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GRID CONNECTED SOLAR POWER PLANT

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ABSTRACT

Solar energy is an abundant and renewable energy source. The annual solar energy incident at the ground in India is about 20,000 times the current electrical energy consumption. The use of solar energy in India has been very limited. The average daily solar energy incident in India is 5kWh/m^2/day and hence energy must be collected over large areas resulting in high initial capital investment; it is also an intermittent energy source. Hence solar energy systems must incorporate storage in order to take care of energy needs during nights and on cloudy days. This results in further increase in the capital cost of such systems.

Solar power is the conversion of sunlight into electricity, either directly using photovoltaic (PV), or indirectly using concentrated solar power (CSP). Concentrated solar power systems uselenses or mirrors and tracking systems to focus a large area of sunlight into a small beam. Photovoltaic convert light into electric current using the photoelectric effect.

EXECUTIVE SUMMARY

India is well-endowed with solar energy as the daily solar radiation incidence varies from 5 to 7kWh/m^2/day for almost 300 or more days of sunshine in a year in different parts of the country. National Solar Mission (NSM) launched by our Prime Minister in the year 2010 is a major initiative of the Government of India with active participation from States to promote ecologically sustainable growth of solar power while addressing India's energy security challenge. Solar Energy Corporation of India (SECI), a Central Public Sector Enterprise established in 2011 by Ministry of New and Renewable Energy (MNRE) to implement the activities conceived under Jawaharlal Nehru National Solar Mission (JNNSM). The company aims at the development and promotion of the solar energy technologies in the country to eventually achieve commercialization.

Due to its distributed nature with negligible operational costs and long life of Solar Photovoltaic (SPV) Power Plants the solar energy has become very attractive in recent years. The solar PV installations in the country are in the line with the global trends and seen rapid growth in last few years due to policy and regulatory initiatives. Technological developments, mass production and increased market penetration reduced

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prices of solar photovoltaic modules thus moving solar power towards grid parity. The present installed capacity is about to reach 4000MW mark.

MNRE, Government of India (GoI) has issued a notification for implementation of scheme for setting up over 300 MW of Grid connected and Off-grid solar PV Power projects by Defense Establishments under Ministry of Defense (MoD). Under this scheme, Bharat Electronics Limited (BEL) (a Defense Public Sector Undertaking (DPSU), MoD will invest capital and establish solar power plants of capacity 50 MW in developer mode in the lands provided by identified Ordnance Factories. The energy developed by these solar plants is primarily for captive consumption by the Ordnance Factory units. Ordnance Factory, Medak (OFMK) is identified as a first such plants for setting up of a 16 MW Solar PV power plant matching their annual energy requirements.

As per the CERC tariff order, the tariff is fixed at Rs. 4.75/KWh and OFMK will get initial preference to consume the generated power. As per the present tariff rate being paid by OFMK which is around Rs. 5.65/kWh the direct benefit of Rs. 0.90/kWh can be realized. The proposed 16 MW plant is estimated to generate 24.75 million unit of energy per annum. Any excess electricity beyond the requirement of OFMK will be exported to the grid by the developer.

1. INTRODUCTION

Since the beginning of time, people have been fascinated by the sun. Ancient civilizations personified the sun, worshipping it as a God or Goddess. Throughout history, farming and agriculture efforts have relied upon the sun's rays to grow crops and sustain populations.

Only recently, however, have we developed the ability to harness the sun's awesome power. The resulting technologies have promising implications for the future of renewable energy and sustainability. Below, we've given a brief on solar power, how it works, and what may be in store for the future of solar.

Solar power is a form of energy harnessed from the power and heat of the sun's rays. It is renewable, and therefore a "green" source of energy.

The most common way of harnessing energy from the sun is through photovoltaic (PV) panels – those large, mirror-like panels you've likely seen on rooftops, handheld solar devices, and even space crafts. These panels operate as conductors, taking in the sun's rays, heating up, and creating energy (and electricity).

On a larger scale, solar thermal power plants also harness the power of the sun to create energy. These plants utilize the sun's heat to boil water and, in turn, power steam turbines. These plants can supply power to thousands of people.

Every hour, the sun beats down with enough power to provide global energy for an entire year.

It takes an average of eight minutes for energy to travel from the sun to the Earth.

Scientists have used solar energy to power spaceships since 1958.

Most solar panels used today have an average life expectancy of between 20-40 years.

Methods of solar energy utilization can be broadly classified as solar photovoltaic and Solar thermal. Solar Thermal systems convert solar radiation into thermal energy which can be used directly or converted into electricity where-as Solar Photovoltaic route converts the solar radiation directly into electricity.

Today most of the energy requirements are being met through the conventional fossil fuels which are finite and the resources are dwindling. Particularly in India 67% of its energy requirements are met by 197 billion tons of rapidly depleting coal deposits. To break this dependency, India needs clean energy revolution. Such a revolution would enhance energy security, promote enduring economic growth and tackle environmental challenges. Moreover, being amongst the top five greenhouse gas emitters globally, India has the responsibility to achieve the growth trajectory in an environmentally sensitive and responsible manner. India has set a voluntary target to cut their emissions intensity of GDP by 20-25 % by 2020 compared to 2005 levels.

2. POTENTIAL FOR SOLAR POWER IN INDIA

India, due to its geo-physical location, receives solar energy equivalent to nearly 5000 trillion kWh/year. This is far than the total energy consumption of the country today.

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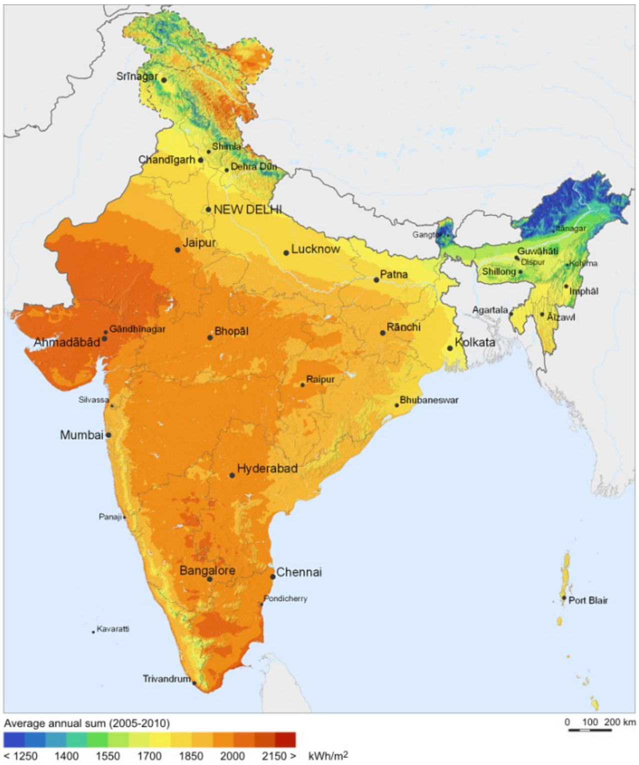

But India produces a very negligible amount of solar energy – a mere 0.2% compared to other energy resources. Currently, India has about 2180 MW of grid connected solar PV capacity. Following graph depicts solar energy potential in the country. While India receives solar radiation of 5-7 kWh/m^2 for almost 300 days in a year, power generation potential using solar PV technology is established to be around 20 MW/sq.km. The above data suggests that there is tremendous scope for growth in solar energy sector. Distributed generation using solar PV panels has not only increased the outreach of the technology to distant parts of the country but also made its economically viable.

