

Design and Financial Analysis of a Grid Connected Solar PV System for an Engineering College in Kerala

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ABSTRACT: Electrical demand is increasing day by day, so it is important to rely on renewable energy resources than non renewable. In the scenario of Kerala, it is obvious to depend on solar energy resources as the solar irradiance is high compared to other renewable resources. This paper concentrates on designing a solar PV system, which is grid connected, for an engineering college in Kerala. The paper envisages the financial analysis of the same by taking Internal Rate of Return (IRR) and Payback period into consideration.

I. INTRODUCTION

In the present situation, the fossil fuels availability is reducing continuously, which results in reduction of power generation by using current methods. So alternative methods like solar energy, wind energy, tidal energy of power generation has to be selected in order to compensate the problem of scarcity of fossil fuels. It also have a major advantages that these are pollution free and also the installation cost is very less.

Solar PV technology converts sunlight directly into electricity using photovoltaic phenomena. PV systems can be installed on rooftops, integrated into building designs, or scaled up to megawatt scale power plants. PV systems can also be used in conjunction with concentrating mirrors or lenses for large scale centralised power.

Electricity generation using photovoltaic (PV) systems is important, reliable and has the potential to play a significant role in CO₂ emission mitigation [1]. It is widely accepted that PV will become one of the major future sources of electricity generation considering the potential for cost reduction of PV systems and grid-parity expected Southern and Northern Europe around 2020 [2].

The cost issues related to solar energy has always been a major negative point for solar energy in general and solar photovoltaic in particular. Increasing manufacturing capacity has led to remarkable reduction in cost of solar PV electricity, but the PV electricity production cost is still far above the electricity price from conventional energy technologies.

This paper describes a design and analysis of a grid connected solar PV system for an engineering college in Kottayam, Kerala, India. Various design considerations are discussed including the factors and parameters with limited data and information resources available. Cost analysis reveals that the proposed design is economical and cost effective for the selected college.

II. SYSTEM CONSIDERATION FOR THE COLLEGE

Energy is an essential element for industrial and socioeconomic development of a country. However, the linkage between energy and environmental pollution is one of the biggest challenges the world is facing today. In this context, the utilization of solar energy is important for sustainable development of each and every country. Daily average solar radiation varies between 4 to 6.5 kWh per square meter. Maximum amount of radiation is available on the month of March-April and minimum on December-January[4].

A. Location

The selected campus is situated at Kottayam, Kerala, India. The geographical co-ordinates of the campus are 25 0 38 29.4936" north, 7648 59.06165"east.

B. Irradiance

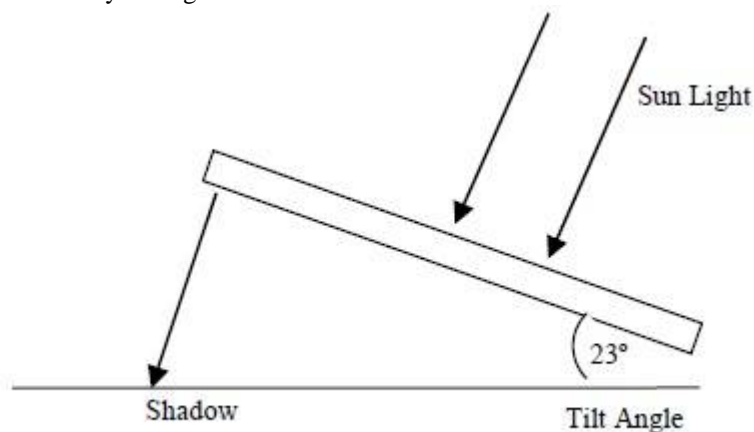
The irradiance of the campus can be obtained directly from the Irradiance meter. The average daily irradiance obtained by taking the mean daily solar insolation of four month period.The value can be given as 4.13 kWh/sq.m.

C. Tilt Angle and Shadow of Module

Table 1: Average Daily Insolation

Month	Average daily solar insolation(kWh/sq.m)
November	3.49
December	3.64
January	4.62
February	4.78
Average Insolation	4.13

Since the sun does not shine perpendicularly on every point of the earth, for maximum efficiency the PV modules are tilted with an angle which depends on the location of the installation. In the northern hemisphere, solar panels should be tilted to face south and vice versa. An easy way to determine the tilt angle is the latitude of the location. If a place has a latitude X degree north, then panels should be tilted with X degrees angle from the horizontal base to face south. The latitude of the college is 25 degrees 38 minutes' and 29.4936 seconds north; the tilt angle for the PV modules at site is approximately 23 degrees.



