this.

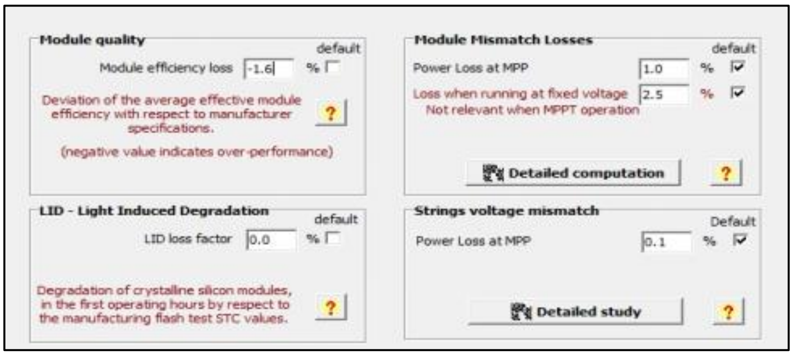


Figure40 Module quality

- ✓ **<u>Soiling factor :</u>** dirt deposited on solar panel which accounts for losses in yield

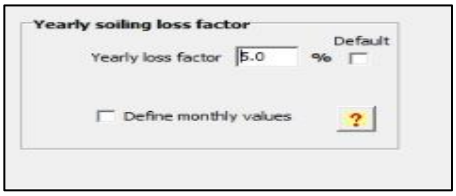


Figure21 Soiling factor

- ✓ **<u>IAM losses</u>**: our module has a glass coating that has R.I. with normal operating voltage, some of the light is reflected and refracted and this causes losses depending upon the angle of incidence.

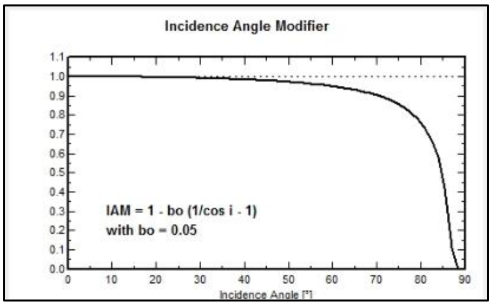


Figure22 Incidence Angle Modifier

- ✓ **<u>Unavailability of the system:</u>** Generally we have planned(outage due to service and maintenance) or unplanned outages (outages due to losses incurred). It affects energy input to grid. We can define a system unavailability as a fraction of time (or a number of days). For these failure hours, the system will be considered inactive (OFF) during the simulation.

We have the opportunity of defining specific periods of unavailability of the system.

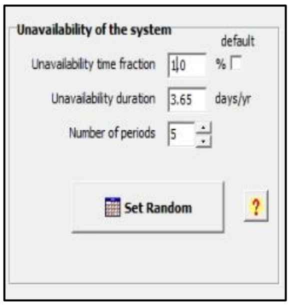


Figure23 Unavailability of the system

- ✓ **<u>Ageing:</u>** the ageing of panels causes decrease in power output and increase in losses over a span of years.