2.1. Solar promotional policies

The Indian Government has identified this potential in solar sector and has initiated the NSM and various other solar policies along with the necessary regulatory framework. It also provides the necessary ecosystem for providing financial support through subsidies, FiT, VGT, etc.

2.2. Benefits of solar projects

The project activity will result in reducing carbon emissions by replacing electricity generated from fossil fuels fired power plants. The project activity has been essentially conceived to generate greenhouse gas emissions free electricity by making use of available solar PV in the project area. The project being a renewable energy project leads to sustainable development through efficient utilization of naturally available sunlight and generation of additional employment for the local stakeholders.

The GoI in its interim approval guidelines for Clean Development Mechanism (CDM) projects has stipulated a set of indicators for describing the sustainable development of a project and according to these indicators, the sustainability of the described project is as follows:

Social well being

The project activity is generating employment opportunities for professional, skilled and unskilled labor for development, engineering, procurement operation and maintenance of the project activity. The development of project specific infra-structure will result in employment and income generation activities for local personnel. In addition various kinds of maintenance work would generate employment opportunities for local contractor on regular basis.

Economic well being

The project activity would promote the application of solar energy based power generation investment to tune of INR 1000 million, which is a significant investment in a green field project in the region.

The project activities will act as a nucleus for other economic activities such as setting up of cottage industries, shops, hotels, etc. around the area contributing to economic development around the project area.

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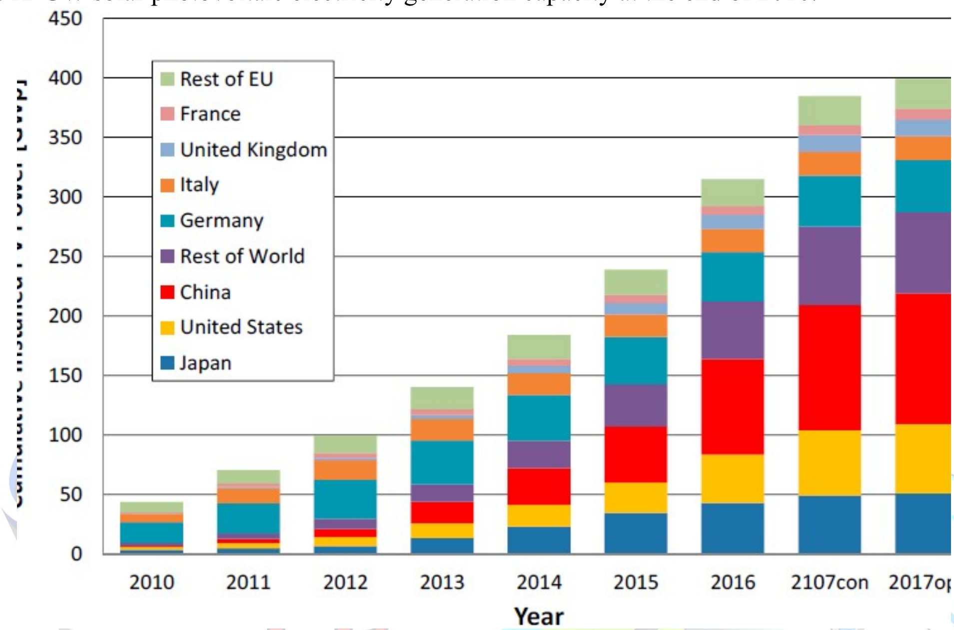
It helps conserve foreign exchange by reducing the need to import fossil fuels to meet country's growing energy demand.

Environmental well being

Solar energy based power generation system employ a robust and clean technology involving the latest state of the art renewable energy options for the purpose of electricity generation. The project implementation will lead to reduction of SO_x, NO_x and particulate matter (pm) emissions. It therefore results in an improvement in air quality and human health.

2.3. Global PV scenario

Solar photovoltaic (SPV) became the third most important energy source after hydro and wind power, in terms of globally installed capacity. Solar plants are being largely deployed around the world.
With a cumulative installed capacity 102 GW, the European Union contributes about one-third to the world-wide total 312 GW solar photovoltaic electricity generation capacity at the end of 2016.



The Asia & Pacific Region saw again an acceleration of photovoltaic electricity system installations driven by China, Japan, and India. In addition, countries such as the Gulf States, Indonesia, Malaysia, Pakistan, South Korea, Taiwan, Thailand, the Philippines, and Vietnam continue a very positive upward trend, thanks to increasing governmental commitment towards the promotion of solar energy and the creation of sustainable cities.

Over the last one and a half decades, the growth of photovoltaic electricity generation has always been faster than predicted. There are a number of reasons for this development, which are a combination of policy-driven demand creation, massive manufacturing capacity investments, and faster than expected technology progress.

At the end of 2016, more than 310 GW of cumulative photovoltaic electricity generation capacity had been installed worldwide. With this capacity, photovoltaicsystemscould contribute about 1.7% of the worldwide electricity demand and is still a small contributor to the electricity supply. However, different to the past, its importance for our future energy mix is now acknowledged.

2.4. Indian PV scenario

The key anticipated themes and developments for 2017 start with a pipeline of around 14 GW of utility scale projects, out of which 7.7 GW is expected to be commissioned in the year (growth of around 90% over 2016). Combined with 1.1 GW of expected rooftop solar capacity, India should add a total of 8.8 GW in 2017, ranking it amongst the top three global markets after China and the USA. On the policy front, impact of central government policies related to manufacturing, power distribution (UDAY) and implementation of GST is awaited keenly.

