Estimation & Analysis of a 5KWP Solar Photovoltaic Power Plant at JIS College of Engineering, Kalyani.

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Abstract— Limitation on application of fossil fuel resources on a worldwide basis due to it's certain limit has necessitated an urgent search for alternative energy sources to meet up the present day demands. Solar energy being a clean, inexhaustible and environment-friendly potential resource among all renewable energy options. This paper presents an estimation & real time analysis of a 5kWp power plant at JIS college of Engineering, Kalyani

Keywords— Carbon Credit, Solar energy, SPV

AN ANALYSIS OF A REAL 5KW SOLAR POWER PLANT AT JIS COLLEGE OF ENGINEERING, KALYANI

(PROJECT APPROVED UNDER RPS)
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Figure 1: SPV Power Plant on the roof of JIS College of Engineering

OBJECTIVE:

It is seen from various earlier works that application of renewable energy will be forecast more and more in near future due to presence of Global Warming and clean renewable energy will reduce unacceptable air pollution and mainly to meet up the heavy energy demand. Grid connected system is well used in various part of world, and many types of technology used is discussed as earlier work review.

The objectives of this research are

i. To improve the I-V Characteristics of the solar cell/ modules with the help of Microcontroller (ATMEGA). It was found that noise caused the I-V curve zigzag slightly near the VOC and to zigzag widely near the knee point of the curve.
ii. Estimate the cost of installation of 5KWP Grid connected solar photovoltaic power plant.
iii. Observe the month wise (Jan to Dec) power consumption throughout the year.
iv. Estimation of the simple Payback Period of the 5KWP solar power plant.
v. Estimation the Payback Period with respect to changing value of the money over the time and degradation the power generation of the system.

The main objective of this research is to estimate real value cost analysis of the 5KWp Solar Power Plant at JIS College of Engineering. The detailed specifications of the plant have also been included in this research. Moreover through this research the possibilities of compensation of power during peak load over base load in existing power plant in West Bengal is explored by using SPV system which will restrain the using of conventional fuel during peak load with base load higher power plant efficiency and in turn will save a huge amount of conventional fuel. So SPV application and its analysis & estimation are the main focus this research.

Carbon Credit

A carbon credit is a generic term for any tradable certificate or permit representing the right to emit one tone of carbon dioxide or the mass of another greenhouse gas with a carbon dioxide equivalent (tCO_2e) equivalent to one tone of carbon dioxide.
Carbon Credit Trading (Emission Trading) is an administrative approach used to control pollution by providing economic incentives for achieving reductions in the emissions of pollutants. There are currently two exchanges for carbon credits: (i) the Chicago Climate Exchange and (ii) the European Climate Exchange. ICE Futures Europe currently offers derivatives contracts on four types of carbon units: EU Allowances (EUAs), EU Aviation Allowances (EUAAs), Certified Emission Reductions (CERs) and Emissions Reductions Units (ERUs).

The present market rate is fluctuating at €20–22 in the European Climate Exchange (www.europeanclimateexchange.com)

METHODOLOGY:

A 5KWp Grid connected SPV power plant is established at JIS College of Engineering. In this paper we are focusing on the reduction of CO_2 by this plant and carbon credit earned.

To find out the solar potential available at Kalyani, West Bengal, reading of solar radiation for site is required. So these readings are taken from National Renewable Energy Laboratory (NREL), Solar Energy Centre. The geographical coordinates of our project site is:
Latitude: 22.95° N , Longitude: 88.45° E

No. of Modules Used (N) (Each of 250WP) = 20
Area of Single Module (A) = 1.609498 m2
Efficiency of the Modules (η) = 15%

Let Solar Insolation be "I"

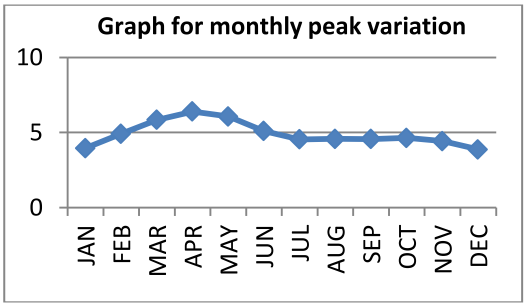
Therefore energy generated by the plant = [N * I * η * A] (KWh/day)

A. ON THE BASIS OF THEORITICAL DATA:

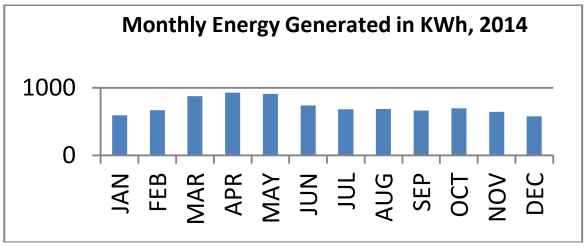
The below table shows the monthly solar insolation and the calculated energy generated by this plant.