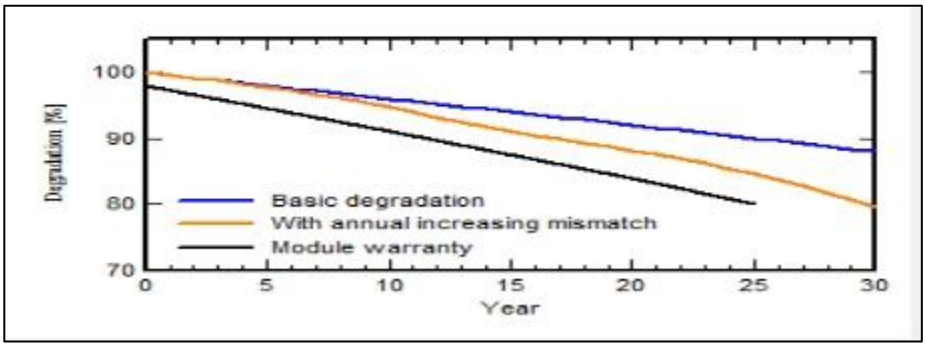


Figure24 Curve for efficiencies

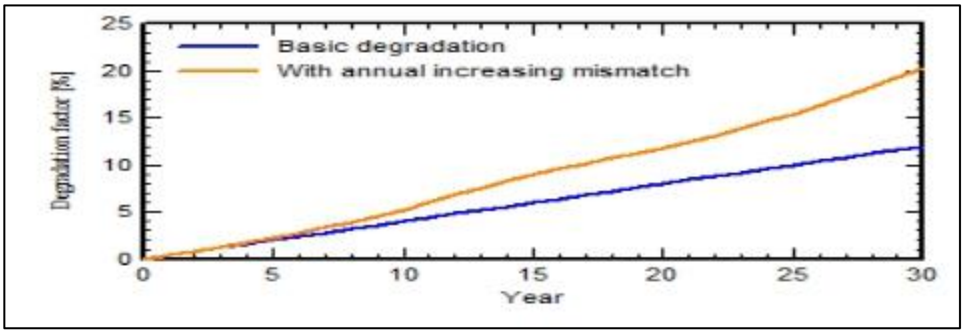


Figure25 Curve for losses

- **Step 6:** - near shading:- the shading between the nearby objects created in solar PV plan . We have to model it in 3D

Table4 Shading factor table

Shading factor table (linear), for the beam component, Orient. #1

Azimuth / Height	-180°	-160°	-140°	-120°	-100°	-80°	-60°	-40°	-20°	0°	20°	40°	60°	80°	100°	120°	140°	160°	180°
90°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
80°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
70°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
50°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
40°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
30°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.067	0.099	0.067	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2°	Behind	Behind	Behind	0.000	0.000	0.031	0.500	0.641	0.697	0.715	0.697	0.641	0.501	0.031	0.000	0.000	Behind	Behind	Behind

Shading factor for diffuse: 0.012 and for albedo: 0.649

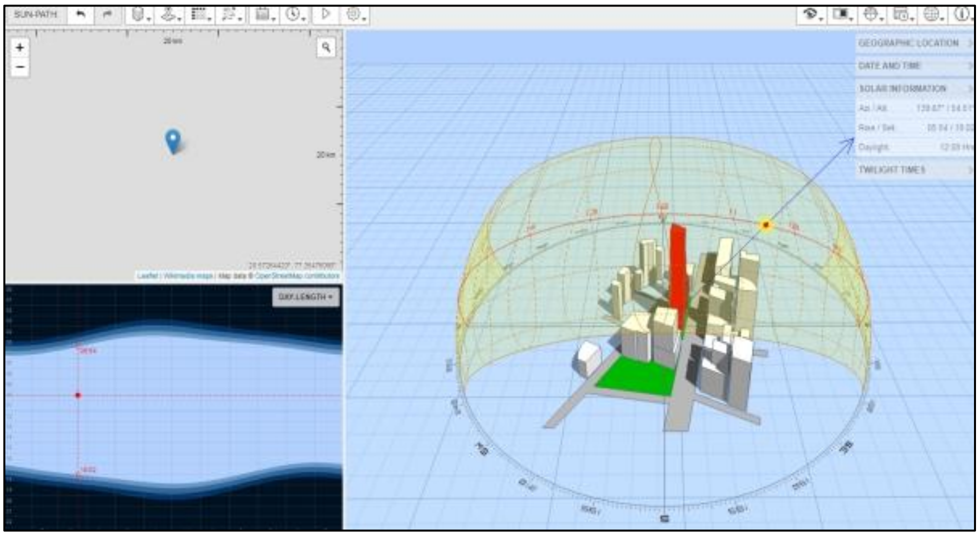


Figure26 3D Visualization-concept of sun-path for Noida

- **Step 7: -** Run simulation

4| Results and Discussion

4.1| Preliminary Design report

METEO DATA AND SYSTEM OUTPUT :

Monthly Meteo Values Source MeteoNorm 7.2 station (modified by user)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year	
Hor. global	0.0	8.0	40.5	89.9	125.2	133.0	121.9	92.2	40.5	13.6	0.0	0.0	664.8	kWh/m².mt
Extraterrestrial	191.6	209.9	277.4	309.1	344.1	341.3	348.3	329.4	284.4	247.9	196.1	179.2	3258.6	kWh/m².mt
Clearness Index	0.000	0.038	0.146	0.291	0.364	0.390	0.350	0.280	0.142	0.055	0.000	0.000	0.204	
Amb. temper.	-3.5	-4.0	-3.5	-1.8	0.6	3.4	6.0	6.8	4.0	1.1	-1.1	-1.9	0.5	°C
Wind velocity	7.5	7.4	7.5	6.5	5.9	4.8	4.2	4.5	5.8	6.9	7.3	7.4	6.3	m/s

Table5 Monthly Meteo values in preliminary design

In report we can get the: **economic prospects** i.e. how much installation cost is incurred and what will be our energy cost; we can optimize this cost for a profitable project.

