Green Pearl
ELECTRONICS

# DETAILED PROJECT REPORT FOR
# 50 KWp GRID CONNECTED
# Roof Top SOLAR PV POWER PLANT

**Customer: M/s. SRM INSTITUTE OF SCIENCE AND TECHNOLOGY**

**Plant Location: KATTANKULATHUR**

# INDEX

## CHAPTER 1: GLOSSARY

| | |
|---|---|
| **Photovoltaic** | The physical effect of direct Conversion of light (sunlight) to electrical energy |
| **PV Cell** | The smallest photovoltaic (PV) element that generates electricity from light. |
| **PV Module** | A collection of interconnected PV cells, encapsulated between protective materials such as glass and back sheet (Poly Vinyl Fluoride) or glass and glass, and mounted in an aluminum frame. This is a hermetically sealed unit. |
| **String** | Multiple PV modules connected in series electrically. |
| **Array** | Several strings of modules with the same orientation and tilt angle, located together. |
| **Inverter** | An electronic device that converts direct current electricity into alternating current electricity suitable for feeding directly to the electrical grid or to normal AC loads. |
| **Insolation** | It is a measure of solar radiation energy received on a given surface area in a given time. It is commonly expressed as average irradiance in watts per square meter ($W/m^2$) or kilowatt-hours per square meter per day ($kW\cdot h/(m^2\cdot day)$) (or hours/day) |
| **Solar Irradiation** | The total electromagnetic radiation emitted by the Sun. |
| **STC** | "Standard Test Conditions" - Incident Solar Irradiance of 1000 Watts/$m^2$, at a spectral density of AM1.5 and cell temperature of 25˚C |
| **Mounting Structure** | Device used to hold modules in place, at desired angle & direction |

| | |
|---|---|
| **Power Evacuation** | Power generated from Solar PV Power Plant is transmitted to a point (sub station) where it is distributed for consumer use. |
| **Sub-station** | The place where the generated power from solar is synchronized with utility grid and metered. |
| **Control Room** | A room housing control equipment. |
| **Cable** | A conductor with one or more strands bound together, used for transmitting electrical energy. |
| **Efficiency** | The ratio of the output to the input of any system. |
| **Junction boxes** | Inputs of several strings are connected to this box and taken as single output |
| **Current** | A flow of electricity through a conductor measured in Amps. |
| **Voltage** | The rate at which energy is drawn from a source that produces a flow of electricity in a circuit; expressed in volts<br>It is the difference of electrical potential between two points of an electrical or electronic circuit, expressed in volts. It is the measurement of the potential for an electric field to cause an electric current in an electrical conductor. |
| **Lightning Arrestor** | Device used to protect all the components from lightning strikes |
| **Earthing** | Described as a system of electrical connections to the general mass of earth |
| **Transformer** | An electrical device by which alternating current of one voltage is changed to another voltage |
| **Grid** | A system of high/low tension cables by which electrical power is distributed throughout a region |

**Abbreviations (Table 01)**

| | |
|---|---|
| AB | Air Breaker |
| ACB | Air Circuit Breaker |
| AC | Alternate current |
| ACSR | Aluminum Conductors Steel Reinforced |
| BOS | Balance of the System |
| CDM | Clean Development Mechanism |
| CER | Carbon Emission Reduction |
| $CO_2$ | Carbon Dioxide |
| CT | Current Transformer |
| DAS | Data Acquisition System |
| DC | Direct Current |
| DP | Double Pole |
| DPR | Detailed Project Report |
| HSEB | Haryana State Electricity Board |
| HT | High Tension |
| LT | Low Tension |
| LV | Low Voltage |
| MNRE | Ministry of New and Renewable Energy |
| kWh | Kilo Watt Hour |
| $NO_2$ | Nitrous Oxide |
| MCB | Main Combiner Box / Miniature Circuit Breaker |
| MFM | Multi Function Meters |
| PLF | Plant Load Factor |
| PFC | Power Finance Corporation |
| PPA | Power Purchase Agreement |
| PV | Photo Voltaic |
| PT | Power Transformer |
| SEB | State Electricity Board |
| $SO_2$ | Sulphur Dioxide |
| SP | Single Pole |
| UNFCCC | United Nations Framework Convention on Climate Change |
| VCB | Vacuum Circuit Breaker |
| XLPE | Cross Linked Polyethylene |

## Units (Table 02)

| | |
|---|---|
| % | Percentage |
| ˚C | Degree Celsius |
| h | Hour |
| kV | Kilo-Volt |
| kW | kilo Watt |
| kWp | kilo Watt Peak |
| m | meter |
| m2 | Square meter |
| m3 | Cubic meter |
| mg | milligram |
| mm | milli-meter |
| MW | Mega Watt |
| MWp | Mega Watt peak |

## CHAPTER 2: EXECUTIVE SUMMARY

1. India is both densely populated and has high solar insolation, providing an ideal combination for **Solar Power in India.** Power is the lifeline of any development of the nation. At present the power requirement is being met by three main sources viz., Thermal, Hydel and Nuclear. While Hydel and Nuclear have their inherent limitations, Thermal Power is often confronted by the challenge associated with the availability of fuel. Currently Thermal Power stations which meet the major part of the power demand use coal as fuel. Conventional fuels such as oil, gas and coal cannot meet the increasing demand forever. In addition to the requirement of huge funds, the implementation of more such projects using conventional means of power generation will also involve issues of growing environmental concern, with depletion of fossil fuels.

2. In order to bring down the dependence of finite fossil fuel for power generation, it is necessary to look into the viability of generating power locally using renewable energy sources.

3. Fortunately, India lies in sunny regions of the world. Most parts of India receive 4.7 kWh of solar radiation per square meter per day with 300-325 sunny days in a year. India has abundant solar resources, as it receives about 3000 hours of sunshine every year, equivalent to over 5,000 trillion kWh. India can easily utilize the solar energy. Today The Government is encouraging generation of electricity from various renewable energy sources such as wind, solar, small hydro, biomass by giving various fiscal & financial incentives. This apart, the state governments are procuring electricity from renewable energy projects at preferential tariff. So far 29,536 MW of renewable power capacity have been installed in the country, which includes 19,933 MW from wind, 2079 MW from solar, 3746 MW from small hydro and 3776 MW from bio energy. The Ministry of New and Renewable Energy is providing various renewable energy systems for decentralized generation of electricity. So far, 10,752 villages have been electrified using various renewable energy systems. About 2.55 lakh solar street lights, 9.93 lakh solar home lightening systems, 9.39 lakh solar lanterns and 138 MW of decentralized solar power plants have been installed.

4. Government of India has separately set up a Ministry called MNRE - Ministry of New Renewable Energy for the promotion of Power Generation through Renewable Energy. The Ministry has been facilitating the implementation of broad spectrum program’s including harnessing renewable power/ Energy( make use of one), renewable energy to rural areas for lighting, cooking and motive power, use of renewable energy in urban, industrial and commercial applications and development of alternate fuels and applications.

5. MNRE has announced a host of fiscal incentives such as concessional custom duties, exemption of excise duty and accelerated depreciation for Solar PV based Power Plants. At the State level, promotion of Solar Power generation is being encouraged by local policies that cover buy back, wheeling and banking of the generated electricity by State Electricity Boards, besides other incentives.

6. Considering the good potential of Solar Power and also the trust given by the Central & State Government in utilizing the abundant Solar Power in the State of Tamil Nadu for Power generation, M/s SRM INSTITUTE OF SCIENCE AND TECHNOLOGY is proposing to set up 50KWp Roof Top Solar PV based Power Plant in Tamil Nadu state.

7. This Technical Proposal highlights the implementation of 50KWp Solar PV based Power generation project at Tamil Nadu state under Independent Power Producer (IPP) mode.

8. The proposed Power Plant will have Solar PV modules, String Inverters as the major components & other accessories for the Power production.

9. All the necessary auxiliary facilities of the Power Plant like Plant Monitoring system, Safety equipments, Instrumentation, Control system etc., will be provided for the Power Plant. The water requirement for the module cleaning & for other requirements can be met from bore-wells at site.

10. The site selection for a Solar Power Plant is pre-dominantly determined by solar isolation availability & grid connectivity for exporting power. The proposed site where M/s SRM INSTITUTE OF SCIENCE AND TECHNOLOGY Power Plant is to be located in Tamil Nadu is found favoring the above factors to a great extent.

11. The Plant and equipment facilities will be designed to comply with all applicable stipulations / guidelines of statutory authorities such as State and Central Pollution Control Boards, Electrical Inspectorate, Inspector of Factories etc.

12. The net send out Power available from 50KWp Power Plant is estimated to be 89MWh per annum for crystalline modules.

13. For the purpose of this report, it is considered that the capital requirement of the project will be met by M/s SRM INSTITUTE OF SCIENCE AND TECHNOLOGY.

14. This report highlights the details of the proposed Power generation scheme, site facilities, features of the main plant, electrical systems evacuation of generated power, environmental and safety aspects, distribution mechanism, Cost estimation, risk mitigation plan and Project viability. It also highlights the complete schedule for the project implementation.

## CHAPTER 3: PROJECT SUMMARY

| | | |
|---|---|---|
| 1. | Name of the Company | SRM INSTITUTE OF SCIENCE AND TECHNOLOGY |
| 2. | Proposed Project Location | KATTANKULATHUR |
| 3. | District Name | Kanchipuram |
| 4. | State | Tamil Nadu |
| 5. | Proposed Power Plant capacity | 50KWp |
| 6. | Technology | Solar Photovoltaic |
| 7. | Location of place on Earth | (i) Latitude : 12,49,24,N<br>(ii) Longitude : 80,2,30,E |
| 8. | Altitude | 75m |
| 9. | Average annual solar isolation | 5.14 kWh/m2/day |
| 10. | Nearest Town | Chennai |
| 11. | Nearest airport | Chennai Airport |
| 12. | Nearest Railway station | Potheri |
| 13. | Type of Module proposed | Mono Crystalline |
| 14. | Type of Inverter proposed | String |
| 15. | Total Inverter capacity | 55kW |
| 16. | Projected Gross Energy Production per year | 89MWh @100% grid availability |

# CHAPTER 4: INTRODUCTION

## 4.1 Power Scenario in India

The electricity sector in India supplies the world's 6th largest energy consumer, accounting for 3.4% of global energy consumption by more than 17% of global population. the Energy policy of India is predominantly controlled by the Government of India's, Ministry of Power, Ministry of Coal and Ministry of New Renewable Energy and administered locally by Public Sector Undertakings (PSUs).

