Design and Development, Installation, Erection and Commissioning of 1MW Solar Power Plant

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Abstract: This study aimed at developing a standard procedure for the design of large-scale 1 MW grid connected solar power plant. The project started with broad database of meteorological data including global daily horizontal solar irradiance. The standard procedure developed was designing of a 1MW grid connected solar power plant established at Padana near Morbi. In this paper, the grid connected solar photovoltaic power plant at the place called Padana of Morbi district in the state of Gujarat is designed and installed. The power plant has solar irradiation of 5.5-6.0 KWh/m^2/day. The area of land is 177.38m x 86.91m. Nominal Operating Cell Temperature (NOCT) rating of module is 44°C (±2°C), with a tilt angle of module 22 degree. We have used PVsys 6.7 Software.

1. INTRODUCTION

Nowadays conventional energy sources are rapidly decreasing. The cost of these energy is rising and therefore solar energy is the non-conventional energy source that is abundant in nature, pollution free, distributed throughout the earth and recyclable. India has very good conditions for the development of PV solar power systems. The disadvantages is its high installation cost and low conversion efficiency. So design of 1MW solar power plant has been done at plant at the place called Padana of Morbi district in the state of Gujarat. PV arrays consist of series combination of PV cells that are used to generate electrical power depending upon the atmospheric conditions basically on sunlight.

System Design and Objectives

The objective in designing a Solar Power Plant to match the capabilities to the load requirements of the consumer, at a minimum cost of the system to the consumer.

In order to do this, the designer will need to know the following types of questions about the system. (1) Power Requirements, (2) Solar Data Availability, (3) Type and Size of Solar Power Plant Required, (4) Cost of Energy Produced, (5) Solar Power Viability, (6) System Characteristics, (7) System Requirement, (8) Evaluation Criteria, (9) Design Optimization, (10) Prospects of Cost Reduction.

1.1 Components in Solar Power

Major components

1. Solar PV Mode
2. Grid tie inverter
3. Utility Grid

Minor components

1. DC array junction box
2. AC bus bar (LT and HT Switch gear)
3. Control room
4. Cables
5. Mounting structures
6. Earthing and lightening

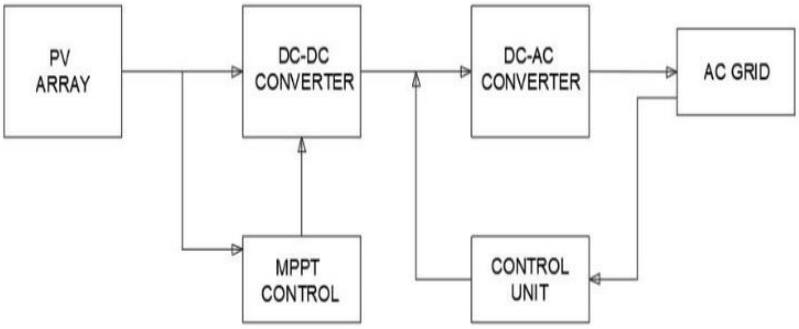

Fig-1: Block diagram of solar PV grid Connected plant

1.2 Factors should be Consider While Designing the System

1. The number of sunshine hours in the location.
2. The proportion of the rainy and cloudy days in the location.
3. The database of the weather report, such as sunshine hours, wind speed, cloudy-rainy days, and natural disaster and so on.
4. And should take full investigation while designing the system,
   a. Surveying the local climatic conditions,
   b. The current needs and future demands clearly
   c. Structure, cost, transportation, construction conditions,
   d. The system protection should be complete and easy to operate, other conditions and the maintenance should be a little and easy as possible.

1.3 DC Side PV Plant Design

a. Modules in Series
   1. Total MPPT voltage at Max Module temperature should be greater than Inverter Min MPPT Voltage
   2. Total Open circuit voltage at Min Module temperature should be less than Inverter Max Voltage

b. Modules in Parallel
   1. Max current should not be more than Inverter Max Input current
   2. No of Array combiner boxes – with or without string monitoring are based on number of inputs selected for each box

c. No. of Main Junction Boxes are based on the Number of Inverter inputs.