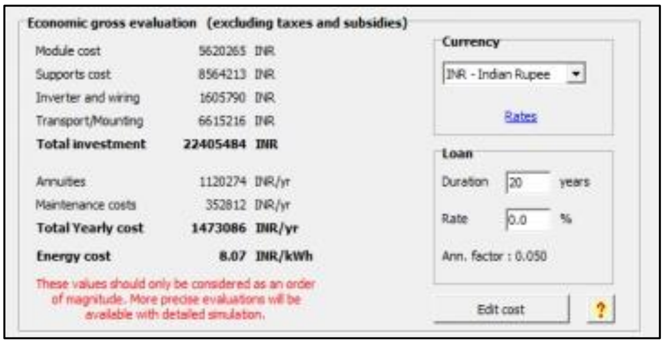


Figure27 Economic Gross Evaluation

Energy output: we can see how much kwh/m^2 day we can get and the global horizontal on a monthly basis in the form of bar graphs.

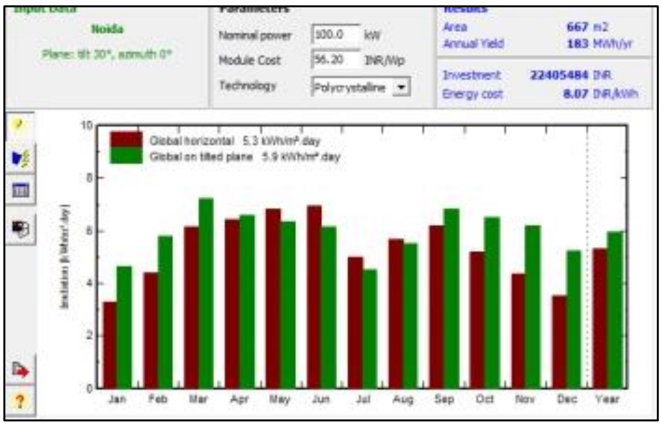


Figure28 Energy output comparison between tilted and horizontal plane

We can see summer months have the most energy output. In preliminary design is the basic project with many assumptions so this data can't be provided to customers.

Grid system presizing

Geographical Site	**Noida**		Country	**India**
Situation	Latitude	28.58° N	Longitude	77.33° E
Time defined as	Legal Time	Time zone UT+5.5	Altitude	214 m
Collector Plane Orientation	Tilt	30°	Azimuth	0°

PV-field installation main features

Module type	Standard
Technology	Monocrystalline cells
Mounting method	Facade or tilt roof
Back ventilation properties	Ventilated

System characteristics and pre-sizing evaluation

PV-field nominal power (STC)	Pnom	100 kWp		
Collector area	Acoll	625 m²		
Annual energy yield	Eyear	183 MWh	Specific yield	1825 kWh/kWp
Economic gross evaluation	Investment	272392 EUR	Energy price	0.10 EUR/kWh