III. SYSTEM DESIGN

A. Solar PV array capacity

Minimum Requirements for the installation of power plant

1. Minimum 10 square meter shade free area is required for installing 1kW Solar panel array.The area required can be estimated by multiplying the Capacity of plant in kW with 10sq.m (ie. Capacity in kWp*10 Sq.m)
2. The system will be in the grid connected mode without battery backup. The electricity generated will be utilised directly and excess electricity could be fed to the grid of Distribution licensee through energy meter with net metering facility.Voltage of the grid should be between 184VAC and 253VAC (for Single Phase) and 332VAC to 456VAC (for Three Phase). Frequency should be between 47.5Hz and 50.5 Hz).
3. Average daily electricity generation on a sunny day will be 4units/kW of solar modules installed. But this will vary according to the availability of solar insolationand presence of grid.

B. System Sizing System

Sizing is based on the availability of shade free area, requirement by the beneficiary and the connectivity permission from the Distribution licensee.

With these assumptions, the recommended capacity of the solar modules array of a proposed grid-connected solar PV system can be calculated:

Step 1: Calculate the maximum system capacity on the basis of the shade free rooftop area.

Formula: Capacity = shade-free rooftop area (in square meters) divided by 10.

The shade-free rooftop area is 392.52 m².

The maximum solar PV capacity that can be installed on this rooftop area would be $392.52/10 = 39$ kWp approximately 40kWp can be preferred.

Step 2: Calculate the system capacity based on annual energy consumption.

Formula: Capacity = 90% of annual energy consumption (in kWh) divided by 1440(average annual energy generation per installed kW of solar PV capacity). The (estimated) annual energy consumption of the college is 53,208 kWh. The solar PV system capacity based on annual energy consumption would be $(90\% * 63850)/1,440 = 39.9$ kWp

Approximately we can take 40 kWp system.

Recommended Capacity: Take the lowest of the above two capacity calculation results. For the three phase connection here we choose system size of 40 kWp.

C. Solar Grid Inverter Capacity

The recommended solar grid inverter capacity in kW shall be in a range of 95% -110% of the solar PV array capacity. Here Solar PV system capacity was calculated to be 40 kW. The solar grid inverter required for this array would be in a range of 38-44 kW.

D. Solar PV system components

A grid connected solar PV system consists of the following main components;

1. Solar PV(photo-voltaic) array
2. Solar PV array support structure
3. Solar grid inverter
4. Protection devices
5. Cables

The figure I shows the block diagram for grid-tied Solar PV system.

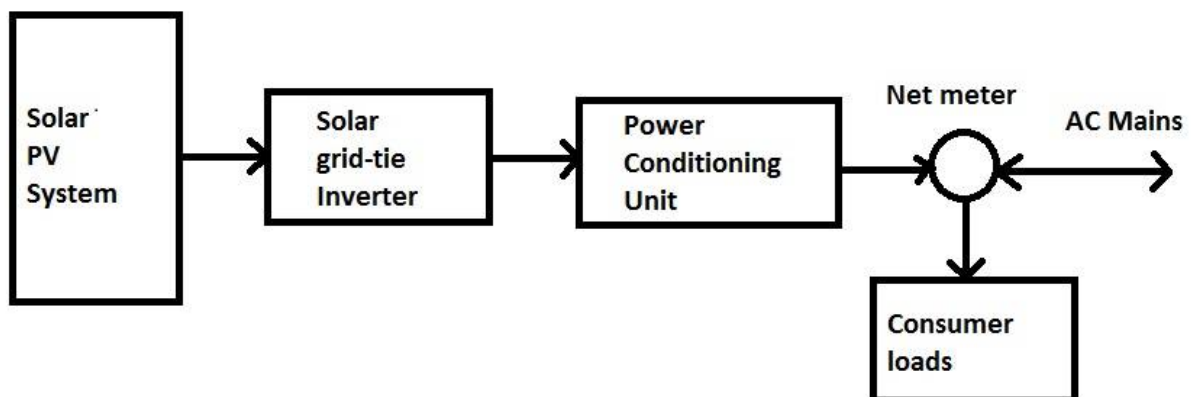


Figure 1: Grid Tied System

E. General Technical Specifications

1. In grid-connected solar photo-voltaic (PV) systems, solar energy is fed into the building loads that are connected to the KSEB grid through a service connection with surplus energy being fed into the grid and shortfall being drawn from the grid. Production of surplus energy may happen when solar energy produced exceeds the energy consumption of the building [3]. This surplus is fed into the grid. During the night, or when during the day energy demand in the building exceeds solar energy generation, energy is drawn from the grid. Gridconnected solar PV systems have no battery storage and will not work during grid outage. For buildings with grid-connected solar PV systems, the service connection meter needs to be of the bidirectional type, whereby import kWh and export kWh are separately recorded.
2. Solar PV modules are designed to last 25 years or more. It is therefore essential that all system components and parts, including the mounting structures, cables, junction boxes, distribution boxes and other parts also have a life cycle of at least 25 years.
3. As per the solar net metering orders of the Kerala State Electricity Regulatory Commission (KSERC) , crediting of energy for the purpose of net-metering is limited to 90% of the consumed energy during a 12 month settlement period. The maximum recommended solar PV capacity for grid-connected solar PV systems is therefore a capacity that produces not more than 90% of the annual energy consumption of the building.