Table 1

MONTHS	Solar Insolation (Acc. To NREL) in KWh/m2/day	Energy Generated (KWh)
January,2014	3.96	592.7459
February	4.92	665.1733
March	5.84	874.1506
April	6.40	927.0708
May	6.07	908.5777
June	5.10	738.7596
July	4.55	681.0591
August	4.58	685.5496
September	4.57	661.9865
October	4.64	694.5306
November	4.43	641.7069
December,2014	3.87	579.2744



Graph 1



Graph 2

Calculated nominal plant output (Y_C) = 8650.584996 KWh per year

Now taking Global incident in collector plane to be 7.2% and the loss factors as follows:

- IAM (Incidence Angle Modifier) = 3%
- Soiling loss factor = 3%
- PV loss due to irradiance level = 3.2%
- PV loss due to temperature = 9.1%
- Module Quality Loss = 1.5%
- LID (Light Induced Degradation) = 2%
- Module Array Mismatch Loss = 1%
- Ohmic wiring loss = 0.3%

- Inverter Loss during operation (efficiency) = 4.7%

We get Performance Ratio (PR) of the plant = 76.7%

Now Performance Ratio =

$$\frac{\text{Actual Plant Output } (Y_A)}{\text{Calculated Nominal Plant Output } (Y_C)} * 100\%$$

Therefore, Actual Plant Output (Y_A) = 6634.99 KWh

So, we can say actual yearly output of the plant = 6635 KWh

Now, the solar modules at guaranteed for 25 years, thus we consider the life span of the plant to be 25 years, though the plant can perform for 30 to 35 years.

Thus total energy generated in 25 years by this plant = 165875 KWh

Cost per unit of energy generated (Case-1):

Now, cost of installing the plant is Rs 6,00,000.

No extra cost is required to run the plant as solar energy is free and renewable. So now we can find the cost of per unit of electricity generated from the plant if the plant has a life cycle of 25 years.

$$(\text{Cost per unit})_1 = \frac{\text{Cost of installing the plant}}{\text{Total units generated in 25 years}}$$

= Rs 3.62

This is the cost per unit generated without trading any carbon credit earned from the plant.

CO_2 Reduction:

The reduction of carbon dioxide by Solar Photovoltaic Power Plants installed all over the world has been compiled by Denis Lenordic. Data for CO2 emission reduction by the top 200 Solar Photovoltaic Power Plants are available at http://www.pvresources.com/en/top50pv.php. The data available include power produced per annum in MWh, annual carbon emission reduction. Average annual carbon emission reduction per MWh of electricity produced, for the top 100 solar voltaic power plants, data of electricity produced in MWh and emission reduction per annum for which are available, comes to 0.932 tons of carbon dioxide emission reduction per MWh of electricity produced. [2]

So we get, 1KWh of energy generated by SPV power plant = 0.932 kg of carbon dioxide reduction

Taking this average (0.932 kg of carbon dioxide emission reduction per KWh for the SAPV plant installed in India)
The carbon dioxide reduction = 0.932 * 6635
= 6.184 tons of CO_2 / annum

In 25 years carbon dioxide reduction = 154.596 tons of CO_2

Carbon Credit earned by the plant:

If carbon dioxide emission reduction at present being traded @ €21/tCO_2e, European Climate Exchange [4], then the carbon emission reduction by this SPV Power plant in 25 years is as follows

Carbon credit earned by this SPV Power plant = 154.596 * 21 * 81.83 = Rs 265662.40
(where 1€ = Rs 81.83 as on 20th June 2014)

Cost per unit of energy generated (Case -2):

In this case we are considering that the carbon credit is being traded for 25 years. Then the cost per unit of energy generated is as follows.

$(\text{Cost per unit})_2$ =

$$\frac{(\text{Cost of installing the plant}) - (\text{Cost of CO2 traded})}{\text{Total units generated in 25 years}}$$

= Rs 2.02

So, percentage of reduction in cost per unit when CO2 is being traded is

Percentage reduction in per unit price =

$$\frac{(\text{Cost per unit})1-(\text{Cost per unit})2}{(\text{Cost per unit})1} * 100\ \%$$

= 44.20%

Thus we can see that by trading the carbon credit earned from this plant there is a 44.20% of reduction in price per unit of energy generated.