Figure29 Preliminary Design Report

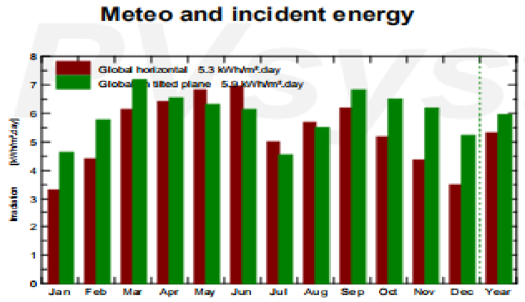


Figure30a Meteo and incident Energy

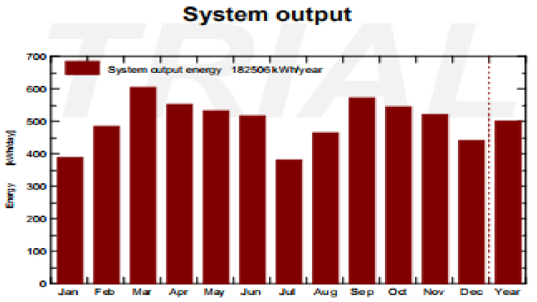


Figure30b System Output

Table6 Final Preliminary design system output table

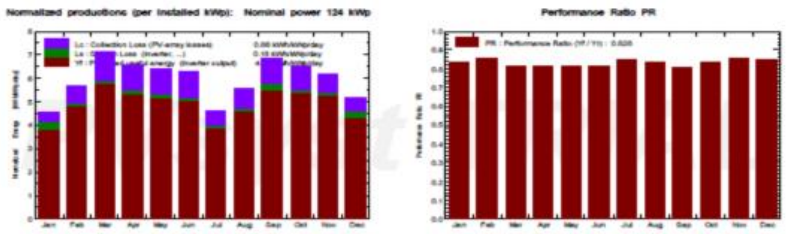
	Gl. horiz. kWh/m².day	Coll. Plane kWh/m².day	System output kWh/day	System output kWh
Jan.	3.29	4.64	389.7	12081
Feb.	4.38	5.78	485.9	13604
Mar.	6.13	7.20	605.3	18764
Apr.	6.41	6.57	551.8	16553
May	6.83	6.33	531.8	16486
June	6.94	6.14	516.3	15488
July	4.99	4.52	379.9	11776
Aug.	5.66	5.51	463.2	14360
Sep.	6.20	6.83	574.4	17232
Oct.	5.18	6.49	545.8	16921
Nov.	4.36	6.19	520.6	15617
Dec.	3.50	5.23	439.5	13625
Year	5.32	5.95	500.0	182506

4.2| Project Design report

Grid-Connected System: Simulation parameters

Project :	**New Project**			
Geographical Site	**Noida**		Country	**India**
Situation	Latitude	28.58° N	Longitude	77.33° E
Time defined as	Legal Time	Time zone UT+5.5	Altitude	214 m
	Albedo	0.20		
Meteo data:	**Noida**	PVGIS api TMY - TMY		
Simulation variant :	**New simulation variant**			
	Simulation date	24/05/20 16h05		
Simulation parameters	System type	**No 3D scene defined, no shadings**		
Collector Plane Orientation	Tilt	30°	Azimuth	0°
Models used	Transposition	Perez	Diffuse	Imported
Horizon	Free Horizon			
Near Shadings	No Shadings			
User's needs :	Unlimited load (grid)			
PV Array Characteristics				
PV module Si-poly	Model	**TSM-310PD14**		
Original PVsyst database	Manufacturer	Trina Solar		
Number of PV modules	In series	26 modules	In parallel	19 strings
Total number of PV modules	Nb. modules	494	Unit Nom. Power	250 Wp
Array global power	Nominal (STC)	**124 kWp**	At operating cond.	111 kWp (50°C)
Array operating characteristics (50°C)	U mpp	693 V	I mpp	160 A
Total area	Module area	**812 m²**	Cell area	721 m²
Inverter	Model	**SG20KTL**		
Original PVsyst database	Manufacturer	Sungrow		
Characteristics	Operating Voltage	480-800 V	Unit Nom. Power	20.0 kWac
Inverter pack	Nb. of inverters	5 units	Total Power	100 kWac
			Pnom ratio	1.24
PV Array loss factors				
Thermal Loss factor	Uc (const)	29.0 W/m²K	Uv (wind)	0.0 W/m²K / m/s
Wiring Ohmic Loss	Global array res.	73 mOhm	Loss Fraction	1.5 % at STC
Module Quality Loss			Loss Fraction	-0.5 %
Module Mismatch Losses			Loss Fraction	1.0 % at MPP
Strings Mismatch loss			Loss Fraction	0.10 %
Incidence effect, ASHRAE parametrization	IAM =	1 - bo (1/cos i - 1)	bo Param.	0.05
Unavailability of the system	3.6 days, 3 periods		Time fraction	1.0 %