About 70% of the electricity consumed in India is generated by thermal power plants, 21% by hydroelectric power plants and 4% by nuclear power plants.[1] More than 50% of India's commercial energy demand is met through the country's vast coal reserves. The country has also invested heavily in recent years in renewable energy utilization, especially wind energy. In 2010, India's installed wind generated electric capacity was 13,064 MW. Additionally, India has committed massive amount of funds for the construction of various nuclear reactors which would generate at least 30,000 MW. In July 2009, India unveiled a $19 billion plan to produce 20,000 MW of solar power by 2020.

Due to the fast-paced growth of India's economy, the country's energy demand has grown an average of 3.6% per annum over the past 30 years. In December 2010, the installed power generation capacity of India stood at 165,000 MW and per capita energy consumption stood at 612 kWh. The country's annual energy production increased from about 190 billion kWh in 1986 to more than 680 billion kWH in 2006. The Indian government has set a modest target to add approximately 78,000 MW of installed generation capacity by 2012 which it is likely to miss. The total demand for electricity in India is expected to cross 950,000 MW by 2030.

According to a research report published by Citigroup Global Markets, India is expected to add up to 113 GW of installed capacity by 2017. Further, renewable capacity might increase from 15.5 GW to 36.0 GW. In the private sector, major capacity additions are planned in Reliance Power (35 GW) and CESC (7 GW).

## Administration

` The Ministry of Power is the apex body responsible for coordination administration of the electrical energy sector in India. This ministry started functioning independently from 2 July 1992; earlier, it was known as the Ministry of Energy. The Union Minister of Power at present is Sushilkumar Shinde of the Congress Party who took charge of the ministry on 28 May 2009.

## Technical

` Major PSUs involved in the generation of electricity include National Thermal Power Corporation (NTPC), Damodar Valley Corporation (DVC), National Hydroelectric Power Corporation (NHPC) and Nuclear Power Corporation of India (NPCI). Besides PSUs, several state-level corporations, such as Tamil Nadu Electricity Board(TNEB) in Tamil Nadu, Maharashtra State Electricity Board(MSEB)in Maharashtra, Kerala State Electricity Board(KSEB) in Kerala, in Gujarat (MGVCL, PGVCL, DGVCL, UGVCL four distribution Companies and one controlling body GUVNL, and one generation company GSEC), are also involved in the generation and intrastate distribution of electricity. The Power Grid Corporation of India is responsible for the inter-state transmission of electricity and the development of national grid.

## Funding

The Ministry of Power provides funding to national schemes for power projects via Rural Electrification Corporation Limited (REC Ltd) and Power Finance Corporation Limited (PFC Ltd) These Central Public Sector Enterprises provide loans for both public sector and private sector companies/ projects involved in building power infrastructure.

## Demand

Electricity losses in India during transmission and distribution are extremely high and vary between 30 to 45%. In 2004-05, electricity demand outstripped supply by 7-11%. Due to shortage of electricity, power cuts are common throughout India and this has adversely effected the country's economic growth. Theft of electricity, common in most parts of urban India, amounts to 1.5% of India's GDP. Despite an ambitious rural electrification program, some 400 million Indians lose electricity access during blackouts. While 80 percent of Indian villages have at least an electricity line, just 52.5% of rural households have access to electricity.

In urban areas, the access to electricity is 93.1% in 2008. The overall electrification rate in India is 64.5% while 35.5% of the population still lives without access to electricity. According to a sample of 97,882 households in 2002, electricity was the main source of lighting for 53% of rural households compared to 36% in 1993. Multi Commodity Exchange has sought permission to offer electricity future markets.

## Generation

Grand Total Installed Capacity (as on 30-09-2010) is **164,835.80 MW**.

## Thermal Power

- ✓ Current installed capacity of Thermal Power (as of 30-11-2010) is 108362.98MW which is 64.6% of total installed capacity.
- ✓ Current installed base of Coal Based Thermal Power is 89,778.38 MW which comes to 53.3% of total installed base.
- ✓ Current installed base of Gas Based Thermal Power is 17,374.85 MW which is 10.5% of total installed capacity.
- ✓ Current installed base of Oil Based Thermal Power is 1,199.75 MW which is 0.9% of total installed capacity.

## Hydro Power

India was one of the pioneering countries in establishing hydro-electric power plants. The power plants at Darjeeling and Shimsha (Shivanasamudra) were established in 1898 and 1902 respectively and are among the first in Asia.

The installed capacity as of 30-9-2010 was approximately 37,328.40 MW. The public sector has a predominant share of 97% in this sector.

## Nuclear Power

Currently, twenty nuclear power reactors produce 4,780 MW

## Renewable Energy

Renewable energy in India is a sector that is still undeveloped. India was the first country in the world to set up a ministry of non-conventional energy resources, in early 1980s. However its success has been very spotty. In recent years India has been lagging behind other nations in the use of renewable energy (RE).

The share of RE in the energy sector is less than 1% of India's total energy needs. Renewable energy in India comes under the purview of the Ministry of New and Renewable Energy.

### Solar power

India is densely populated and has high solar insolation, an ideal combination for using solar power in India. Much of the country does not have an electrical grid, so one of the first applications of solar power has been for water pumping; to begin replacing India's four to five million diesel powered water pumps, each consuming about 3.5 kilowatts, and off-grid lighting. Some large projects have been proposed, and a 35,000 km² area of the Thar Desert has been set aside for solar power projects, sufficient to generate 700 to 2,100 giga watts.

The Indian Solar Loan Programme, supported by the United Nations Environment Programme has won the prestigious Energy Globe World award for Sustainability for helping to establish a consumer financing program for solar home power systems. Over the span of three years more than 16,000 solar home systems have been financed through 2,000 bank branches, particularly in rural areas of South India where the electricity grid does not yet extend.

Announced in November 2009, the Government of India proposed to launch its Jawaharlal Nehru National Solar Mission under the National Action Plan on Climate Change with plans to generate 1,000 MW of power by 2013 and up to 20,000 MW grid-based solar power, 2,000 MW of off-grid solar power and cover 20 million sq meters with collectors by the end of the final phase of the mission in 2020.

### Wind Power

The development of wind power in India began in the 1990s, and has significantly increased in the last few years. Although a relative newcomer to the wind industry compared with Denmark or the US, a combination of domestic policy support for wind power and the rise of Suzlon (a leading global wind turbine manufacturer) have led India to become the country with the fifth largest installed wind power capacity in the world.

As of June 2010 the installed capacity of wind power in India was 12009.14 MW, mainly spread across Tamil Nadu (4132.72 MW), Maharashtra (1837.85 MW), Karnataka (1184.45 MW), Rajasthan (670.97 MW), Gujarat (1432.71 MW), Andhra Pradesh (122.45 MW), Madhya Pradesh (187.69 MW), Kerala (23.00 MW), West Bengal (1.10 MW), other states (3.20 MW) [32] It is estimated that 6,000 MW of additional wind power capacity will be installed in India by 2012.[33] Wind power accounts for 6% of India's total installed power capacity, and it generates 1.6% of the country's power.

### Strategies

Power Generation Strategy with focus on low cost generation, optimization of capacity utilization, controlling the input cost, optimization of fuel mix, Technology up gradation and utilization of Non Conventional energy sources.

Transmission Strategy with focus on development of National Grid including Interstate connections, Technology up gradation & optimization of transmission cost. Distribution strategy to achieve Distribution Reforms with focus on System up gradation, loss reduction, theft control, consumer service orientation, quality power supply commercialization, Decentralized distributed generation and supply for rural areas.

Regulation Strategy aimed at protecting Consumer interests and making the sector commercially viable. Financing Strategy to generate resources for required growth of the power sector. Conservation Strategy to optimize the utilization of electricity with focus on Demand Side management, Load management and Technology up gradation to provide energy efficient equipment / gadgets. Communication Strategy for political consensus with media support to enhance the general public awareness.

## 4.2 Renewable Energy

India is facing an acute energy scarcity which is hampering its industrial growth and economic progress. Setting up of new power plants is inevitably dependent on import of highly volatile fossil fuels. Thus, it is essential to tackle the energy crisis through judicious utilization of abundant the renewable energy resources, such as Solar energy, Biomass energy, Wind energy and Geothermal energy. Apart from augmenting the energy supply, renewable resources will help India in mitigating climate change. India is heavily dependent on fossil fuels for its energy needs. Most of the power generation is carried out by coal and mineral oil-based power plants which contribute heavily to greenhouse gases emission.

The average per capita consumption of energy in India is around 500 W, which is much lower than that of developed countries like USA, Europe, Australia, Japan etc However, this figure is expected to rise sharply due to high economic growth and rapid industrialization. The consumption of electricity is growing on the worldwide basis.

### Average per capita consumption of energy

| SL.NO. | COUNTRY | POWER CONSUMPTION | |
|---|---|---|---|
| | | MWh/Year | Watts |
| 1 | India | 488,500,000 | 489 |
| 2 | USA | 3,816,000,000 | 3816 |
| 3 | Japan | 974,200,000 | 974 |
| 4 | Germany | 545,500,000 | 546 |
| 5 | China | 2,859,000,000 | 2859 |

Energy is a necessity and sustainable renewable energy is a vital link in industrialization and development of India. A transition from conventional energy systems to those based on renewable resources is necessary to meet the ever-increasing demand for energy and to address environmental concerns. India has a large potential for renewable energy (RE), an estimated aggregate of over 100,000MW. In addition, the scope for generating power and thermal applications using solar energy is huge. However, only a fraction of the aggregate potential in renewable, and particularly solar energy, has been utilized so far.