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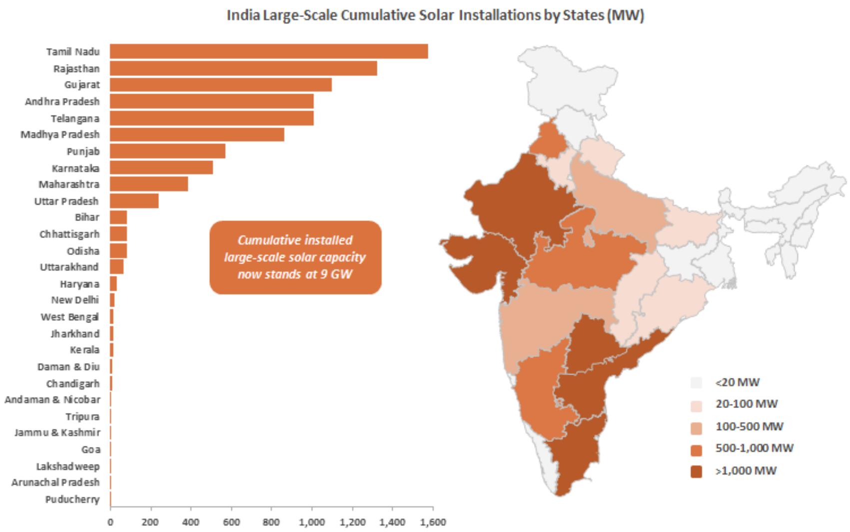
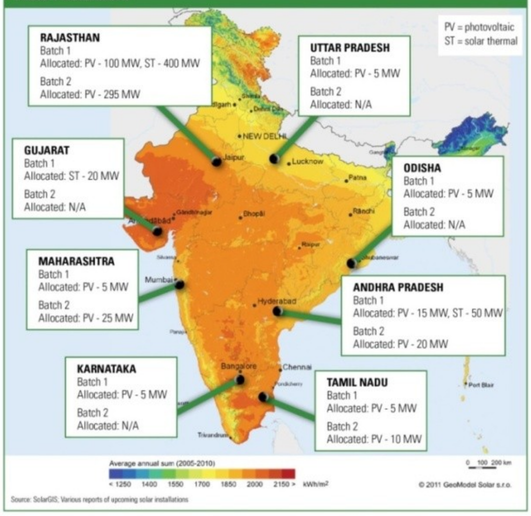


As the Indian market ramps up, it will become a key pillar for demand growth when demand in other leading countries including China, Japan and even possibly the USA is expected to slow down. Despite concerns about weak power demand growth and growing incidence of grid curtailment, solar power outlook in India remains very strong. 2017 will be a bumper year for the sector in India with total installed capacity reaching around 18 GW by the end of the year.

There has been some concern about weak power demand growth in India and growing incidence of grid curtailment and what it means for growth of solar power.Demonetization may also impact power demand negatively. But we believe that continuing reduction in module prices and downward trend in domestic interest rates will provide strong ongoing demand impetus to the market. Solar tariffs are expected to fall below the critical INR 4.00 (USD 0.06)/ kWh mark making solar power the cheapest new source of power.

FIGURE 2: Rajasthan and Gujarat, which are endowed with the highest irradiation, led Phase 1 installations



Source: SolarGIS; Various reports of upcoming solar installations

As the Indian market ramps up, it will become a key pillar for demand growth when demand in other leading countries including China, Japan and even possibly the USA is expected to slow down. We already see leading international equipment suppliers paying more attention to this market and developing specific pricing and product strategies for India.

However, we are still unsure if improving domestic demand will lead to large-scale investments in Greenfield manufacturing capacity. Notwithstanding the Indian government's keenness to support domestic manufacturing as part of 'Make in India' campaign, the competitive dynamics are stacked against this sector.

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Implementation of Goods and Services Tax (GST) during the year will lead to marginal cost increases and may create uncertainty for developers and contractors although there is a widespread expectation that any adverse impact will be passed through to the distribution companies.

Rooftop solar will also continue its spectacular growth trajectory in 2017. We expect around 1.1 GW of rooftop solar capacity to be added in 2017, up 75% from 2016, driven by capital subsidies and substantial demand from public sector.

3. SITE ASSESSMENT FOR A SOLAR POWER PLANT ESTABLISHMENT

The energy yield and economic viability of solar PV plants largely depends on the site conditions. It is an established climatic fact that the meteorological parameters are not uniform across the world, but vary with one location to other due to change of geographical locations (latitude and longitude), and earth-sun angular relationship. Solar radiation intensity is essentially governed by the earth-sun angles which comprise the geography of the location, declination of the earth and operating parameters (horizontal, fixed tilt or tracking). Solar energy is a dilute source of energy which requires significant area for collection of higher amount of energy.

There are lots of aspects in doing a site survey for an installer. The amount of details a site surveyor collects depends on the scope of project. A detailed analysis might be required if it involves industrial and commercial entities involving lot of equipment and appliances. In particular, we need to know the following in a site assessment.

- ✓ A suitable location for Solar Panels.
- ✓ What and where are the shaded areas that might fall on proposed solar arrays during day time with maximum Sun, typically 9.00am to 4.00pm.
- ✓ What type of Mounting is required for the Solar Array?
- ✓ Where do we locate the Balance of System components? E.g. Inverter, DC Combiner box, AC Distribution Box, Batteries, if required.
- ✓ What are the Energy Needs of the Building?
- ✓ How is the PV system going to be connected to the existing electrical systems?

In general, the engineering aspects are in terms of

- ✓ Land topology and conditions
- ✓ Access to the plant
- ✓ Geotechnical conditions
- ✓ Availability of resources
- ✓ Electrical setup and power evacuation infra-structure
- ✓ Shadow free area
- ✓ Climatic study which includes ambient temperature, wind speed, precipitation, etc.
- ✓

4. TECHNOLOGICAL OVERVIEW ON PHOTO VOLTAIC CELLS

Photovoltaics (PV) is a term which covers the conversion of light into electricity using semiconducting materials that exhibit the photovoltaic effect, a phenomenon studied in physics, photochemistry, and electrochemistry.

A typical photovoltaic system employs solar panels, each comprising a number of solar cells, which generate electrical power. PV installations may be ground-mounted, rooftop mounted or wall mounted. The mount may be fixed, or use a solar tracker to follow the sun across the sky.

Solar PV has specific advantages as an energy source: its operation generates no pollution and no greenhouse gas emissions once installed, it shows simple scalability in respect of power needs and silicon has large availability in the Earth's crust.

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PV systems have the major disadvantage that the power output is dependent on direct sunlight, so about 10-25% is lost if a tracking system is not used, since the cell will not be directly facing the sun at all times. Dust, clouds, and other things in the atmosphere also diminish the power output. Another main issue is the concentration of the production in the hours corresponding to main insolation, which don't usually match the peaks in demand in human activity cycles. Unless current societal patterns of consumption and electrical networks mutually adjust to this scenario, electricity still needs to be made up by other power sources, usually hydrocarbon.

4.1. Photovoltaic cells

The solar cell is a simple semiconductor p-n junction diode. When sun strikes a PV cell, the photons get absorbed by the semiconductor material and excite the electrons from the valence band to the conduction thus leaving behind a positive charge called hole. The electrons and holes gets separated by the junction potential making a p-region as positively charged and n-region as negatively charged. The charges create potential difference among the two ends of the solar cell generate electric current upon connecting to the external circuit. The complete process is called as photovoltaic effect and the cells are called photovoltaic cells.