SIMPLE PAYBACK ANALYSIS

A simplified form of cost/benefit analysis is the simple payback technique. In this method, we have taken into account a 6% economic growth of the country which results in rise of electricity price from conventional energy source every year. This method yields the number of years required for the system to pay for itself. Present Electricity Rate = Rs 6.19/ unit (acc. To WBSEDCL for the year 2014-15) (1unit = 1KWh) The following table shows the price of electricity for next 11 years and savings by the SPV power plant every year.

Table 2

Years	Electricity Rates (in Rs)	Savings (in Rs)
1st	6.19	41070.65
2nd	6.5614	43534.89
3rd	6.955084	46146.98
4th	7.372389	48915.8
5th	7.814732	51850.75
6th	8.283616	54961.79
7th	8.780633	58259.5
8th	9.307471	61755.07
9th	9.86592	65460.38
10th	10.45787	69388
11th	11.08535	73551.28

Case 1: When Carbon Credit is not considered.

From the above table we can find that the simple payback period is 10 years 9 $\frac{1}{2}$ months.

Case 2: When Carbon Credit is considered.

From the above table we can find that the simple payback period is 6 years 10 months.
Thus we can see that the payback period decreases by almost 4 years when the carbon credit is traded.

RETURN ON CAPITAL COST

Now we will see the effect of carbon credit in the return on capital cost of the system.

We will calculate the return on capital cost of the system per annum.

Cost of electrical power produced per annum = Rs 41070.65

Cost of CO_2 traded per annum = Rs 10626.77

Net present cost of the system = Rs 600000

Case 1: Carbon Credit is not considered

$$\text{Return on capital cost} = \frac{\text{Cost of electrical power produced}}{\text{Net present cost of the system}}$$

$$= 0.0685 = 6.85\%$$

Case 2: Carbon credit is considered

Return on capital cost =

$$\frac{(\text{Cost of electrical power produced}) + (\text{Cost of CO2 traded})}{\text{Net present cost of the system}}$$

$$= 0.0862 = 8.62\%$$

Thus we can see from the above calculations that an increase of 1.77% in return on capital cost on the system per annum when the carbon credit is traded.

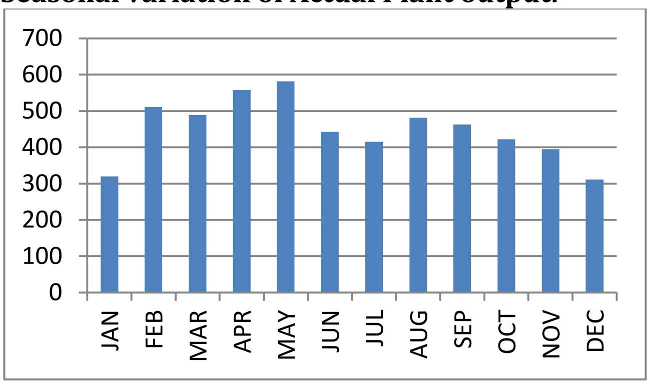
B. ON THE BASIS OF PRACTICAL DATA

The plant started operating from 7th January 2014, and daily data were collected for one year. The monthly generation was tabulated as follows:

Months	Energy Generated
January,2014	320.1
February	510.6
March	489.3
April	557.7
May	581.8
June	442
July	415.1
August	481.1
September	462.8
October	421.9
November	394.5
December,2014	310.8
Total	5387.7

Table 3

Seasonal variation of Actual Plant output:



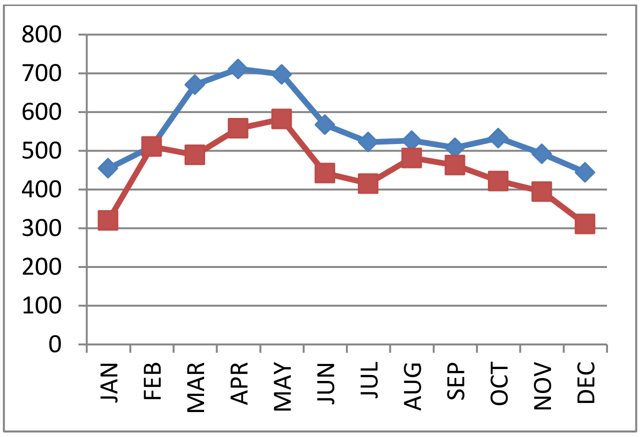
Graph 3

Now, theoretically calculated Actual Plant Output (Y_A) = 6634.99 KWh and practically found Plant output = 5387.7 KWh

The difference between theoretical and practical value of plant output is mainly due to the following reasons:

- Contingencies occurred during the plant operation. They are mainly due to main grid power failure due to which the solar inverter isolates.
- Maintenance of the plant during which the plant is switched off.
- As the plant is situated in a college, the plant remains switched off on some holidays, and on days when the college remains closed. So, we had not got any useful power for that period.