India is planning to add about 19,500 MW power generating capacity from renewable by the end of 11th plan (2011-2012). As per CEA's (Central Electricity Authority) fourth National Power Plan, anticipated capacity additions from Renewable Energy sources in presented in the following table:

The following table gives the estimated potential & cumulative achievement in Renewable Energy as of 30th September 2013 (source: MNRE report)

## ALL INDIA INSTALLED CAPACITY (IN MW) OF POWER STATIONS LOCATED IN THE REGIONS OF MAIN LAND AND ISLANDS

(As on 31.12.2013)
(UTILITIES)

| Region | Ownership/ Sector | Modewise breakup | | | | | | | Grand Total |
|---|---|---|---|---|---|---|---|---|---|
| | | Thermal | | | | Nuclear | Hydro (Renewable) | RES (MNRE) | |
| | | Coal | Gas | Diesel | Total | | | | |
| Northern Region | State | 14713.00 | 2579.20 | 12.99 | 17305.19 | 0.00 | 7052.55 | 1221.81 | 25579.55 |
| | Private | 7870.00 | 108.00 | 0.00 | 7978.00 | 0.00 | 2148.00 | 4507.81 | 14633.81 |
| | Central | 12000.50 | 2344.06 | 0.00 | 14344.56 | 1620.00 | 6492.20 | 0.00 | 22456.76 |
| | **Sub Total** | **34583.50** | **5031.26** | **12.99** | **39627.75** | **1620.00** | **15692.75** | **5729.62** | **62670.12** |
| Western Region | State | 18932.50 | 2266.72 | 17.28 | 21216.50 | 0.00 | 5480.50 | 461.74 | 27158.74 |
| | Private | 22229.00 | 3188.00 | 0.20 | 25417.20 | 0.00 | 447.00 | 9463.45 | 35327.65 |
| | Central | 11738.01 | 3533.59 | 0.00 | 15271.60 | 1840.00 | 1520.00 | 0.00 | 18631.60 |
| | **Sub Total** | **52899.51** | **8988.31** | **17.48** | **61905.30** | **1840.00** | **7447.50** | **9925.19** | **81117.99** |
| Southern Region | State | 12582.50 | 555.70 | 362.52 | 13500.72 | 0.00 | 11398.03 | 1495.76 | 26394.51 |
| | | 3210.00 | 4047.50 | 576.80 | 7834.30 | 0.00 | 0.00 | 11631.57 | 19465.87 |
| | Central | 10140.00 | 359.58 | 0.00 | 10499.58 | 1320.00 | 0.00 | 0.00 | 11819.58 |
| | **Sub Total** | **25932.50** | **4962.78** | **939.32** | **31834.60** | **1320.00** | **11398.03** | **13127.33** | **57679.96** |
| Eastern Region | State | 6790.00 | 100.00 | 17.06 | 6907.06 | 0.00 | 3168.92 | 289.56 | 10365.54 |
| | Private | 6391.38 | 0.00 | 0.14 | 6391.52 | 0.00 | 99.00 | 127.85 | 6618.37 |
| | Central | 11556.50 | 90.00 | 0.00 | 11646.50 | 0.00 | 845.20 | 0.00 | 12491.70 |
| | **Sub Total** | **24737.88** | **190.00** | **17.20** | **24945.08** | **0.00** | **4113.12** | **417.41** | **29475.61** |
| North Eastern Region | State | 60.00 | 445.70 | 142.74 | 648.44 | 0.00 | 382.00 | 252.65 | 1283.09 |
| | Private | 0.00 | 24.50 | 0.00 | 24.50 | 0.00 | 0.00 | 0.00 | 24.50 |
| | Central | 0.00 | 738.30 | 0.00 | 738.30 | 0.00 | 860.00 | 0.00 | 1598.30 |
| | **Sub Total** | **60.00** | **1208.50** | **142.74** | **1411.24** | **0.00** | **1242.00** | **252.65** | **2905.89** |
| Islands | State | 0.00 | 0.00 | 50.02 | 50.02 | 0.00 | 0.00 | 5.25 | 55.27 |
| | Private | 0.00 | 0.00 | 20.00 | 20.00 | 0.00 | 0.00 | 5.10 | 25.10 |
| | Central | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | **Sub Total** | **0.00** | **0.00** | **70.02** | **70.02** | **0.00** | **0.00** | **10.35** | **80.37** |
| ALL INDIA | State | 53078.00 | 5947.32 | 602.61 | 59627.93 | 0.00 | 27482.00 | 3726.77 | 90836.70 |
| | Private | 39700.38 | 7368.00 | 597.14 | 47665.52 | 0.00 | 2694.00 | 25735.78 | 76095.30 |
| | Central | 45435.01 | 7065.53 | 0.00 | 52500.54 | 4780.00 | 9717.40 | 0.00 | 66997.94 |
| | **Total** | **138213.39** | **20380.85** | **1199.75** | **159793.99** | **4780.00** | **39893.40** | **29462.55** | **233929.94** |

**Figures at decimal may not tally due to rounding off**

**Abbreviation:-** SHP=Small Hydro Project (≤ 25 MW), BP=Biomass Power, U&I=Urban & Industrial Waste Power, RES=Renewable Energy Sources

**Note :-** RES include SHP, BP, U&I, Solar and Wind Energy. Installed capacity in respect of RES (MNER) as on : **30.09.2013**

| Sl.No. | Source of Energy | Programme Capacity in MW | | |
|---|---|---|---|---|
| | | 9th Plan (1997-2002) | 10th Plan (2002-2007) | 11th Plan (2007-2012) |
| 1. | Solar Photovoltaic | 200 | 400 | 600 |
| 2. | Solar Thermal Power | 300 | 600 | 900 |
| 3. | Wind Power | 3000 | 6000 | 9000 |
| 4. | Small Hydro | 1000 | 2000 | 3000 |
| 5. | Biomass Co-generation | 1000 | 2000 | 3000 |
| 6. | Bioenergy/Biomass Power | 1000 | 2000 | 3000 |

| | | | | |
|---|---|---|---|---|
| | **Total** | **6500** | **13000** | **19500** |
| Source: CEA report on Fourth National Power Plan | | | | |

## 4.3 Solar PV Potential

Solar Power, a clean renewable resource with zero emission, has got tremendous potential of energy which can be harnessed using a variety of devices. With recent developments, solar energy systems are easily available for industrial and domestic use with the added advantage of minimum maintenance. Solar energy could be made financially viable with government tax incentives and rebates.

With about 301 clear sunny days in a year, India's theoretical solar power reception, just on its land area, is about 5 Peta hour/year (i.e. = 5000 trillion kWh/yr ~ 600 Tera Watt). The daily average solar energy incident over India varies from 4 to 7 kWh/m2 with about 2300 - 3200 sunshine hours per year, depending upon location. This is far more than current total energy consumption. For example, even assuming 10% conversion efficiency for PV modules, it will still be thousand times greater than the likely electricity demand in India by the year 2015.

Exploitation of the abundant solar energy resources available in our country is therefore, being accorded a high priority by the Ministry of New and Renewable Energy. The Ministry has come forward to support Solar PV based Power Plants in big way throughout the country with a host of fiscal incentives. For encouraging investment by the private sector in power generation through renewable energy, MNRE has formed nodal agencies in all the states, and has issued a set of guidelines for their consideration.

## 4.4 Proposed Power Plant

Considering the good potential available and also the thrust given by the Government of India and State Government to this national endeavor of exploiting renewable source of energy for power generation and with the availability of abundant Solar Power SRM INSTITUTE OF SCIENCE AND TECHNOLOGY is proposing to set up a 50KWp Grid connected Roof Top Solar PV Power Plant in Tamil Nadu.

The proposed Power Plant site is well connected & all necessary infrastructure facilities are available in & around the site. The proposed plant will have crystalline modules, module mounting structures, inverters and all accessories as the major components. The power generated will be evacuated to the LT panel. Thus in Promoter's perception, setting-up of the above power plant will go a long way to meet the growing energy demand and also benefit the state.

# CHAPTER 5: LOCATION AND INFRASTRUCTURE FACILITIES

## 5.1 Site Selection

The site selection for a Solar Power Plant is pre-dominantly determined by solar insolation availability & grid connectivity for exporting power. Equally important are other essential factors/considerations such as:

- ✓ Availability of adequate roof top space for Power Plant and green belt development
- ✓ Availability of water and power during construction
- ✓ Availability of labor force in the proximity
- ✓ Availability of load centers (towns) within vicinity
- ✓ Easy accessibility of the site

The proposed site where Power Plant is to be located is near Chennai city of Tamil Nadu state and is found favoring all the above factors to a reasonable extent.


## 5.2 Proposed Location and Land Availability

Chennai is the largest industrial city in Tamil Nadu.

### Topographical & Geological Conditions

**SRM IST is** located 12, 49, 24, N and 80, 2, 30, E

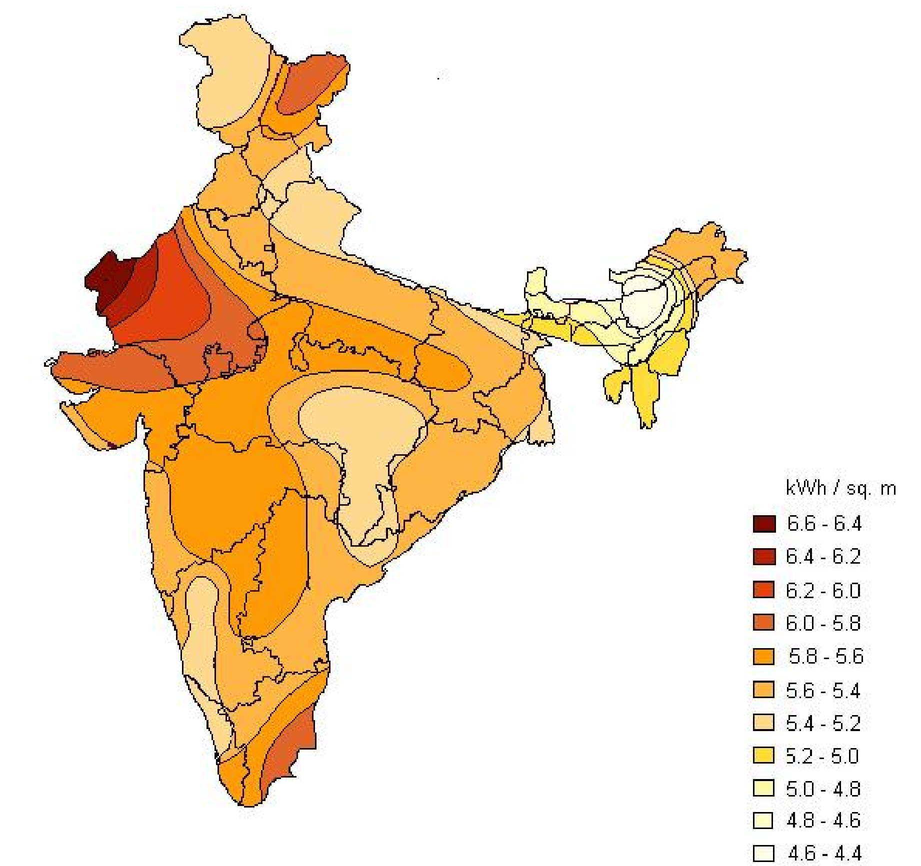
Building has an average elevation of 75 meters.