1.4 AC Side PV Plant Design

1. AC side cable
2. Power Transformer (LV to MV)
3. LT Switchgear and MV switchgear
4. HT Switchyard, Protection and Metering
5. Transmission lines3

2 SITE AND TECHNICAL DETAILS

2.1 Site Location

The proposed site is located at Padana village in Morbi district in state of Gujarat. Latitude 22.7659° N and Longitude 22.765° N.

Fig 2: 1 MW solar plant location

Other environmental aspects:
1. No wildlife is reported to be present in this area.
2. No health hazards are caused by solar plant. In fact, the solar plant is environment friendly.
3. There are no archaeological monuments or historical places in this area.

2.2 Solar PV Technology

Solar Panel converts sun's natural energy to useful electrical energy. Photo Voltaic modules are made of mono crystalline / polycrystalline solar cells connected in series and parallel modes. Type of solar panel used in this project are multi crystalline.

Polycrystalline solar panels basically have less efficiencies than monocrystalline panel, but advantage is the lower price point. Also, polycrystalline solar panels are in blue color instead of the black color as monocrystalline panels. Polycrystalline solar panels are also made from silicon. However, instead of using a single crystal of silicon, manufacturers use many fragments of silicon together to form the panel. Polycrystalline solar panels are also called as "multi-crystalline," or many-crystal silicon. Because there are more crystals in each cell. As a result, polycrystalline solar panels have lower efficiency than monocrystalline panels.

Fig 3: Multi-Crystalline PV Panels

Watt	325 Watt
Voltage	734.5 Volts
Current	9.25 A
Type	Multi-crystalline
No's of module	3080 Nos

No's of modules per MW	3080 Nos
Efficiency	16.8%
Nominal Operating Cell Temperature (NOCT)	44°C (±2°C)
Dimensions of single module(mm)	1956 × 992 × 40 mm (77.0 × 39.1 × 1.57 inches)
Tilt angle(slope) of PV Module	22 degree
Wind speed rating	150 Km/h
Mounting	Fixed Type
Protective device	under voltage relay

Table -1: Solar Panel Specification

2.3 Inverter

Inverter is an electronic device which converts direct current (DC) to alternating current (AC). We are using ABB string type inverter, with 3 independent MPPT and power ratings of up to 60 kW (480 V version). It has separate and configurable AC and DC compartments which increase the ease of installation and maintenance with their ability to remain separately wired from the inverter module inside the system. It has up to 15 DC inputs with fast connectors, string protection fuses, AC and DC switches and type II AC and DC surge arresters.

20 numbers of 50KW inverters are used in the plant.

Fig-4: GEC [Grid Export Condition] inverter

KVA rating	50 KW
Input DC voltage	610 Volts DC
Maximum Input DC current	36 A
Output AC voltage	400 V ac (phase voltage) 400 V ac (line voltage)
No. of Phases	3-φ
Efficiency	98.3%
No of inverters	20

Table-2: Inverter Specifications

2.4 Grid Connecting Equipments

1) 1250 KVA, 415/11000V, 3 phase, 50Hz Transformer type of cooling ONAN
2) Lightning arrestors of suitable rating.
3) 11 KV switch yard consisting of Current Transformer (CT), Potential Transformer (PT), SF6/ Vacuum circuit Breaker, Bus bar, isolators, protection system etc. along with incoming and outgoing feeders.
4) 11 KV isolators.
5) Aluminium conductor, of suitable diameter, aluminium armoured cable suitable for carrying current from the switch yard.

2.5 LT Panel

LT Panel is called Low Tension panel. It consists of protective devices. It is a electrical distribution board which receives the power from the solar panels through inverters and distributes the same to various electronics device and distribution board. The location of LT panel is close to the inverters so that the incoming cables required for LT panel will be less and cost laying the cable will be economical.

(1) MCCB: It is known as Molded Case Circuit breaker. It is used in electrical energy distribution network having short circuit and over current protection. This circuit breaker offers short circuit and over current protection in circuits ranging from 63A to 3000A. The primary function of MCCB is to automatically open the circuit in case of short circuit or overload conditions. Unlike a fuse this circuit breaker can be reset simply after a mistake and enhance operator safety and ease without operating cost.