Figure31 BASIC SPECIFICATION AND PROJECT LOCATION



New simulation variant
Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR
January	102.1	48.64	14.18	140.6	137.1	15.80	14.55	0.838
February	122.6	43.99	15.68	158.5	154.9	17.13	16.74	0.855
March	190.1	58.12	24.55	220.5	215.5	22.58	22.08	0.811
April	192.4	70.30	28.21	197.1	192.0	20.28	19.83	0.815
May	211.7	86.96	33.33	198.3	192.7	20.27	19.81	0.809
June	208.1	96.85	34.55	188.1	182.4	19.23	18.81	0.810
July	154.7	93.60	28.71	142.8	138.3	15.34	14.98	0.850
August	175.4	84.85	30.03	172.0	167.0	18.15	17.74	0.835
September	186.0	65.15	28.51	205.4	200.4	21.52	20.44	0.806
October	160.5	57.74	26.16	200.9	196.3	21.16	20.69	0.834
November	130.9	46.07	21.30	184.9	180.7	19.95	19.52	0.855
December	108.6	43.78	16.97	159.2	155.5	17.73	16.62	0.845
Year	1943.1	796.05	25.23	2168.4	2112.8	229.14	221.81	0.828

Legends:
GlobHor Horizontal global irradiation
DiffHor Horizontal diffuse irradiation
T_Amb T amb.
GlobInc Global incident in coll. plane
GlobEff Effective Global, corr. for IAM and shadings
EArray Effective energy at the output of the array
E_Grid Energy injected into grid
PR Performance Ratio