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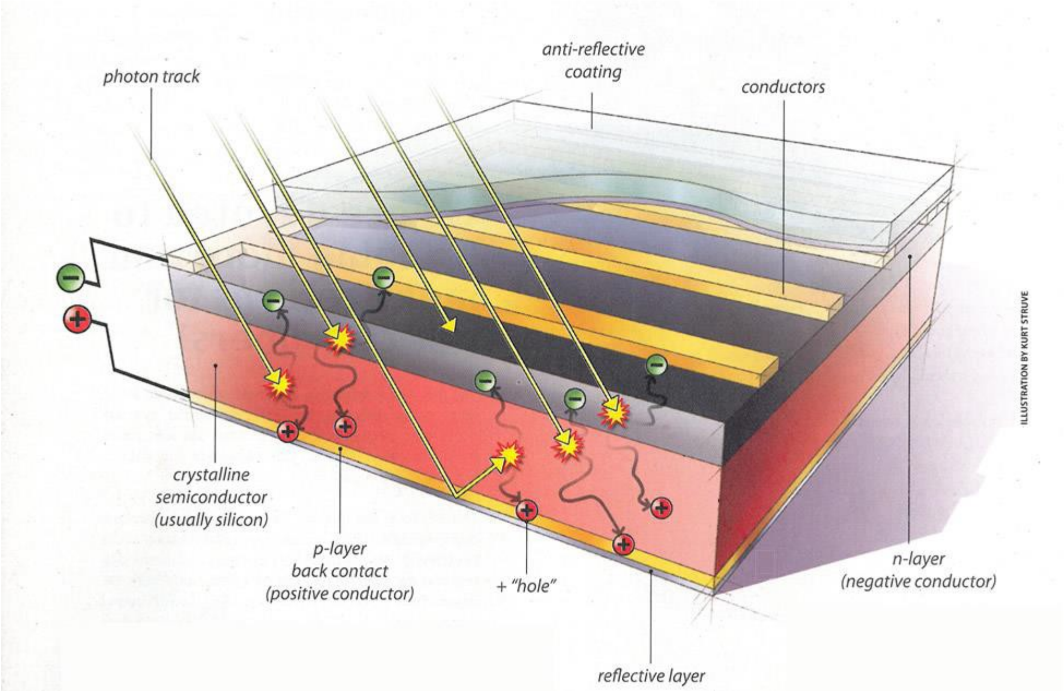
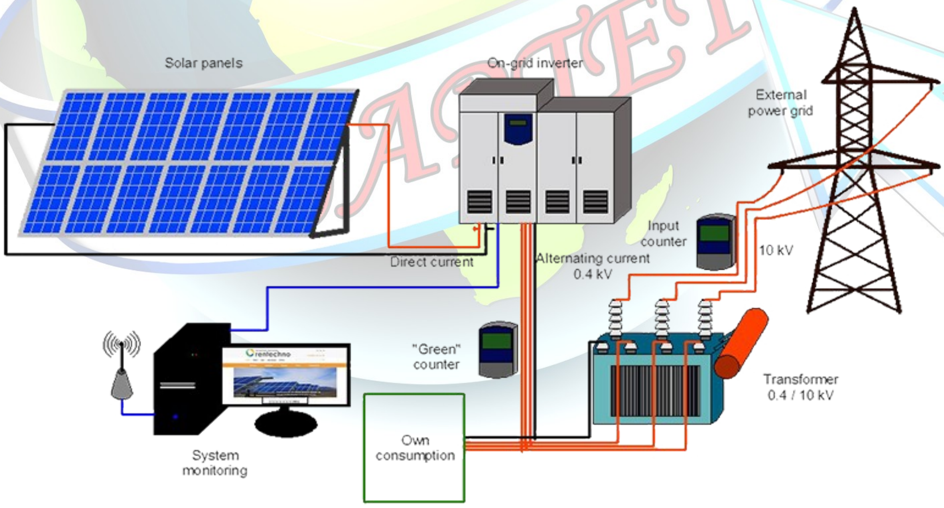


The electricity output of the solar cells per unit radiation is called solar cell efficiency. Present day solar cells are made up of different materials and the efficiencies are ranging between 10-23% for terrestrial applications. The solar cells used for space applications are highly expensive and are made of multi junction technology with the efficiencies between 36-42%.



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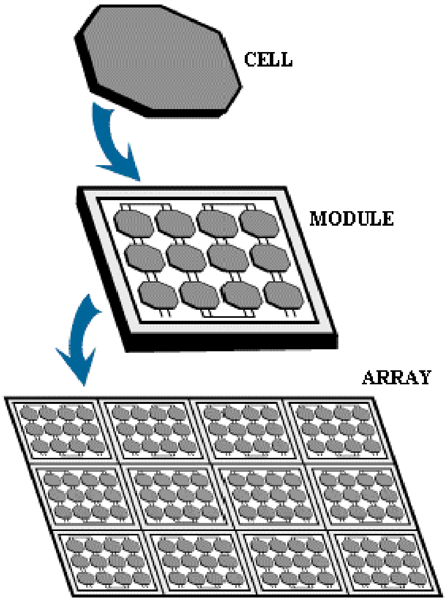

4.2. PV cell technologies

All photovoltaic (PV) cells consist of two or more thin layers of semi-conducting material, most commonly silicon. When the semiconductor is exposed to light, electrical charges are generated and this can be conducted away by metal contacts as direct current (DC). The electrical output from a single cell is small, so multiple cells are connected together to form a 'string', which produces a direct current.

In many roof-integrated applications, strings are encapsulated (usually behind glass) to form a module (commonly referred to as a 'panel'). The PV panel is the principal building block of a PV system and any number of panels can be connected together to give the desired electrical output.

Here, we only look at commercially available types of PV cell or film, any of which might be found in a module or film used on an active solar roof. We do not consider: Gallium Arsenide cells. Due to their toxicity and potential carcinogenic properties, these are only used in rare applications such as satellites or demonstration solar-powered cars.

Major PV technologies commercially available are as follows:

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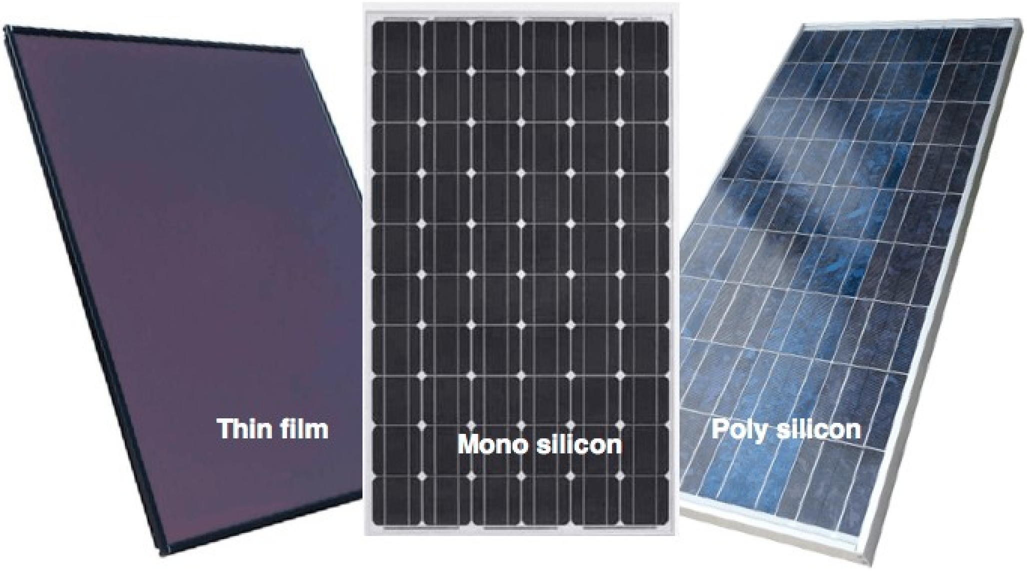
Mono-crystalline silicon PV panels



These are made using cells sliced from a single cylindrical crystal of silicon. This is the most efficient photovoltaic technology, typically converting around 15% of the sun's energy into electricity. The manufacturing process required to produce mono-crystalline silicon is complicated, resulting in slightly higher costs than other technologies.