(2) Multifunctional Meter (MFM): Multifunctional Meter measures various electrical parameters of 3 phase 3 wire or 4 wire system. These meters are widely used in application areas where accurate and reliable monitoring of power line parameter is essential. It has programmable CT and PT ratios. It is compact and easy installations.

(3) Current Transformer (CT): It is a type of transformer which is used to measure alternating current (AC). Current transformers scale the large values of current too small, standardized values that are easy to handle for measuring instruments and protective relays. They are the current-sensing units of the power system and are used at generating stations, electrical substations, and in industrial and commercial electric power distribution.

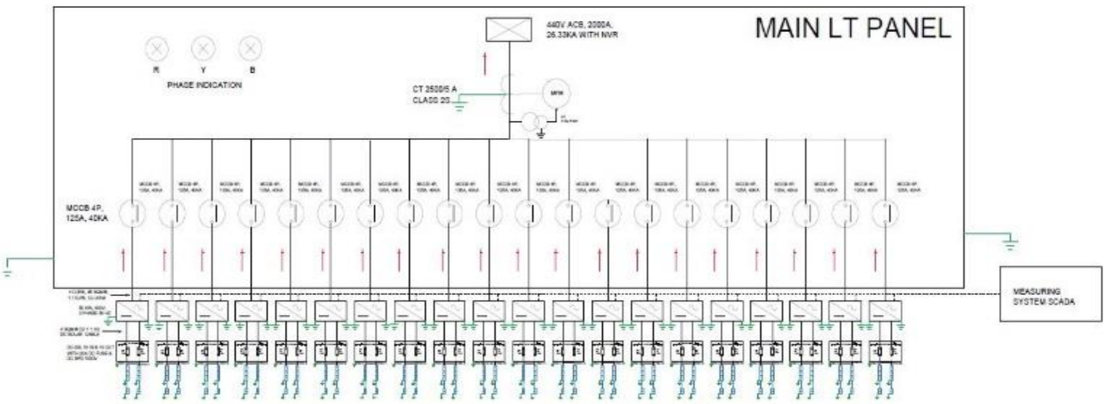

Fig 5-: Main LT Panel

2.6 Transformer

The transformer, transfers the electrical energy to circuits through electromagnetic induction. Electromagnetic induction produces an electromotive force within a conductor which is exposed to time varying magnetic fields. these are used to increase or decrease the alternating voltages in electric power plant.

• 1250 KVA, 415/11000V, 3 phase, 50 Hz Dyn11.

Fig-6: Transformer

KVA rating	1250 KVA
No of phases	3-φ
Frequency rating	50 Hz
Primary voltage rating	440 V
Secondary voltage rating	11KV
Primary current rating	64.18 A + (10-15% extra)
Secondary current rating	27.27 A + (10-15% extra)
Connections	Primary - star (for suppressing Secondary - delta 3rd harmonics) 10 to 25 taps in secondary
Efficiency	Almost 98 %
Extra features	Air cooled
No of transformers	1

Table-3: Transformer Specifications

2.7 Switch Yard

The 11KV switch yard has been set up for power transmission and protection of the various systems as per the detailed specification. 11KV switch yard consist of current transformers, potential transformers, sf6 or vacuum circuit breaker, bus bar, isolators, protective devises etc.

Features of 11 KV switch yard:

a) AC Circuit breakers
b) Potential transformers
c) Current transformers
d) Isolators and earthing switches
e) Metal enclosed Switchgear & Control gear for rated voltages
f) Direct Indicating digital electrical measuring Instruments & accessories
g) AC Energy measuring meters
h) AC Watt hour meters
i) Relays for power system protection

j) Protective relays
k) Push button or switches
l) Bushings
m) High voltage AC circuit breakers

2.8 Combiner Box/ Junction Box

Wires from the PV modules or strings go to the combiner box, located on the roof. These wires may be of single conductor pigtails with connecters which are pre-wired into the PV modules. The output of the combiner box is one larger or two wire conductors in conduit. A combiner box includes a safety fuse or breaker for each string and may also include a surge protector.

Fig-7: Junction Box

3 Design and Software

Design and Estimate of the results of 1MW solar power plant by using PV syst software version 6.70. It is possible to have preliminary data and as well as post evaluation data for the feasible power generation report.