Specification of Solar PV Modules is given in the table II:

Table 2: SPECIFICATION OF SOLAR PV MODULES

Type	Crystalline silicon
Origin	Manufactured in India
Efficiency	$\geq 13\%$
Fill factor	$\geq 70\%$
Degradation warranty	Panel output (Wo) capacity to be $\geq 90\%$ of design nominal power after 10 years and $\geq 80\%$ of design nominal power after 25 years
Module frame	Non- corrosive and electrolytically compatible with the mounting structure material
Termination box	Thermo-plastic, IP 65, UV resistant
Blocking diodes	Schottky type
Module minimum rated power	The nominal power of a single PV module shall not be less than 74Wp.

Solar PV Modules Mounting Structure: The PV modules shall be mounted on fixed metallic structures having adequate strength and appropriate design, which can withstand the load of the modules and high wind velocities. The support structure shall be hot dip galvanized steel or aluminium.

Detailed specifications for the mounting structure are given in the Table III

Wind velocity withstanding capacity	150 km / hour
Structure material	Hot dip galvanised steel with a minimum galvanisation thickness of 120 microns or aluminium alloy.
Bolts, nuts, fasteners, panel mounting clamps	Stainless steel SS 304
Mounting arrangement for RCC-flat roofs	With removable concrete ballast made of pre-fabricated PCC (1:2:4), M15
Minimum distance between roof edge and mounting structure	0.6m
Panel tilt angle	North south orientation with a fixed tilt angle of 23 degrees (depending on location), south facing.

Specifications for Solar grid-tie inverter is given the table below.

Operation AC voltage	Single phase 230V or Three phase 415V (+ 12.5%, -20%)
Operating Frequency range	47.5 52.5 Hz
Nominal frequency	50 Hz
Power factor of the inverter	>0.98 at nominal power
Total harmonic distortion	Less than 3%
Built-in Protection	AC high / low voltage; AC high /low frequency

F. System Capacity Calculation

Considering the various monthly KSEB bills ,the analysis proved that average daily consumption is 147.8 units and studies proved that average units obtained from a 1 kW PV system is 4 kWh from the table average daily irradiance in CEK campus is 4.13 kWh, so we can decide that 40 kW system is suitable for meeting the energy needs. The nominal power output of the proposed solar PV system is 40 kW. That is it will give 160 kWh(40*4kWh) of power daily The output of a solar PV system is different from its nominal capacity. Numerical values of various factors that reduce the system nominal capacity are presented. These include site location, climatic condition, performances of the PV modules, transmission and other losses.

IV. COST ANALYSIS

The nancial assessment done in this paper based on calculating the Internal Rate of Return (IRR) and Payback period after considering certain assumptions, which are given below.

A. IRR

The internal rate of return of a project is the discount rate which will make the net present value of the project equal to where CF_i is the cash ow at the end of year i ; r is the discount rate and n is the life of the project. The calculations done in this paper are done by taking $r = 8\%$ and $n = 10$. The project period is not usually considered to be more than 10 years since the waiting period will be very high for the project to be financially feasible. The project with a higher IRR is always preferred over a project with lesser IRR.

B. Payback Period

The payback period is calculated by considering the annual discounted cash ow and the period at which the net present value becomes equal to zero is taken as the break-even period or the payback period. Here payback period is constrained to a limit of less than or equal to 10. The payback period is calculated by considering the annual discounted cash flow and the period at which the net present value becomes equal to zero is taken as the break-even period or the payback period. The internal rate of return of a project is the discount rate which will make the net present value of the project equal to zero .where CF_i is the cash flow at the end of year i ; r is the discount rate and n is the life of the project. The calculations done in this paper are done by taking $r = 8\%$ and $n = 10$ years. The project period is not usually considered to be more than 10 years since the waiting period will be very high for the project to be financially feasible. The project with a higher IRR is always preferred over a project with lesser IRR. From a 40 kWp system meeting all the energy needs,we will get annual savings of 2,52,352 Rupees. Here we get the payabck period for without subsidy investment will be 12 years and it takes only 7 years to get back the with subsidy investment .The IRR rate of without subsidy investment is 5.2618 % and we get 16.9645 % of IRR for with subsidy investment.

So we can conclude that the project will be feasible for college.

V. CONCLUSION

This paper presents a solar PV system for an engineering college in Kerala, India. Detailed design including system specification has been worked out. Detailed energy generation and cost analysis shows that though the payback time is high for the estimated capacity, yet the cost per unit is somewhat feasible for 25 years scale under the present state.

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