Polycrystalline silicon PV panels

Also sometimes known as multi-crystalline cells, polycrystalline silicon cells are made from cells cut from an ingot of melted and re-crystallized silicon. The ingots are then saw-cut into very thin wafers and assembled into complete cells. They are generally cheaper to produce than mono-crystalline cells, due to the simpler manufacturing process, but they tend to be slightly less efficient, with average efficiencies of around 12%.

Thin film PV panels

Thin film solar cells are made up of high absorption coefficient materials which require a few microns of material to absorb >90% of the solar radiation. Earlier the amorphous form of silicon was being used to make solar cells. These cells are being used mostly in consumer electronic products which require lower power output and cost of production.

There are numerous compound semiconductor materials being investigated for the production of thin film solar cells. Thin film solar cells based on other materials like Copper, Indium, Gallium Selenide (CIGS) and Cadmium Telluride (CdTe) are also successful in recent years. The performance of thin film solar modules is better than crystalline Si modules in diffused radiation conditions and hence finds applications in shady areas with no drastic loss of efficiency and for building integrated applications.

Technology	Typical Conversion Efficiency	Lowest Cost Per Watt
Monocrystalline	15–20%	$3.48
Multicrystalline	12–15%	3.29
Thin-film	4–14%	2.47

Concentrated PV panels

These are based upon concentrators. The solar radiation is focused to multiply the intensity from 2-500 times by using polished metals or mirrors. The solar cells, based on different technologies are places in the area of focus to produce power. Highly efficient space quality cells are being used in high concentrator solar cells.

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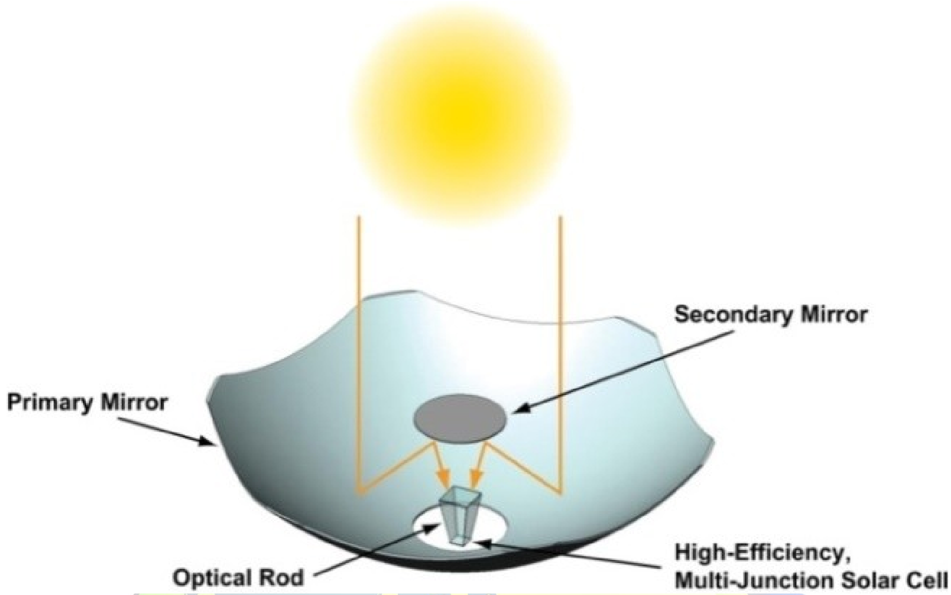

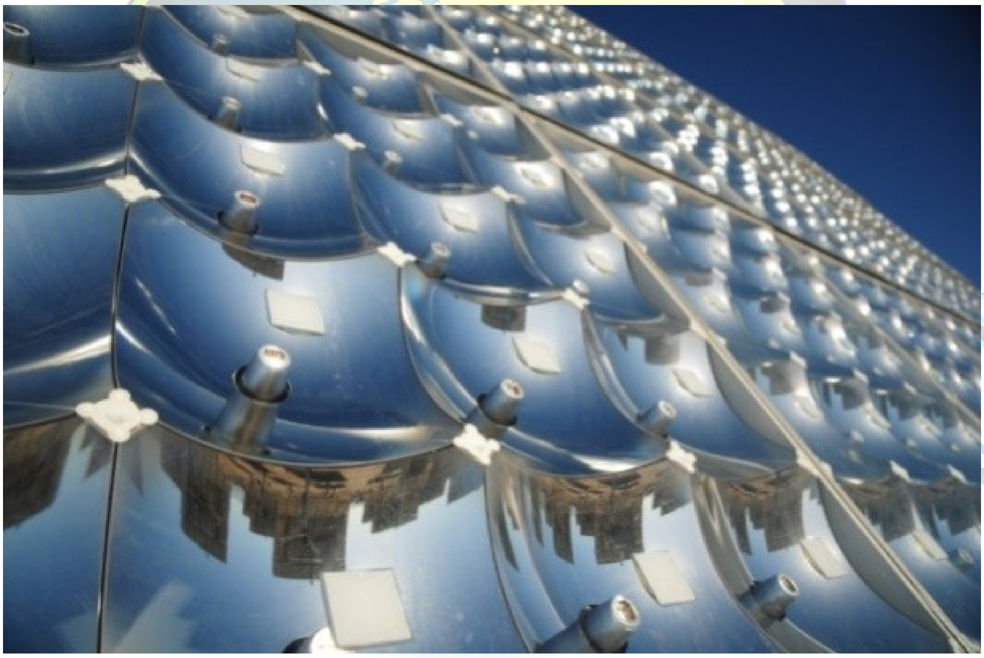

Due to the recent drop in Si solar module prices the concentrator solar modules are not commercially viable.