### Electric Power

The power generated from the Power Plant will be connected to the existing grid line within the college premises.

## CHAPTER 6: IRRADIATION DATA

Chennai irradiation level is in the level of 5.6 to 5.8 kWh / Sq.m and since the site is very close to the




Chennai town, the Irradiation data of the Chennai town is considered for all design purpose.

The following are the actual site co-ordinates.

| | |
|---|---|
| Latitude | : 12, 49, 24, N |
| Longitude | : 80, 2, 30, E |
| Building Elevation | : 75 m |
| Annual Solar radiation | : 5.14 kWh/ Sq.m/day |

**Mean Global Solar Radiant Exposure**

**Kattankulathur @ Chennai.**

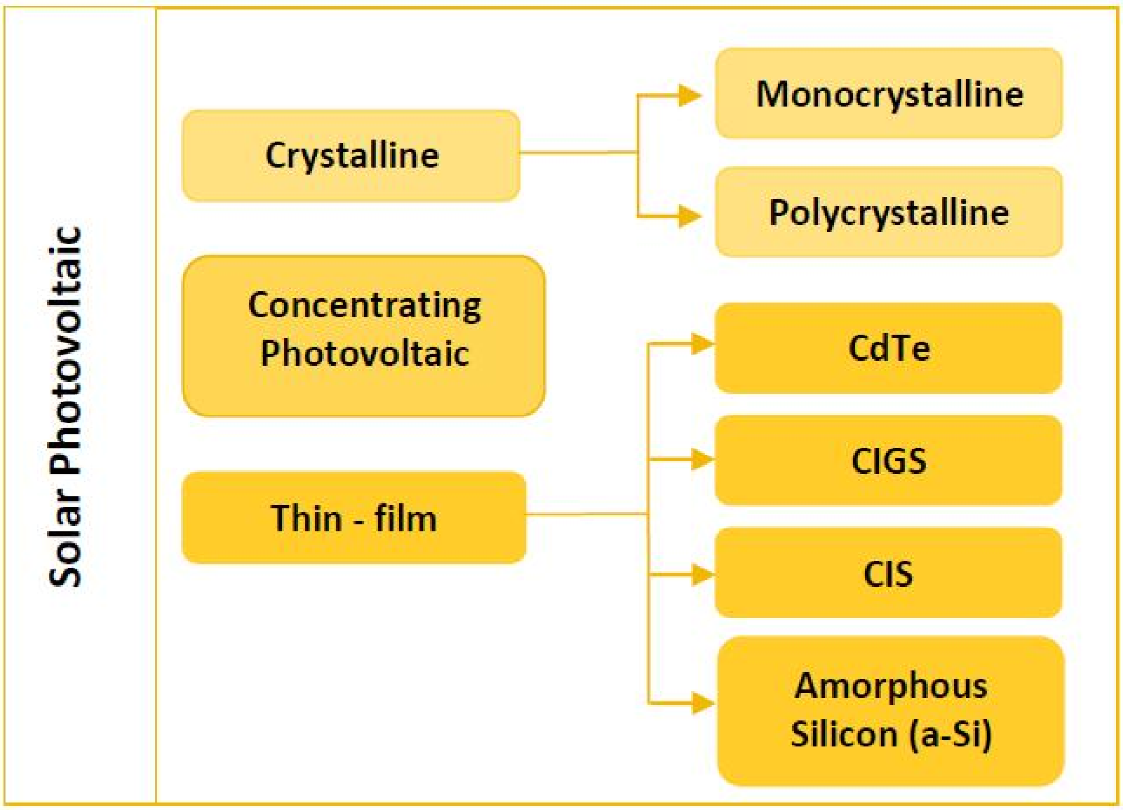
| Month | Daily solar radiation-Horizontal |
|---|---|
| | Kwh/m²/d |
| January | 4.89 |
| February | 5.85 |
| March | 6.51 |
| April | 6.60 |
| May | 6.26 |
| June | 5.72 |
| July | 5.28 |
| August | 5.20 |
| September | 5.39 |
| October | 4.56 |
| November | 4.00 |
| December | 4.16 |
| Annual | 5.37 |

Monthly Parameters at site

# CHAPTER 7: SELECTION OF PV TECHNOLOGY

## 7.1 Existing Solar PV Technology

According to the crystalline structure amorphous, poly-crystalline and mono-crystalline solar cells are known. According to technological procedures used by production solar cells can be divided into silicon solar cells, produced from Si wafers, and thin-film solar cells produced with vacuum technologies. Basic features from different solar cell types can be found below.




### Light-absorbing materials

All solar cells require a light absorbing material contained within the cell structure to absorb photons and generate electrons via the photovoltaic effect. The materials used in solar cells tend to have the property of preferentially absorbing the wavelengths of solar light that reach the earth surface; however, some solar cells are optimized for light absorption beyond Earth's atmosphere as well. Light absorbing materials can often be used in multiple physical configurations to take advantage of different light absorption and charge separation mechanisms.

Photovoltaic panels are normally made of either silicon or thin-film cells.

Many currently available solar cells are configured as bulk materials that are subsequently cut into wafers and treated in a "top-down" method of synthesis (silicon being the most prevalent bulk material).

Other materials are configured as thin-films (inorganic layers, organic dyes, and organic polymers) that are deposited on supporting substrates, while a third group are configured as nano-crystals and used as quantum dots (electron-confined nano-particles) embedded in a supporting matrix in a "bottom-up" approach. Silicon remains the only material that is well-researched in both bulk (also called wafer-based) and thin-film configurations.

There are many new alternatives to Silicon photocells. Proprietary nano-particle silicon printing processes promises many of the photovoltaic features that conventional silicon can never achieve. It can be printed reel-to-reel on stainless steel or other high temperature substrates. However, most of the work on the next generation of photovoltaic is directed at printing onto low cost flexible polymer film and ultimately on common packaging materials. The main contenders are currently CIGS, CdTe, DSSC and organic photovoltaic.

The following is a current list of light absorbing materials, listed by configuration and substance-name:

### Bulk

These bulk technologies are often referred to as wafer-based manufacturing. In other words, in each of these approaches, self-supporting wafers between 180 to 240 micron thick are processed and then soldered together to form a solar module. A general description of silicon wafer processing is provided in Manufacture and Devices.

### Crystalline Silicon

By far, the most prevalent bulk material for solar cells is crystalline silicon (abbreviated as a group as c-Si), also known as "solar grade silicon". Bulk silicon is separated into multiple categories according to crystallinity and crystal size in the resulting ingot, ribbon, or wafer.

1. *Monocrystalline silicon* (c-Si): often made using the Czochralski process. Single-crystal wafer cells tend to be expensive, and because they are cut from cylindrical ingots, do not completely cover a square solar cell module without a substantial waste of refined silicon. Hence most *c-Si* panels have uncovered gaps at the four corners of the cells.

   *Ribbon silicon* is a type of monocrystalline silicon: it is formed by drawing flat thin films from molten silicon and having a multicrystalline structure. These cells have lower efficiencies than poly-Si, but save on production costs due to a great reduction in silicon waste, as this approach does not require sawing from ingots.

2. *Poly- or multicrystalline silicon* (poly-Si or mc-Si): made from cast square ingots — large blocks of molten silicon carefully cooled and solidified. Poly-Si cells are less expensive to produce than single crystal silicon cells, but are less efficient.

Crystalline silicon has average 15% efficiency.

### Thin films

The various thin-film technologies currently being developed reduce the amount (or mass) of light absorbing material required in creating a solar cell. This can lead to reduced processing costs from that of bulk materials (in the case of silicon thin films) but also tends to reduce energy conversion efficiency average 7 to 10% efficiency), although many multi-layer thin films have efficiencies above those of bulk silicon wafers.

They have become popular compared to wafer silicon due to lower costs and advantages including flexibility, lighter weights, and ease of integration.

### Cadmium telluride solar cell (CdTe)

A cadmium telluride solar cell is a solar cell based on cadmium telluride, an efficient light-absorbing material for thin-film cells. Compared to other thin-film materials, CdTe is easier to deposit and more suitable for large-scale production.

Despite much discussion of the toxicity of CdTe-based solar cells, this is the only technology (apart from amorphous silicon) that can be delivered on a large scale. The perception of the toxicity of CdTe is based on the toxicity of elemental cadmium, a heavy metal that is a cumulative poison. However it has been shown that the release of cadmium to the atmosphere is lower with CdTe-based solar cells than with silicon photovoltaics and other thin-film solar cell technologies.