The total system performance and efficiency of each systems of plant is to be evaluated by entering the specifications of a particular design. Design the system According to the above specifications of all components.

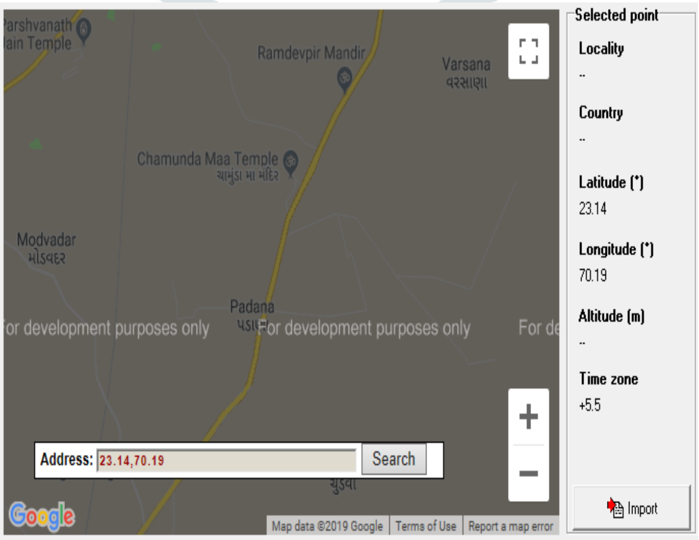

Fig-8: Geographical conditions

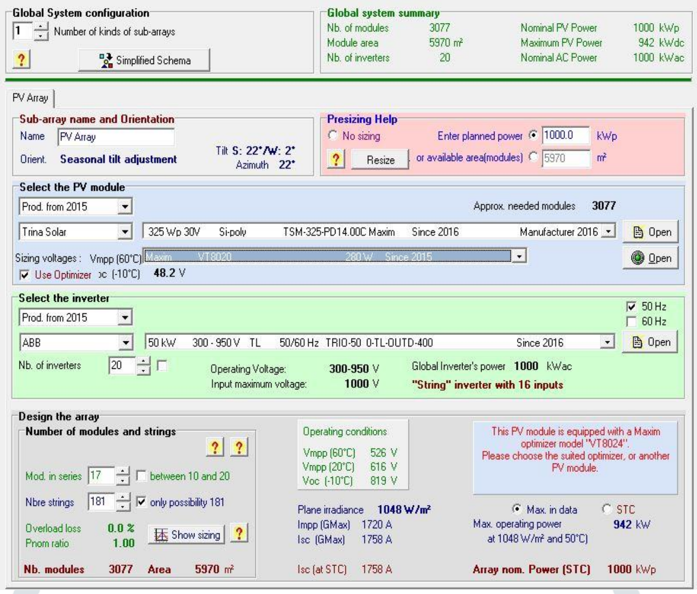

Fig-9: System Design (Solar module, inverter, array design)

4 Results and Discussion

Monthly Meteo Values Source Meteonorm 7.1, Sat=100%

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year	
Hor. global	157.5	160.8	210.5	199.3	224.5	195.8	142.5	141.7	165.0	175.0	149.7	144.0	2066.4	kWh/m².mth
Hor. diffuse	23.5	31.9	41.5	74.8	81.3	95.8	99.0	93.4	81.9	56.1	35.5	26.6	741.4	kWh/m².mth
Extraterrestrial	220.2	231.3	293.5	314.7	340.9	333.9	342.3	330.8	295.6	268.8	222.4	209.0	3403.3	kWh/m².mth
Clearness Index	0.715	0.695	0.717	0.633	0.659	0.586	0.416	0.428	0.558	0.651	0.673	0.689	0.607	
Amb. temper.	20.6	23.3	27.9	30.6	32.1	31.0	29.0	27.7	28.2	29.6	26.0	22.3	27.4	°C
Wind velocity	2.1	2.3	2.8	3.8	5.1	4.9	4.5	4.1	3.2	2.0	1.6	1.9	3.2	m/s