Figure32 MONTHLY ENERGY PRODUCTIONS, PERFOMANCE RATIO, NORMALIZED PRODUCTION

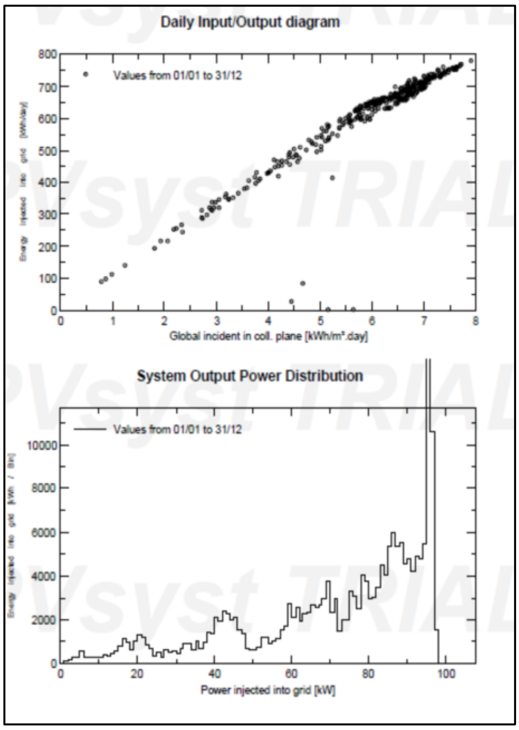


Figure33 DAILY INPUT OUTPUT DIAGRAM AND POWER INJECTED TO GRID

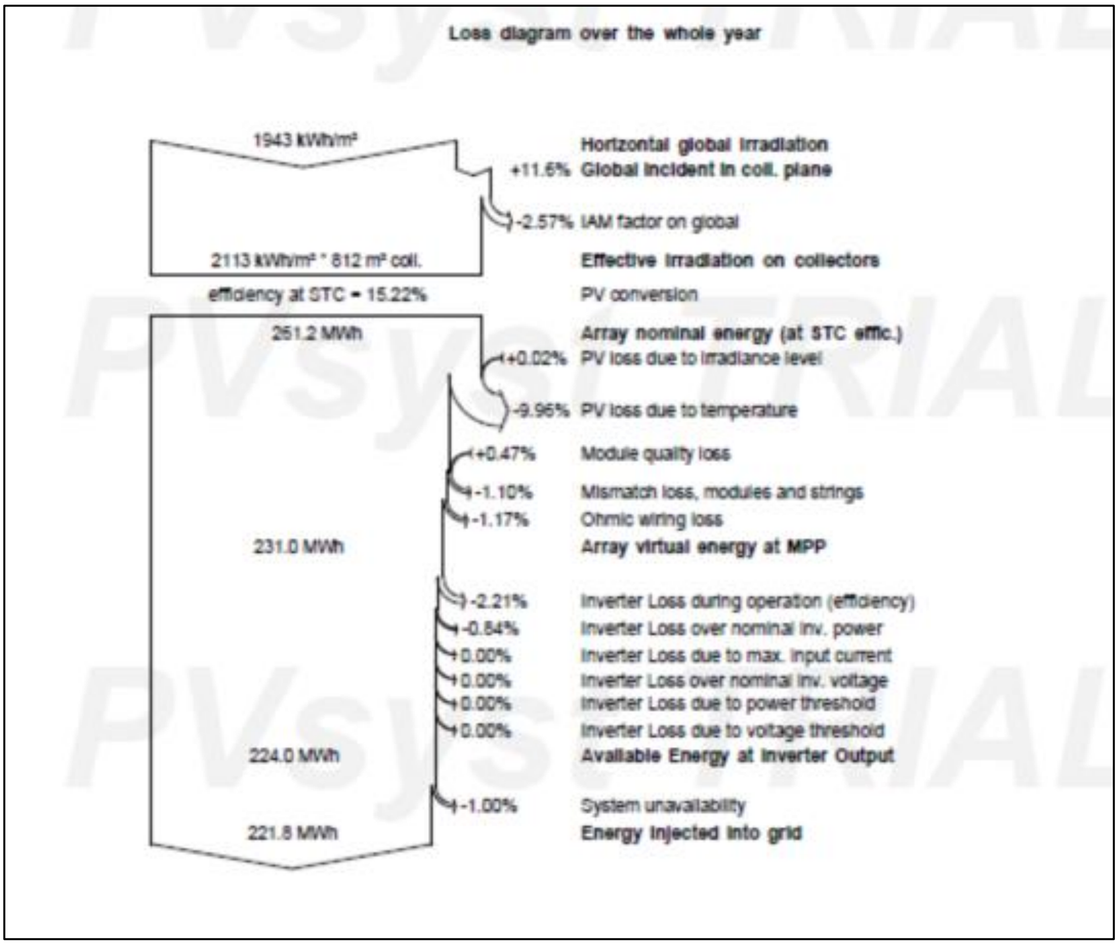


Figure34 LOSS DIAGRAM

Produced Emissions	**Total:**	**204.09 tCO2**		
	Source:	Detailed calculation from table below		
Replaced Emissions	**Total:**	**6228.5 tCO2**		
	System production:	221.81 MWh/yr	Lifetime:	30 years
			Annual Degradation:	1.0 %
	Grid Lifecycle Emissions:	936 gCO2/kWh		
	Source:	IEA List	Country:	India
CO2 Emission Balance	**Total:**	**5200.1 tCO2**		

System Lifecycle Emissions Details:

Item	Modules	Supports
LCE	1713 kgCO2/kWp	6.24 kgCO2/kg
Quantity	104 kWp	4160 kg
Subtotal [kgCO2]	178123	25971

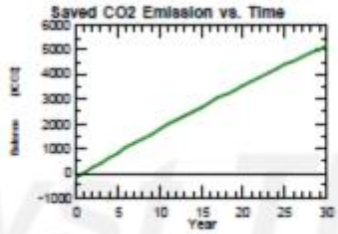


Figure35 CO_2 BALANCE

5| Conclusion

Photovoltaic gets its name from the mechanism of transforming light (photons) to electricity (voltage), which is called the photovoltaic effect. This phenomenon was first overworked in 1954 by scientists at Bell Laboratories who devised a working solar cell made from silicon that generated an electric current when exposed to sunlight. Solar cells were soon being used to power space satellites and smaller items such as calculators and watches. In today's world, electricity from solar cells has become cost-competitive in many regions and photovoltaic systems are being utilized at large scales to help feed a dynamic electric grid.

Therefore photovoltaic research is more than just making a high-efficiency, low-cost solar cell. Homeowners and businesses must be confident that the solar panels they install will not degrade in performance and will continue to reliably generate electricity for many years. Researches have been going on since the past decades so as to deploy solar PV systems to the electric grid without destabilizing the careful balancing act between electricity supply and demand. Here in our project, we will deal with the solar resource assessment to have a clear idea of the Annual Solar Energy Production and the losses that it encounters throughout the process affecting the efficiency of power plants.

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