### Copper-Indium Selenide (CIS)

The materials based on $CuInSe_2$ that are of interest for photovoltaic applications include several elements from groups I, III and VI in the periodic table. These semiconductors are especially attractive for thin film solar cell application because of their high optical absorption coefficients and versatile optical and electrical characteristics which can in principle be manipulated and tuned for a specific need in a given device. CIS is an abbreviation for general chalcopyrite films of copper indium selenide (**C**u**I**n**S**e$_2$), CIGS mentioned below is a variation of CIS. CIS films (no Ga) achieved greater than 14% efficiency. However, manufacturing costs of CIS solar cells at present are high when compared with amorphous silicon solar cells but continuing work is leading to more cost-effective production processes. The first large-scale production of CIS modules was started in 2006 in Germany by Wuerth Solar.

When gallium is substituted for some of the indium in CIS, the material is sometimes called CIGS, or copper indium/gallium diselenide, a solid mixture of the semiconductors $CuInSe_2$ and $CuGaSe_2$, often abbreviated by the chemical formula $CuIn_xGa_{(1-x)}Se_2$. Unlike the conventional silicon based solar cell, which can be modeled as a simple p-n junction (see under semiconductor), these cells are best described by a more complex hetero junction model. The best efficiency of a thin-film solar cell as of March 2008 was 19.9% with CIGS absorber layer. Higher efficiencies (around 30%) can be obtained by using optics to concentrate the incident light. The use of gallium increases the optical band gap of the CIGS layer as compared to pure CIS, thus increasing the open-circuit voltage. In another point of view, gallium is added to replace as much indium as possible due to gallium's relative availability to indium. Approximately 70% of indium currently produced is used by the flat-screen monitor industry. Some investors in solar technology worry that production of CIGS cells will be limited by the availability of indium. Producing 2 GW of CIGS cells (roughly the amount of silicon cells produced in 2006) would use about 10% of the indium produced in 2004. For comparison, silicon solar cells used up 33% of the world's electronic grade silicon production in 2006. Nanosolar claims to waste only 5% of the indium it uses. As of 2006, the best conversion efficiency for flexible CIGS cells on polyimide is 14.1% by Tiwari et al, at the ETH, Switzerland.

That being said, indium can easily be recycled from decommissioned PV modules. The recycling program in Germany is an example that highlights the regenerative industrial paradigm: "From cradle to cradle".

Selenium allows for better uniformity across the layer and so the number of recombination sites in the film are reduced which benefits the quantum efficiency and thus the conversion efficiency.

### Gallium arsenide (GaAs) multi junction

High-efficiency multi junction cells were originally developed for special applications such as satellites and space exploration, but at present, their use in terrestrial concentrators might be the lowest cost alternative in terms of $/kWh and $/W. These multi junction cells consist of multiple thin films produced using Metalorganic vapor phase epitaxy. A triple-junction cell, for example, may consist of the semiconductors: GaAs, Ge, and $GaInP_2$. Each type of semiconductor will have a characteristic band gap energy which, loosely speaking, causes it to absorb light most efficiently at a certain color, or more precisely, to absorb electromagnetic radiation over a portion of the spectrum. The semiconductors are carefully chosen to absorb nearly the entire solar spectrum, thus generating electricity from as much of the solar energy as possible.

GaAs based multi junction devices are the most efficient solar cells to date, reaching a record high of 40.7% efficiency under solar concentration and laboratory conditions.

This technology is currently being utilized in the Mars rover missions.

Tandem solar cells based on monolithic, series connected, gallium indium phosphide (GaInP), gallium arsenide GaAs, and germanium Ge pn junctions, are seeing demand rapidly rise. In just the past 12 months (12/2006 - 12/2007), the cost of 4N gallium metal has risen from about $350 per kg to $680 per kg. Additionally, germanium metal prices have risen substantially to $1000-$1200 per kg this year. Those materials include gallium (4N, 6N and 7N Ga), arsenic (4N, 6N and 7N) and germanium, pyrolitic boron nitride (pBN) crucibles for growing crystals, and boron oxide, these products are critical to the entire substrate manufacturing industry.

Triple-junction GaAs solar cells were also being used as the power source of the Dutch four-time World Solar Challenge winners Nuna in 2005 and 2007, and also by the Dutch solar cars Solutra (2005) and Twente One (2007).

The Dutch Radboud University Nijmegen set the record for thin film solar cell efficiency using a single junction GaAs to 25.8% in August 2008 using only 4 µm thick GaAs layer which can be transferred from a wafer base to glass or plastic film.

### Light-absorbing dyes (DSSC)

Typically a ruthenium metalorganic dye (Ru-centered) is used as a monolayer of light-absorbing material. The dye-sensitized solar cell depends on a mesoporous layer of nano-particulate titanium dioxide to greatly amplify the surface area (200-300 $m^2/g$ $TiO_2$, as compared to approximately 10 $m^2/g$ of flat single crystal). The photo generated electrons from the *light absorbing dye* are passed on to the *n-type* $TiO_2$, and the holes are passed to an electrolyte on the other side of the dye. The circuit is completed by a redox couple in the electrolyte, which can be liquid or solid. This type of cell allows a more flexible use of materials, and is typically manufactured by screen printing, with the potential for lower processing costs than those used for *bulk* solar cells. However, the dyes in these cells also suffer from degradation under heat and UV light, and the cell casing is difficult to seal due to the solvents used in assembly. In spite of the above, this is a popular emerging technology with some commercial impact forecast within this decade.

### Organic/polymer solar cells

Organic solar cells and Polymer solar cells are built from thin films (typically 100 nm) of organic semiconductors such as polymers and small-molecule compounds like polyphenylene vinylene, copper phthalocyanine (a blue or green organic pigment) and carbon fullerenes. Energy conversion efficiencies achieved to date using conductive polymers are low compared to inorganic materials, with the highest reported efficiency of 6.5% for tandem cell architecture. However, these cells could be beneficial for some applications where mechanical flexibility and disposability are important.

These devices differ from inorganic semiconductor solar cells in that they do not rely on the large built-in electric field of a PN junction to separate the electrons and holes created when photons are absorbed. The active region of an organic device consists of two materials, one which acts as an electron donor and the other as an acceptor. When a photon is converted into an electron hole pair, typically in the donor material, the charges tend to remain bound in the form of an exciton, and are separated when the exciton diffuses to the donor-acceptor interface. The short exciton diffusion lengths of most polymer systems tend to limit the efficiency of such devices. Nano structured interfaces, sometimes in the form of bulk hetero junctions, can improve performance.

### Silicon Thin Films

Silicon thin-film cells are mainly deposited by chemical vapor deposition (typically plasma-enhanced (PE-CVD)) from silane gas and hydrogen gas. Depending on the deposition parameters, this can yield:

1. Amorphous silicon (a-Si or a-Si:H)
2. Protocrystalline silicon or
3. Nanocrystalline silicon (nc-Si or nc-Si:H), also called microcrystalline silicon.

These types of silicon present dangling and twisted bonds, which results in deep defects (energy levels in the bandgap) as well as deformation of the valence and conduction bands (band tails). The solar cells made from these materials tend to have lower *energy conversion efficiency* than *bulk* silicon, but are also less expensive to produce. The quantum efficiency of thin film solar cells is also lower due to reduced number of collected charge carriers per incident photon.

Amorphous silicon has a higher bandgap (1.7 eV) than crystalline silicon (c-Si) (1.1 eV), which means it absorbs the visible part of the solar spectrum more strongly than the infrared portion of the spectrum. As **nc-Si** has about the same band gap as c-Si, the nc-Si and a-Si can advantageously be combined in thin layers, creating a layered cell called a **tandem cell**. The top cell in a-Si absorbs the visible light and leaves the infrared part of the spectrum for the bottom cell in nano-crystalline Si.

Recently, solutions to overcome the limitations of thin-film crystalline silicon have been developed. Light trapping schemes where the weakly absorbed long wavelength light is obliquely coupled into the silicon and traverses the film several times can significantly enhance the absorption of sunlight in the thin silicon films. Thermal processing techniques can significantly enhance the crystal quality of the silicon and thereby lead to higher efficiencies of the final solar cells.

A silicon thin film technology is being developed for building integrated photovoltaics (BIPV) in the form of semi-transparent solar cells which can be applied as window glazing. These cells function as window tinting while generating electricity.

### Nano crystalline solar cells

These structures make use of some of the same thin-film light absorbing materials but are overlain as an extremely thin absorber on a supporting matrix of conductive polymer or mesoporous metal oxide having a very high surface area to increase internal reflections (and hence increase the probability of light absorption). Using nanocrystals allows one to design architectures on the length scale of nanometers, the typical exciton diffusion length. In particular, single-nano crystal ('channel') devices, an array of single p-n junctions between the electrodes and separated by a period of about a diffusion length, represent a new architecture for solar cells and potentially high efficiency.

### õ Concentrating Photovoltaic's (CPV)

Concentrating photovoltaic systems use a large area of lenses or mirrors to focus sunlight on a small area of photovoltaic cells. If these systems use single or dual-axis tracking to improve performance, they may be referred to as *Heliostat Concentrator Photovoltaic's* (HCPV). The primary attraction of CPV systems is their reduced usage of semi conducting material which is expensive and currently in short supply. Additionally, increasing the concentration ratio improves the performance of general photovoltaic materials. Despite the advantages of CPV technologies their application has been limited by the costs of focusing, tracking and cooling equipment.