4.3. Nominal power

The nominal power is the nameplate capacity of photovoltaic (PV) devices, such as solar cells, panels and systems, and is determined by measuring the electric current and voltage in a circuit, while varying the resistance under precisely defined conditions. These Standard Test Conditions (STC) are specified in standards such as IEC 61215, IEC 61646 and UL 1703; specifically the light intensity is 1000 W/m^2, with a spectrum similar to sunlight hitting the earth's surface at latitude 35°N in the summer (air mass 1.5), the temperature of the cells being 25 °C. The power is measured while varying the resistive load on the module between an open and closed circuit (between maximum and minimum resistance). The highest power thus measured is the 'nominal' power of the module in watts. This nominal power divided by the light power that falls on a given area of a photovoltaic device (area × 1000 W/m^2) defines its efficiency, the ratio of the device's electrical output to the incident energy.

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The nominal power is important for designing an installation in order to correctly dimension its cabling and converters. If the available area is limited the solar cell efficiency and with it the nominal power per area (e.g. kW/m^2) is also relevant. For comparing modules, the price per nominal power (e.g. $/W) is relevant. For a given installation's physical orientation and location the expected annual production (e.g. kWh) per annual production assuming nominal power i.e. the capacity factor is important. With a projected capacity factor the price per projected annual production (e.g. $/kWh) can be estimated for a given installation. Finally, with a projected value of the production, the amortization of the cost of an installation can be estimated.

The peak power is not the same as the power under actual radiation conditions. In practice, this will be approximately 15-20% lower due to the considerable heating of the solar cells.

Watt-peak

The International Bureau of Weights and Measures, which maintains the SI-standard, states that the physical unit and its symbol should not be used to provide specific information about a given physical quantity and that neither should be the sole source of information on a quantity. Nonetheless, colloquial English sometimes conflates the quantity power and its unit by using the non-SI unit watt-peak and the non-SI symbol W_p prefixed as within the SI, e.g. kilowatt-peak (kW_p), megawatt-peak (MW_p), etc. As such a photovoltaic installation may for example be described as having "one kilowatt-peak" in the meaning "one kilowatt of peak power". Similarly outside the SI, the peak power is sometimes written as "P = 1 kW_p" as opposed to "P_{peak}=1 kW". In the context of domestic PV installations, the kilowatt (kW) is the most common unit for peak power, sometimes stated as kW_p.

4.4. Balance of plant

On an average, Balance of Plant (BoP) constitutes of 40-45% of the total cost of a solar PV project. For a solar PV plant, the BoP comprises of inverters, cables, mounting systems, foundations and power electronics. Often assigned secondary importance irrespective of their being a significant cost component, BoP are critical determinants of the actual plant life. High technical standards of BoP components should therefore be ensured as a matter of standard practice.

Inverter technologies

An inverter is an electrical device that converts direct current (DC) to alternating current (AC). The converted AC can be at any required voltage and frequency with the use of appropriate transformers, switching, and control circuits.

Inverter efficiencies if reputed brands have reached up to 98% and can be String-type (up to 100kW) or Central-type(>100kW). String-type are used in residential, small and medium scale applications. Central type are used for utility scale applications as they have the advantage of lowering the DC watt unit cost and fewer component connections, they may also entail higher installation costs and higher DC wiring and combiner costs. String inverters on the other hand have the advantage of lower balance of system costs, lower maintenance costs and modularity, but entail higher DC watt unit cost, more inverter components and require more distributed space to mount the inverters.

Some of the new trends in the inverter technologies involve the use of features that take care of grid stabilization and optimization of self-consumption, battery management controller chips and innovative use of semiconductors that allow very high efficiencies. For the scope of solar project at OFMK Central Inverters are in application.

Cabling

Working with solar PV arrays can be extremely hazardous since solar panels connected together in an array are often configured to produce high voltages. So DC cables are double insulated and polarized and DC connectors should always be used. Adequate size of cables is selected for minimal voltage drop i.e. maximum voltage drop in the string designed to be around 1%. For calculation purpose positive cable is taken around 5m and negative cable is taken around 25 m in length per string. Hence, to achieve proposed string voltage drop, positive and negative cables area of cross-section is taken around $10mm^2$.

AC cables from the inverter, which are 3-phase, are connected to the AC distribution connector unit for more reliability and to facilitate maintenance. The voltage output of the inverter is connected to the transformer, the lines are connected to grid. AC cables sizing are designed to achieve <1% of AC voltage drop from inverter to transformer.

Mounting systems

The prime consideration in the design of mounting structures is the nature of wind loads in the proposed location, taking into the cognizance any seasonal/local winds that may exert additional load. Typically the mounting structures are designed to withstand a wind of speed of about 150-200 kmph.

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5. PROJECT IMPLEMENTATION

Ordnance Factory Medak (OFMK) Introduction

Ordnance Factory Medak manufactures armored vehicles and is one of the 41 Indian Ordnance Factories under Ordnance Factories Board of the Ministry of defence controlled by Government of India. Ordnance Factory Medak was established on 19 July 1984 by the then Prime Minister of India, Smt. Indira Gandhi for the indigenous production of Infantry Combat Vehicles (ICV). The company is headed only by an IOFS officer called General Manager (ex officio Additional Secretary to Government of India) who is the Chief Executive Officer responsible for the overall management of the company and is the main judicial authority. OFMK is the only manufacturer of ICVs in India.

OFMK has designed one of the best Infantry Combat Vehicles in the world known as SARATH for the Indian Army.

The requirement of Army for Infantry Combat Vehicles has been totally met by Ordnance Factory Medak. The factory is now producing Bullet Proof Vehicles and poised for production of hulls and turrets for Main Battle Tank (Arjun) and Armor Amphibious Dozer, Rocket Launchers (Pinaka) etc. The diversified product mix in special vehicles and Naval Products is the result of indigenous R & D efforts fortified by in-house CAD / CAM center at Ordnance Factory, Medak. This has greatly reinforced the Security Forces and also improved the economy of our factory. This factory has successfully made forays in Civil Trade and Export Market as well. Their business share to the Ministry of Home Affairs and Other Defence Departments has steadily gone up.

OFMK energy policy

"OFMK, a large scale manufacturing unit of armored personnel carriers, is committed for conservation of energy and continual improvement in its energy performance by complying with energy rated statutory laws, rules & regulations and promoting the use of renewable energy sources, energy efficient equipments & technologies."

5.1. Solar power plant implementation

Solar power plants are based on the principle of Distributed Generation and are generally of smaller scale. Large, MW scale of solar PV plants, though, have also been commissioned or are in construction phase in different parts of the world, including India. Plants have become feasible in light of the drastically falling PV prices over the years and incessant R&D efforts to increase the solar cell efficiencies.