Table-4: Monthly Meteo values

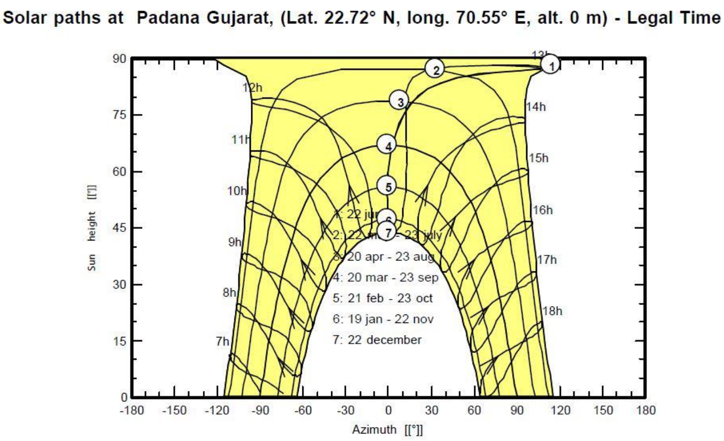

Chart-1: Solar Paths at Padana (22.7659° N, 70.4789° E.)

All the parameters underlying this simulation: Geographic situation and Mateo data used, plane orientation, general information about shadings (horizon and near shadings), components used and array configuration, loss parameters, etc.

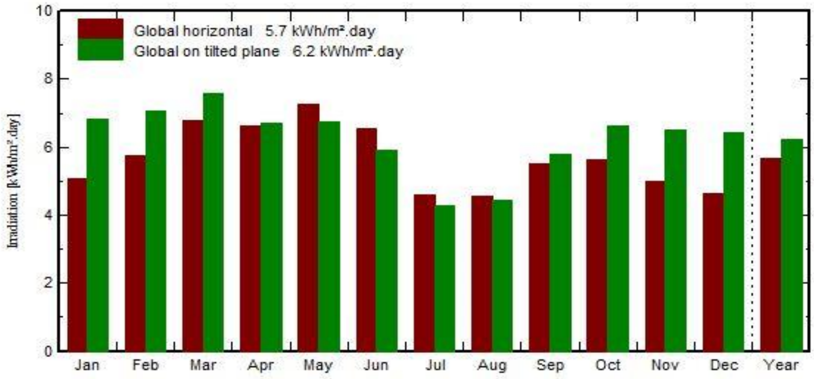

Chart-2 Graph of irradiation

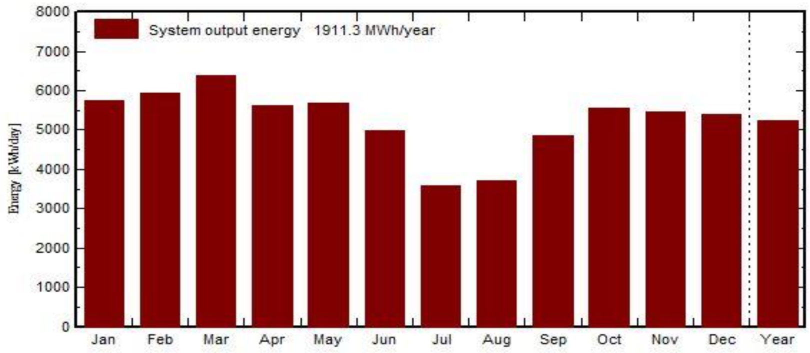

Chart-3 Graph of output energy

- The system energy output is 1911.3 MWh/year.

5. Conclusion

Using PV SYST V6.70 simulation software, the energy yield analysis for 1MW PV Solar power generation was performed on geographical at Padana. Which is located at latitude of 22.7659° N, and longitude of 70.4789° E. And it was found that, for a horizontal global irradiation of 5.7 kWh/m². The available energy at the inverter output which can be fed to the nearby grid is 1911.3MWh. This much amount of energy, which can be generated by establishing 1MW Solar Power plant at Padana, Gujarat.

The impact of temperature variation on the performance of photovoltaic multi crystalline silicon was studied both on daily and yearly basis. It was observed that the efficiency of modules is more sensitive to temperature than the solar irradiation. The efficiency of modules is 16.8% with Nominal Operating Cell Temperature (NOCT) of 44^{0}C (±2 ^{0}C). Hence cooling of solar modules may be desirable to increase the efficiency.

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