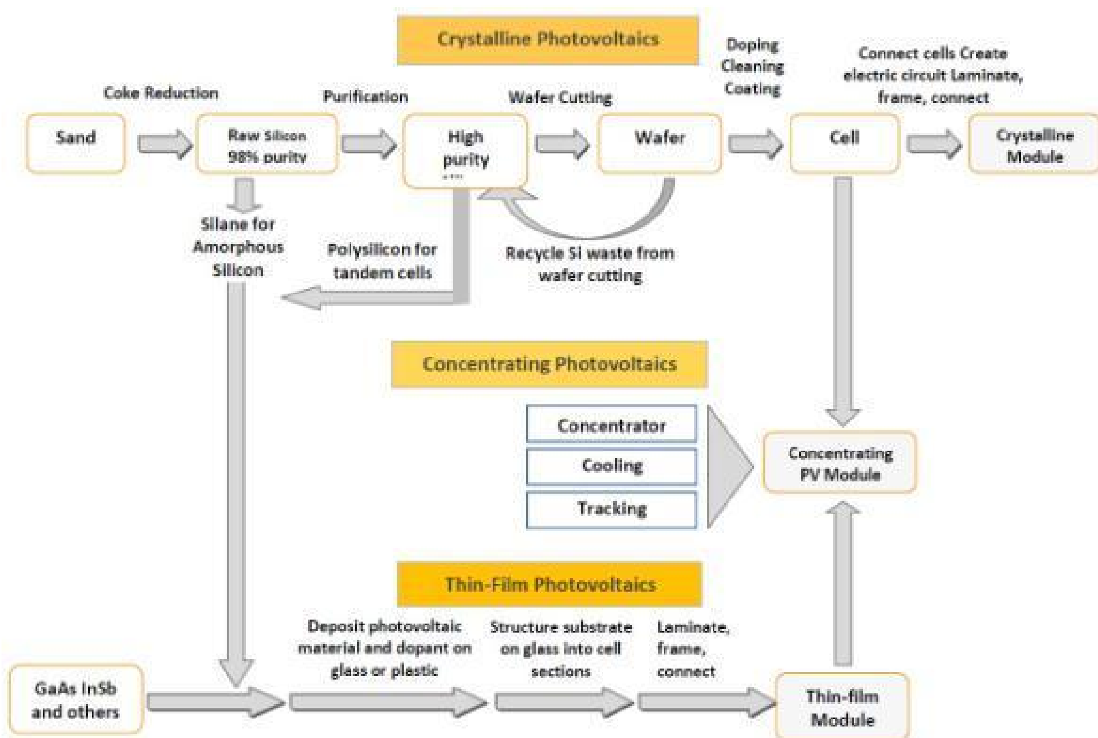
## 7.2 Selection of Technology

In the previous section the various technologies available for PV are explained in detail. From the above available technologies customer would like to have detail technical proposal for the following three technologies.

1. Crystalline Silicon
2. Thin Film
3. Concentrating PV (CPV)

The advantages & disadvantages of each technology are discussed in the following section.

### Crystalline Silicon PV




- ✓ Longevity: Crystalline solar panels are first generation solar technology and have been around a long time, providing evidence of their durability and longevity.

- ✓ Efficiency: PV panels made from crystalline solar cells are able to convert the highest amount of solar energy into electricity of any type of flat solar panel.

- ✓ Embodied Energy: While thin-film solar panels offer a lower level of embedded energy per panel, the fact that more panels are needed somewhat negates this aspect, especially given the extra mounting rails sometimes needed.

- ✓ Environmental Friendly: Crystalline solar panels are not hazardous to the environment. Some thin film solar products uses cadmium telluride (CdTe) . Cadmium is a heavy metal that accumulates in plant and animal tissues. Cadmium is a 'probable carcinogen' in humans and animals.

## Thin Film

- ✓ Better performance in weak sunlight environment
- ✓ Silicon thin film PV with high absorption coefficient also brings the benefit of module installation against any direction of sunlight.
- ✓ Better performance at high ambient temperature
- ✓ Silicon thin film PV with low temperature coefficient has much better capability in hot environment.
- ✓ More resistant against Shading.
- ✓ Silicon thin film PV outputs power robustly even in shading condition. Oppositely, crystalline silicon PV doesn’t work well due to some cells without output.
- ✓ High energy yield.

## Concentrated Photovoltaic (CPV)

- ✓ Commercially available over 16 billion kWh of operational experience;
- ✓ operating temperature potential up to 500°C (400°C commercially proven)
- ✓ Commercially proven annual net plant efficiency of 14% (solar radiation to net electric output)
- ✓ Commercially proven investment and operating costs
- ✓ Modularity
- ✓ Good land-use factor
- ✓ Lowest materials demand
- ✓ Hybrid concept proven
- ✓ Storage capability

# CHAPTER 8: POWER PLANT SCHEME

## 8.1 Power Plant Sizing

The Power Plant is sized on the following major criteria:

- Solar Power (average insolation available)
- Power evacuation facility in the vicinity of the proposed site along with Grid availability on 24 Hours a day basis.

The Design Team brings in its vast International engineering expertise in the field of large PV power projects to offer the best solution in terms of technology, innovative components, reliable results and performance during the lifetime of the power plant. We have used our Engineering Best practices and knowledge from our International experience in the field of large PV power projects to present this technical system solution.

Few details from our design process and ideology are presented as follows:

### Optimal Plant design:

The total area required for installing the 50KWp solar Power Plant is approximately 7500 sqft.

1) For a complete reliable system and to ensure high energy yield from the plant, innovative components with latest technology are selected. The inverter that is selected is of very high efficiency over a wide range of load. The inverter operates in excess of 95.0% efficiency.
2) We have understood the monitoring system requirement for such a large power plant and have proposed our state of the art monitoring and analysis central system. Few features are presented as follows:
   - Monitors the performance of the entire power plant (string wise monitoring, junction boxes, inverters, etc)
   - Evaluates (strings, inverter, nominal/actual value), quantity of DC Power & AC Power produced.
   - Measures instantaneous irradiation level and temperature at site. It also measures the module back surface temperature.
   - Alerts in case of error (discrepancy in normal operation of components, like module string/ diodes/ inverter/ junction box / loose contacts/ etc,) to facilitate recognition and correction of the fault with minimum downtime.

- Visualizes nominal status of the connected components via Control Center PC Software (diagnosis on site or remote)
- Logs system data and error messages for further processing or storing
- Stores and visualizes energy yield data (for life of the plant) in the Portal from where the data can be accessed remotely.

3) We have adopted the best engineering practice for complete cable routing in the power plant by using minimal cable length while connecting in series string, using optimal size cables to ensure the entire plant cable losses are minimum.

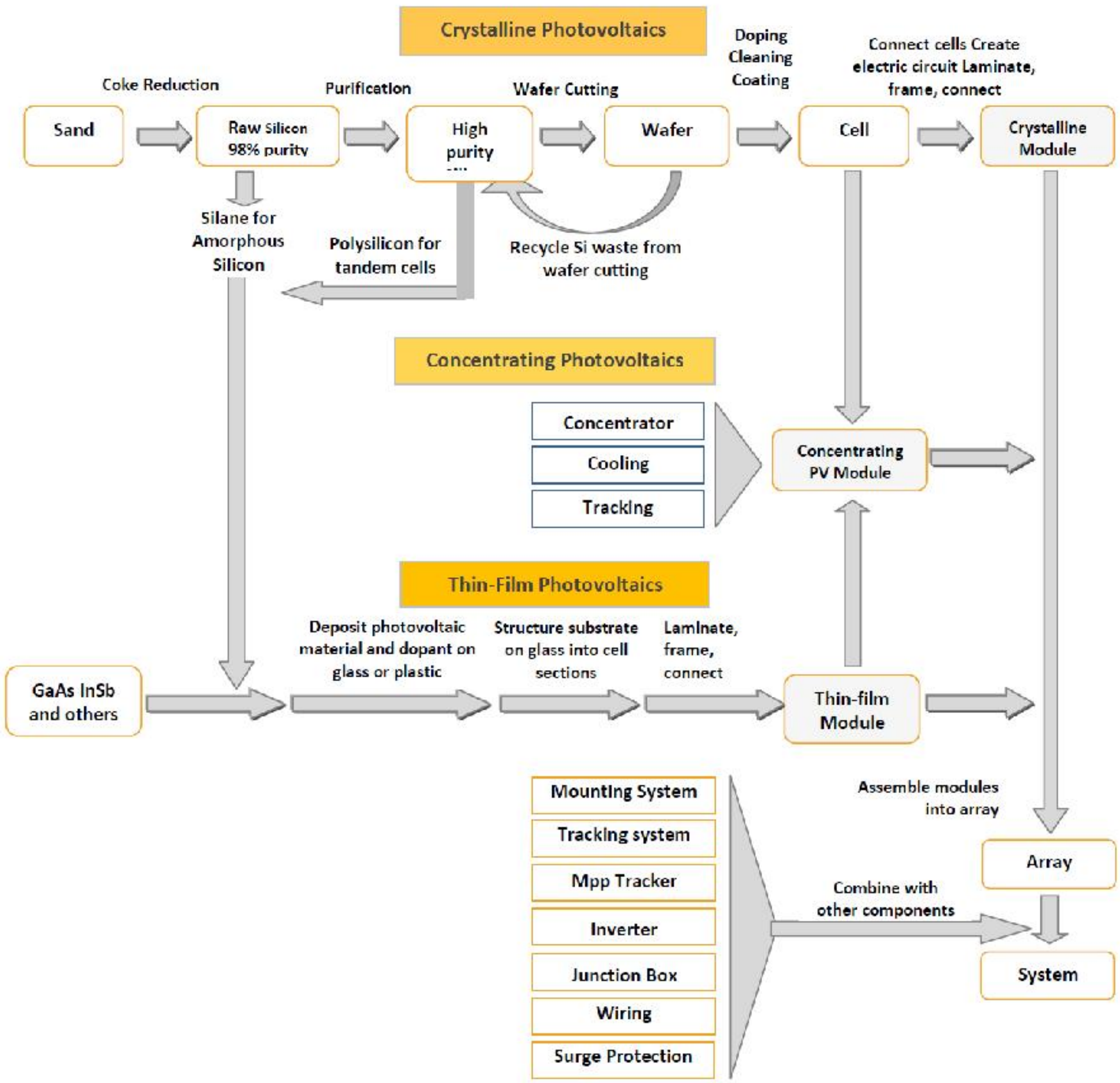
4) The junction boxes proposed are completely pre-wired to ensure ease of installation, maintenance and eliminates any installation hassles. These junction boxes not only combine the DC power from strings but also monitor each string performance and feed the same data to the central monitoring system.

## 8.2 Major Components of the Power Plant

As the Customer would like to explore the various option of the Solar PV Technology, the Design Team would like to propose the best components that are available in the market.

The following are the major components that would be discussed in the following section.