Area (acres)	80
Possible capacity of solar PV power plant (MW)	16
Availability of shadow free area	Complete area is shadow free only

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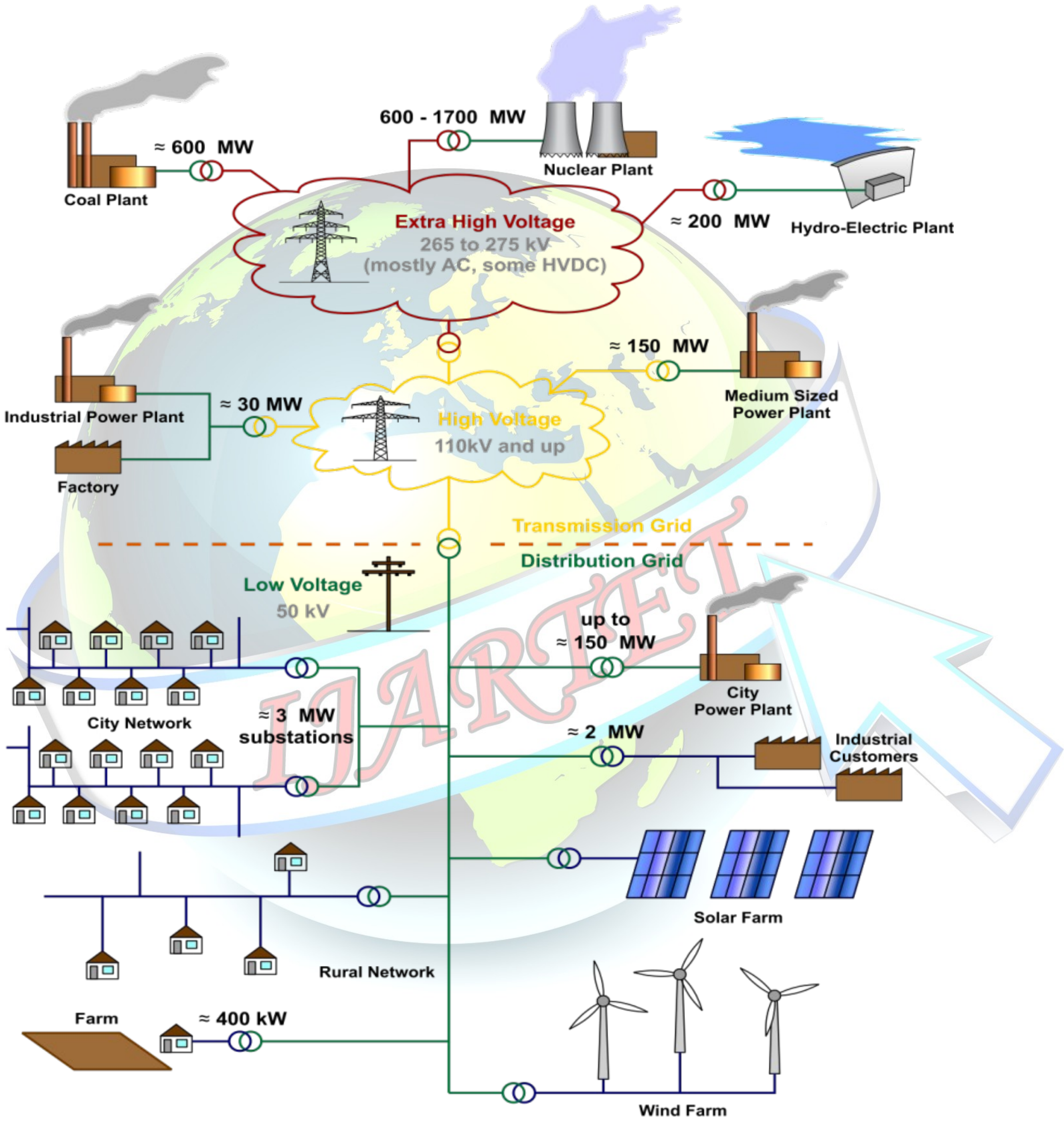
A MW scale project as is being proposed in this document will not only demonstrate the reliability of solar PV power but also provide further impetus to this clean and abundant source of power, so it can be taken from the niche markets to the common populace and allay fears about energy security.

5.2. Power evacuation



An electrical grid is an interconnected network for delivering electricity from generators to consumers. It encompasses generating stations that produce electrical power, high and medium voltage transmission lines that carry power from distant sources to load centers and distributed lines that finally carry the energy to individual consumers.

In a grid interactive system, the energy generated from the solar field is exported directly to the grid without any intermediate storage. DC to AC conversion including voltage regulation, power factor and harmonic control are done through solid state inverters or power conditioning units (PCU).

During the site visit, it was observed that in the premise of the OFMK, the existing voltage level where 220 kV, 132 kV, 33 kV and 11 kV and existing infrastructure are capable for evacuation of proposed capacity. In order to

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take benefit of Telangana State's Energy Balancing policy, it is proposed to connect the plant directly to TRANSCO's substation at 132 kV level.

In the solar PV power plant at OFMK, 24 PV modules are connected in series (forming an array) and 15 arrays are connected in parallel with each line of 15 arrays giving out 2 strings (positive and negative). These strings from 15 arrays are given to a SMB (String Monitoring Box).

14 SMBs are connected with an inverter in the inverter room and there are 3 inverter rooms each having 4 inverters connected with synchronizing unit respectively. Out of the 4 inverters, every 2 inverters are connected to a step up 3 winding transformer. And every inverter room accommodates 2 such transformers, whose secondary windings are parallel connected to a feeder. Hence 3 feeders are given to the control room from the 3 inverter rooms respectively and to outlet to the local supply via a transformer. This description can be understood by the enclosed power flow diagram in the report.

Hence, in simple means the power evacuation at OFMK solar power plant can be depicted as in the following figure:

PV system specifications at OFMK

The below are under standard test conditions: Irradiance = 1000 Whm^2, Temp = 25° C.
The PV arrays are oriented with a tilt of 21° angle and azimuth angle of 0°.

PV module type	Si-Poly
Power (P_{max})	255 W
Short Circuit Current (I_{sc})	8.85 A
Open Circuit voltage (V_{oc})	37.82 V
Current at Max Power (I_{pm})	8.53 A
Voltage at Max Power (V_{pm})	29.91 V
Max over current protection	20 A
No. of modules used (approx.)	60000
No. of modules in an array	24 (in series)
No. of arrays connected to SMBs	15

As mentioned in the tabular form presented above SMBs (String Monitoring Box) are the electronic modules used for monitoring the condition of every PV module and the information is directly send to the Supervisory Control and Data Acquisition (S.C.A.D.A).