A. Solar Modules
   a. Crystalline Modules – Multi & Mono
B. Inverter
   a. String Inverter
C. Module Mounting Structure
D. Balance of System
   a. Junction boxes
   b. Cables
   c. Monitoring System
   d. Earthing & Lightning Protection


Crystalline Photovoltaics
Coke Reduction
Purification
Wafer Cutting
Doping Cleaning Coating
Connect cells Create electric circuit Laminate, frame, connect
Sand
Raw Silicon 98% purity
High purity
Wafer
Cell
Crystalline Module
Silane for Amorphous Silicon
Polysilicon for tandem cells
Recycle Si waste from wafer cutting
Concentrating Photovoltaics
Concentrator
Cooling
Tracking
Concentrating PV Module
Thin-Film Photovoltaics
Deposit photovoltaic material and dopant on glass or plastic
Structure substrate on glass into cell sections
Laminate, frame, connect
GaAs InSb and others
Thin-film Module
Mounting System
Tracking system
Mpp Tracker
Inverter
Junction Box
Wiring
Surge Protection
Assemble modules into array
Combine with other components
Array
System

## 8.3 Basic System Description

Solar Photovoltaic power generator consists of solar modules in series and parallel connections, these convert solar radiations into DC electrical power at the pre-determined range of Voltages whenever sufficient solar radiation is available. The individual crystalline solar cells are connected together in a module (in series connection), which are hermetically sealed to survive in rugged weather conditions and ensures optimum performance during its ling life.

In order to achieve a higher system voltage, modules are installed in a row arrangement, called a string. A higher system voltage has the advantage of lesser installation work, higher efficiency of the entire plant and usage of smaller cross section cables. Calculated no. of strings is connected in parallel by cables in Junction Boxes. Outputs from many such junction boxes are connected in parallel in the Main Combiner Box (MCB). This Main Combiner Box output is fed to the central inverters/Power Control Unit (PCU) to invert solar generated DC power in to conventional 3 phase AC power.

AC power from inverters will be fed to LV panel.

## 8.4 Operation Philosophy

Solar panels mounted in the field generate DC electric power. The DC electric power generated by the solar panels cannot be fed directly in to the utility grid. The inverters invert the direct current output from the solar array into grid compliant AC voltage, feeds it in to the utility grid system with proper protection and control. The grid connected inverter (GCI) range of inverters comes with built-in transformer that ensures galvanic isolation of the DC side from the AC network. This is an important requirement for many utilities to permit connection of solar panels on to the grid. The system automatically starts up in the morning and begins to export power to the grid, provided there is sufficient solar energy and the grid voltage, frequency is within the range. If the grid goes out of range the inverter will be immediately disconnected and reconnected automatically at a pre determined time after the grid comes back within range.

# CHAPTER 9: POWER PLANT COMPONENT DESCRIPTION

This chapter discusses in detail the technical aspects of the components that shall be used in the Power Plant. As indicated the following are the major components of the Power Plant.

| Sl. No. | Item | Description |
|---|---|---|
| 1 | Solar Module | 250Wp Mono Crystalline modules |
| 2 | Module Mounting Structure | Fixed Tilt Angle |
| 3 | Inverter | String inverter for 50kW |
| 4 | Combiner box | Array Junction Boxes |
| 5 | Control Panels | LT (Low Tension) Panel |
| 6 | Cables | PVC Copper Cables |
| 7 | Accessories | Accessories for cable interconnection , installation kit & conduits |
| 8 | Lightning | Lightning Protection Units |

## 9.1 Solar PV Panel

Solar cells produce Direct Current (DC) electricity from light, which can be used to power equipment or to recharge a battery. Cells require protection from the environment and are usually packaged tightly behind a glass sheet. When more power is required than a single cell can deliver, cells are electrically connected together to form photovoltaic modules, or solar panels. A photovoltaic module is a packaged, interconnected assembly of photovoltaic cells, which converts sunlight into electrical power. The cells are hermitically sealed between glass and back cover (Tedlar) to protect them from harsh environments.

### Crystalline Module

| Technical Specifications for Crystalline Modules | |
|---|---|
| Capacity of PV Modules | 250Wp/Mono |
| Output power – Pmax (Watts) | 250 Wp |
| Voltage at Pmax | 30.16 V |
| Current at Pmax | 8.29 A |
| Open-circuit voltage | 37.88 V |

| | |
|---|---|
| Short circuit current | 8.75 A |
| Module Efficiency(%) | 15.2 |
| Maximum system voltage (Volts) | IEC: DC 1000V / UL: DC600V |
| Type of solar PV cell | Poly / Multi - Crystalline silicon |
| Solar cells | 60 nos. of 6" silicon cells |
| Module output | MC 4 terminations |
| Certification | IEC61215 & EN IEC 61730 Class A, Safety Class II |
| Power warranty | • 25-year limited warranty on power output & 5-year product warranty<br>• 25-year performance warranty<br>- 10 years: 90% minimum performance - 25 years: 80% minimum performance |

## 9.2 Module Mounting Structure

The module mounting structure is designed for holding suitable number of modules in series. The frames and leg assembles of the array structures is made of MS hot dip galvanized of suitable sections of Angle, Channel, Tubes or any other sections conforming to IS:2062 for steel structure to meet the design criteria. All nuts & bolts considered for fastening modules with this structure are of very good quality of Stainless Steel. The array structure is designed in such a way that it will occupy minimum space without sacrificing the output from SPV panels at the same time it will withstand severe wind speed up to maximum 100 kmph.

| **Technical Specification – Module Mounting Structures** | |
|---|---|
| Material | GI |
| Overall dimension | As per design |
| Wind rating | 100 km/hr |
| Tilt angle | 15° -Fixed angle |
| Foundation | RCC/ PCC As per design |
| Fixing type | SS 304 fasteners |

### 9.3 Junction Boxes

In the Junction boxes, individual module strings are bundled and safely routed to the inverter. It is a combination of an exact, well-organized string monitoring system and a safety concept adapted to the PV technology.

The junction boxes will have suitable cable entry points fitted with cable glands of appropriate sizes for both incoming and outgoing cables. They monitor the output of solar PV arrays. If difference between string outputs is too large, the operator is informed though monitoring system. Active disconnection allows string voltages to be measured separately.

These junction boxes are enclosed in an IP 65 rated stainless steel housing, making it ideal for long-term use in PV systems. In addition, the direct connection between the strings and the spring clamp connectors ensures a durable and safe installation.

| **Technical Specification – Combiner Boxes** | |
|---|---|
| Material | Thermoplastic / Metal Sheet |
| Type | Dust, Vermin & Water proof |
| Hardware | SS 304 |
| Cable Gland | Thermoplastic |
| Protection | IP 65 |

### 9.4 String Inverter

A multi-function power conditioning system combining the functionality of a grid-interactive solar inverter with a highly efficient conversion unit. The inverters achieve their distinguished efficiency factor through the use of IGBTs (Insulated Gate Bipolar Transistors) with Trench Gate Structure, and through the use of iron powder chokes and high quality transformers with losses less than 1 %.

String / Central inverters operate on MPPT (Maximum Power Point Tracking) mode to ensure maximum output from the solar generators at different ambient conditions. String inverters use higher system voltages to reach very high plant efficiency. Furthermore, installations can be expanded with additions of more modules without problems.

The design of the technical parameters has been optimized with regard to the operating time of the inverter. For example, the IGBTs not only increase the efficiency factor, but their high dielectric strength inhibits the transmission of voltage spikes. The intelligent minimum-performance recognition system protects the AC contactors and a fast over-current recognition system for all transistors protects the IGBTs.

With a wide range of input voltages from 350 to 1000 V, the inverter allows the largest possible range of module connection possibilities. For larger installations, the proposed inverters can be easily combined to provide higher performance.

## 9.5 Cables

The size of the cables between array interconnections, array to junction boxes, junction boxes to PCU etc shall be so selected to keep the voltage drop and losses to the minimum.

The bright annealed 99.97% pure bare copper conductors that offer low conductor resistance, they result in lower heating thereby increase in life and savings in power consumption. These wires are insulated with a special grade PVC compound formulated. The skin coloration offers high insulation resistance and long life.

Cables are flexible & of annealed electrolytic grade copper conductor and shall confirm to IS 1554/694-1990 and are extremely robust and resist high mechanical load and abrasion.

Cable is of high temperature resistance and excellent weatherproofing characteristics which provides a long service life to the cables used in large scale projects.

The connectors/lugs of copper material with high current capacity and easy mode of assembly are proposed.

| Technical Specification – Cables | |
|---|---|
| Type | PV Insulated, sheath & UV resistant |
| Material | Copper |
| Voltage | Max. 1100V for DC |
| Temperature | 10 – 70 °C |
| Colour | Red/ Black /Yellow/Green |

## 9.6 Power Evacuation

The Direct Current (DC) from modules will be converted into Alternating Current (AC) by Inverters. The inverter outputs are given to a Low Voltage (LT) panels installed inside the School premises.

## 9.7 Monitoring System

Monitoring systems is mainly used to monitor the performance of the Inverters, energy yield, temperature, irradiance level etc. It provides an extremely flexible interface to facilitate PC-based inverter monitoring via analog modem, GSM, Ethernet, or Internet connections.

**Industry-Leading Features and Performance:**

- Inverter monitoring parameters include: energy yield, power, array voltages, array currents and AC parameters.
- Environmental-sensor interface capabilities include: temperature, wind speed, and irradiation sensors.

**Field-Proven Reliability:**

- Enhanced remote-monitoring capabilities enable the collection and analysis of critical data needed to facilitate increased power system reliability.

**Installer Friendly:**

- A front-mounted LCD display provides visual confirmation of all critical operating parameters.
- Compact easy-to-install package with readily-accessible electrical connections.

**Unmatched Applications Flexibility:**

- Active alarm management capabilities with automatic delivery of SMS (GSM mode), e-mail, or fax alarm messages.
- Data logger and display-enabled configurations are available.

## 9.8 Protection System

Earthing: The array structure of the PV yard will be grounded properly using adequate number of earthing kits. All metal casing / shielding of the plant shall be thoroughly grounded to ensure safety of the power plant.

Lightning Protection: The SPV Power Plant shall be provided with lightning & over voltage protection. The main aim in this protection shall be to reduce the over voltage to a tolerable value before it reaches the PV or other sub system components. The source of over voltage can be lightning, atmosphere disturbances etc. Metal oxide variastors shall be provided inside the Array Junction Boxes. In addition suitable SPDs also shall be provided in the Inverter to protect the inverter from over voltage.

# CHAPTER 10: DESIGN OF THE POWER PLANT

The Power Plant components are selected & discussed on the previous chapter. Based on the component selection the Power Plant Design is discussed in this chapter.

## 10.1 Design Assumption for Crystalline Modules

| | |
|---|---|
| Location | :KATTANKULATHUR |
| Place of installation | : SRM INSTITUTE OF SCIENCE AND TECHNOLOGY |
| Latitude | : 09° 49’ N |
| Longitude | : 79° 01’ E |
| Elevation | : 75 m |
| Annual Solar radiation | : 5.22 kWh/ Sq.m/day |
| Module Facing | : True South |
| Module Tilt angle | : 15° |
| Type of System | : Grid Connected System |
| Sun hours | : 8.30 – 4 Hrs. |
| Modules in series per String | : Will be designed as per site conditions |
| Strings in parallel | : Will be designed as per site conditions |
| Shading | : No Shading |
| NOCT | : 45°C |
| Module efficiency loss | : 2.5% |
| Power loss at MPP | : 2% |
| Soiling loss | : 2% |

# CHAPTER 11: PROJECT IMPLEMENTATION AND SCHEDULE

The project is planned to be implemented at the earliest. The most essential aspect regarding the implementation of this project is to ensure that the project is completed within the schedule, spanning from eighteen months from the date of completion of the DPR. A good planning, scheduling, and monitoring program is imperative to complete the project on time and without cost overruns.

## 11.1 Project Implementation Strategy

It is envisaged that the project will have the below mentioned phase of activities. These phases are not mutually exclusive; to implement the project on fast track basis some degree of overlapping is envisaged.

Phase I - Project Development
Phase II - Finalization of the Equipment and accessories
Phase III - Procurement and Construction
Phase IV - Plant Commissioning

## Phase I - Project Development

In a power project, development of the project development plays an important role. Almost 50 % of the work is done if one achieves power purchase agreement from the respective state utilities. The project development starts with visits to the region, understanding about the regional conditions, socio economic conditions, transportation facilities and infrastructure facilities available in the region.
Apart from the above the below listed tasks will be under project development:

- Preparation of Detailed Project Report (DPR)
- Submission of DPR
- Power purchase agreement (PPA)
- Expedite Central Regulatory Authority clearance
- Land acquisition / mortgage

During this phase, a project team will be formed during the execution of the project. The engineers from group will be involved from early stages of execution of the project. This would give them the opportunity to familiarize with the equipment and systems being installed. These personnel should involve with the critical team of installation and commissioning. After the plant being commissioned, these engineers and technicians would occupy key positions in the organization structure for the operation and maintenance of the plant.

The responsibilities of the project team shall be:

- Planning and programming of all the resources required for project completion
- Inspection of major fabrication items
- Organize the construction and commissioning of the plant
- Monitoring and controlling the project progress
- Execute the project within the planned budget

## Phase II- Finalization Of The Equipment And Contracts

In the Power Plant modules and inverters are the lead items and the planning schedule for the project implementation should provide adequate time period for the acquisition and installation of these equipments. The specifications for major equipment shall be drawn up at an early stage of the project. Program of design information, from the equipment suppliers, that satisfies the overall project schedule shall be drawn up.

Since, the project execution calls for closer coordination among the contractors, consultants and the company, proper contract co-ordination and monitoring procedures shall be made to plan and monitor the project progress.

## Phase III - Procurement And Construction

The Procurement is an important function of the implementation of the project. Once the purchase order is placed, the project team follows up regularly to ensure smooth and timely execution of the contract and for obtaining technical information for the inter-package engineering.

When the contracts for the equipment are awarded, detailed programme in the form of network are tied up with the supplier to clearly indicate the owner's obligations and the supplier's responsibilities. And upon placement of the purchase order, the project team follows up regularly to ensure smooth and timely execution of the contract and or obtaining technical information for the inter-package engineering. The procurement activity includes review of drawings, expediting, stage and final pre delivery inspection, supervision of installation and commissioning.

During Construction, the erection and commissioning phase of all the contracts proceed simultaneously. Adequate power and water shall be made available for the construction. Construction manager takes the overall responsibility of the site.

## Phase IV- Erection and Commissioning Phase

The commissioning phase in a project is one where design, manufacturing, erection and quality assurance expertise are put to test. The commissioning team will be from manufacturer of the equipment, consultant and the company. As discussed in the earlier section, staff identified to operate the plant will be involved in the commissioning phase of the project it self.

When construction phase is complete, the check list designed to ensure that the plant has been properly installed with appropriate safety measures. The commissioning team will follow the internal operating instructions. The plant shall be subjected to a performance test.

## Project Schedule

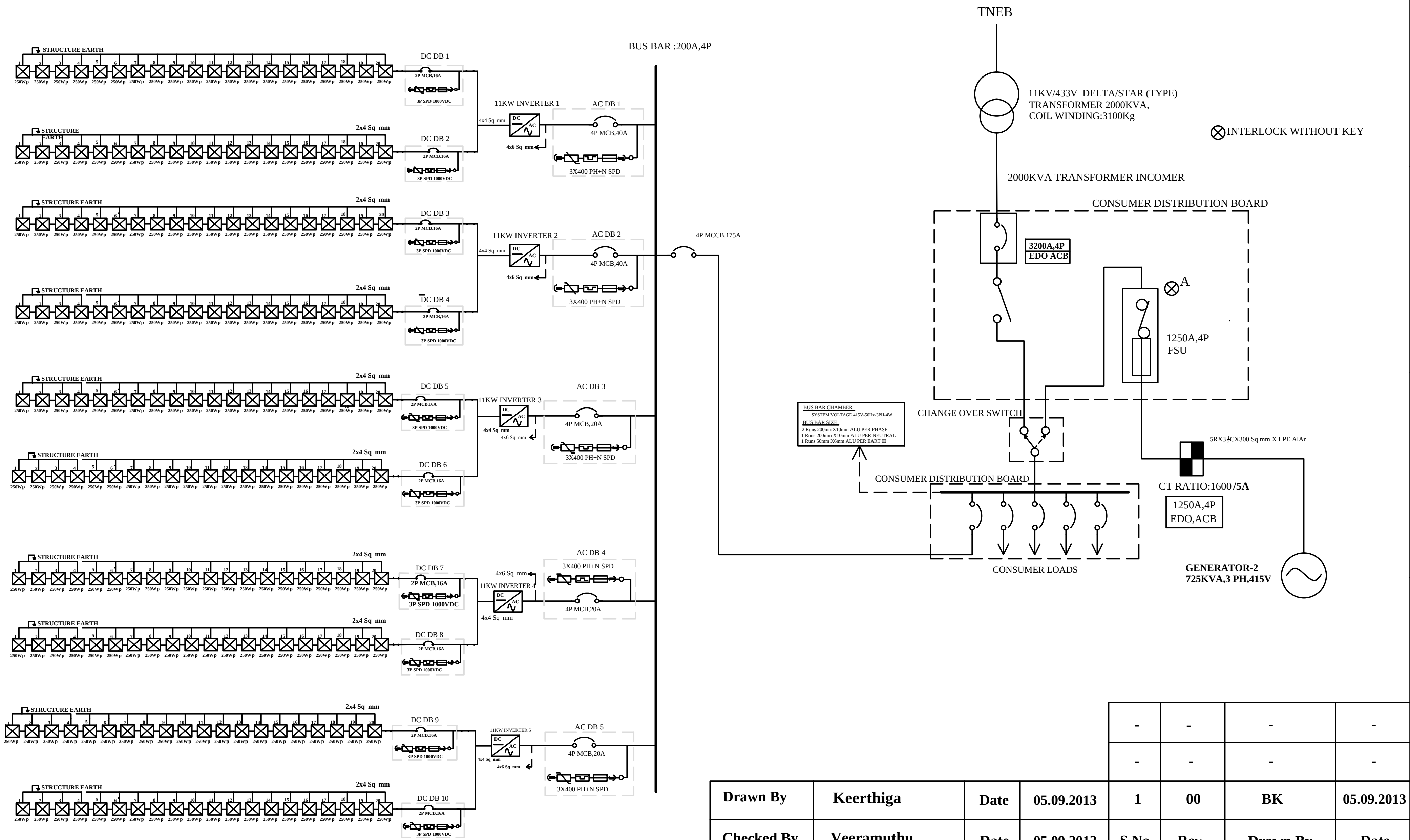
The overall Project completion is scheduled for 3 months from the date of finalization of contract. The same can be discussed and agreed mutually during the detail discussion.

# CHAPTER 12: BILL OF MATERIAL

Based on the design and technical discussion from the above Chapters the Bill of Material for both the option is provided below.

## 12.1 Bill of Material for Crystalline Modules

| Sl.No. | Description | Qty | Unit |
|---|---|---|---|
| 1 | 250Wp Solar Module Mono | 200 | Nos. |
| 2 | String Inverter 11KW | 5 | Nos. |
| 3 | PV Junction Box | 10 | Nos. |
| 4 | Module Mounting Structure | For 50KWp | sets |
| 5 | DC Cable 1C x 4Sq.mm | 1000 | Mtrs. |
| 6 | AC Cable 4 C of 6sqmm armour Cu cable | 25 | Mtrs. |
| 7 | AC Cable 4C of 70sqmm armour Alu cable | 100 | Mtrs. |
| 8 | DC earthing kit | 1 | Set |
| 9 | Lightning Arrestor | 1 | Set |

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| Approved By | Ganesamurthy | Date | 05.09.2013 | Sheet 1 of 1 | | | |
| TITLE | | | | Drawing Number | | | |
| 50KW GRID TIE SOLAR ROOF TOP POWER PLANT-SRM IST | | | | GPE-50KWGTSPP-SLD-01 | | | |

Green Pearl Electronics Pvt. Ltd.