Inverter system specifications at OFMK

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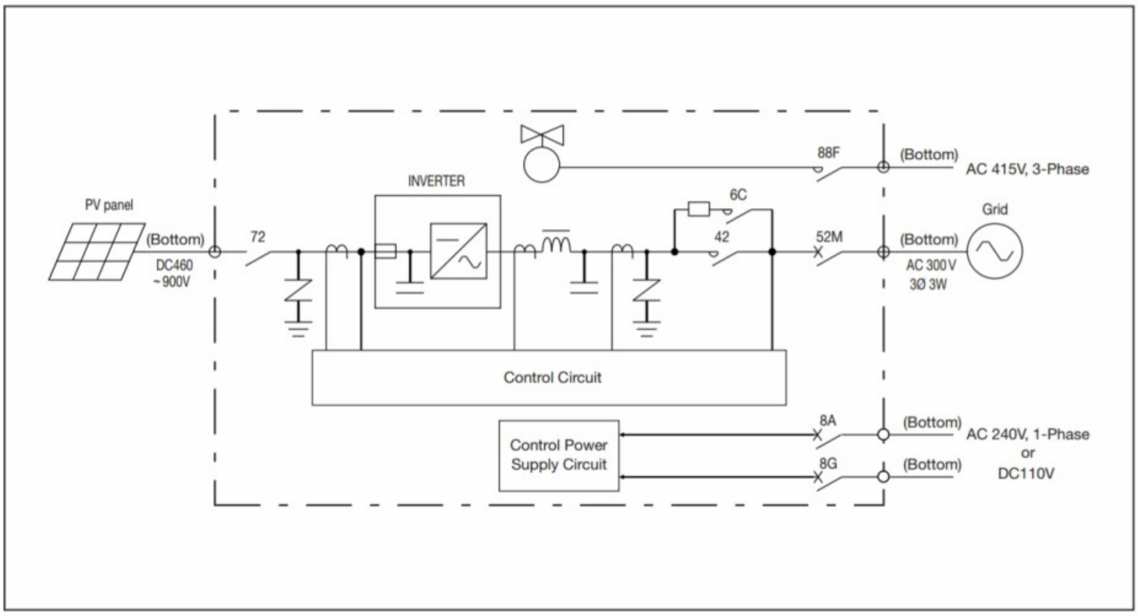

The DC voltage from the PV array, which is of 750V, is converted to 350V AC by the inverters present in the inverter rooms.

Controlling unit (Switch Gear)

The controlling and monitoring of the condition, electrical parameters and the reliability of the components used in the plant which includes the PV panels, SMBs, inverters cabling, etc. are done at the control unit.

Stepping up phase

The AC voltage, after inverting the DC voltage from PV panels, is about 350V. This voltage is stepped up to 132kV in steps as shown

350V>> 33kV>> 132 kV

The grid voltage received at the Main Receiving Station (MRS) at OFMK is about 132kV from the grid. Hence the above stepped up voltage i.e. 132 kV is given to the grid.

5.3. The Overall losses in the plant

5.4. The Financials of the Project

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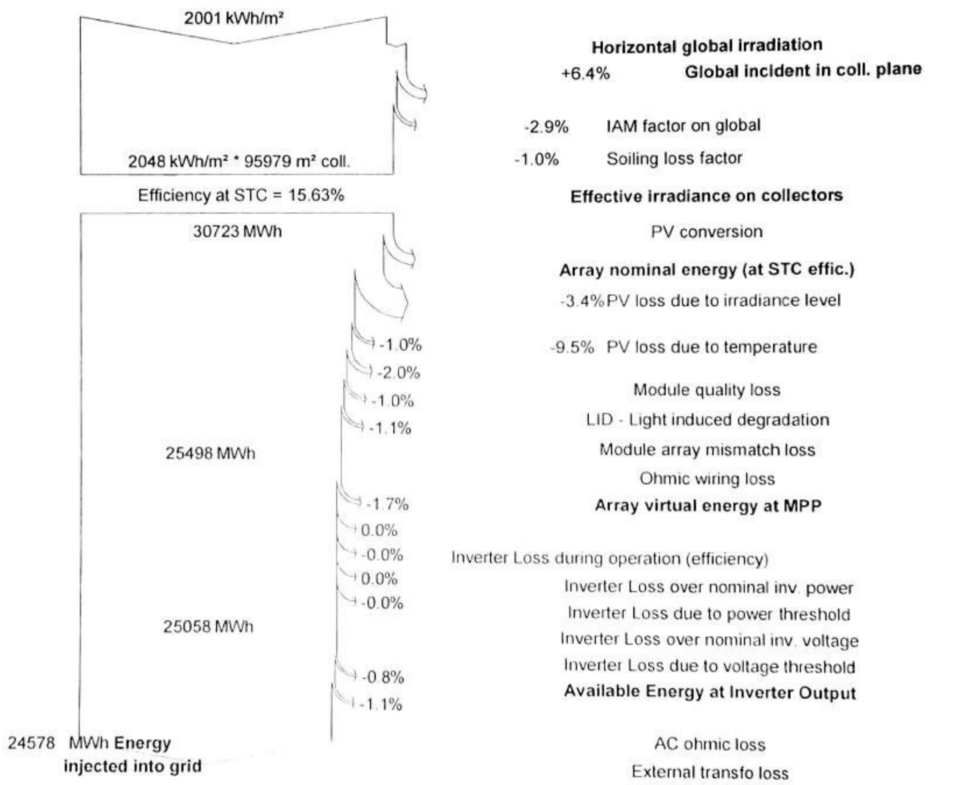

The financial analysis of the plant is carried out considering the project life of 25 years. The power shall be made available to the beneficiary at a rate of Rs. 4.75/ kWh. Hence, by considering the present rate, which is Rs.5.65/ kWh, a direct benefit of 0.90/ kWh can be a gain for the organization. The particulars are briefed as below:

Plant capacity	16MW
Estimated cost	Rs.6.71 Cr/MW
O&M cost	Rs. 13 lakhs/MW
Tariff	Rs. 4.75 (-2% deduction on banked power)
The overall annual savings to OFMK	Rs. 86.73 lakhs (approx.)

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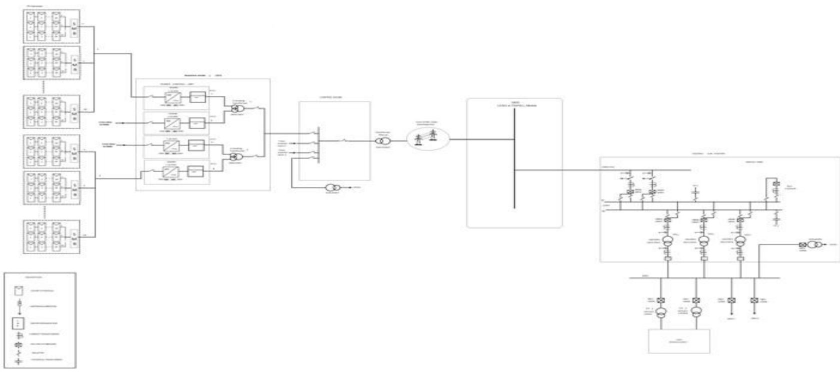

CONCLUSION

The sun is a powerful source that can help our planet by giving us clean, reusable energy to power our world. The use of this energy is free, does not create pollution, and if used wisely can help us become less dependent on other more costly and damaging forms of power. After viewing this report on solar power we hope you are able to see the benefits of this valuable resource and help change the future for energy use.

The results showed promise for solar development in the future. While the area studied may not have the best solar suitability on the west coast, it should be strongly considered for solar power plant development as solar technology advances and alternative energy as a whole becomes more affordable relative to fossil fuels.

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