Graph 4 represents the variation between the variation between theoretical and practical (actual) plant output.



Graph 4

Now, according to this practical data and based on first years performance of the plant:

CO_2 reduction = 0.932 * 5387.7 = 5.021 tons of CO_2 / annum

In 25 years carbon dioxide reduction = 125.53 tons of CO_2

Carbon credit earned by this SPV Power plant in 25 years = 125.53 * 21 * 81.83 = Rs 2, 15,714.52

Payback period based on the first years performance is around 12 years and 6 months.

Cost per unit generated (taking plant life cycle to be 25 years) is Rs 4.46

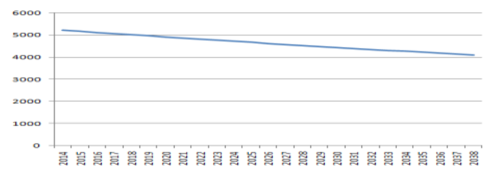
This project gives an analysis of electrical energy that can be produced from the 5KWP SPV power plant and correspondingly the carbon credit that can be earned from this plant in 25 years. It can be observed that there is a 44.20% of reduction in cost per unit of electricity generated and the payback period also decreases by almost 4years when the carbon credit is traded according to Kyoto Protocol. It can express that the Government of India can earn total carbon credit of around Rs 10626.77 per annum from a 5KWP SPV power plant. Thus when implemented on a large scale a huge return on capital can be earned by trading the carbon credits. It can also can be conclude from this work that in long run that is say 25years cost of per unit of electricity is also much less than that of thermal power plant.

In the first year of running the plant already it have been faced some problems and found out that there is a difference of around 18.8% in theoretical and actual energy output of the plant. It must be find and implement proper steps to overcome this and reduce the difference. These also have been seen that in its first year the plant has helped in around 5tons of CO2 reduction. The plant has also produced electricity equivalent to around Rs 33,350 as per present electricity rates.

SIXTEEN YEAR'S (2014-29) REVENUES FROM ENERGY SAVED AT CHANGING VALUE OF MONEY OVER TIME.

Table 4

YEAR	TOTAL COST(RS.)	TOTAL COST WITH PREVIOUS YEAR(RS.)
1ST YEAR(2014)	31,335	31,335
2ND YEAR	32,883	64,218
3RD YEAR	34,499	98,717
4TH YEAR	36,180	1,34,897
5TH YEAR	37,976	1,72,873
6TH YEAR	39,831	2,12,704
7TH YEAR	41,792	2,54,496
8TH YEAR	43,807	2,98,303
9TH YEAR	45,971	3,44,274
10TH YEAR	48,231	3,92,505
11TH YEAR	50,582	4,43,087
12TH YEAR	53,069	4,96,156
13TH YEAR	55,685	5,51,841
14TH YEAR	58,427	6,10,268
15TH YEAR	61,290	6,71,558
16TH YEAR(2029)	64,314	7,35,872



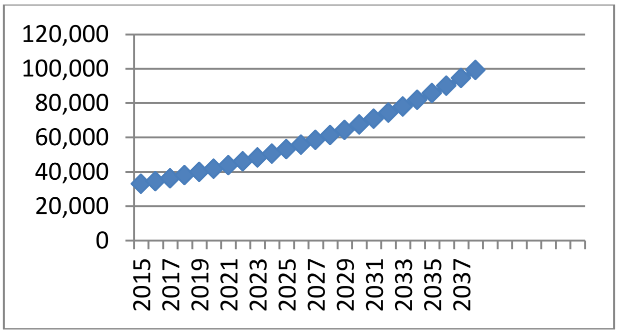
Graph 5: Variation Power Generation with respect to year

Tabel 5

Year wise Cost saving Calculation for 25Years

YEAR	PER UNIT RATE(RS)	TOTAL ENERGY Generation(KWH)	TOTAL RATE(RS)
2014	6	5222.5	31,335
2015	6.36	5170.2	32,883
2016	6.74	5118.5	34,499
2017	7.14	5067.3	36,180
2018	7.57	5016.6	37,976
2019	8.02	4966.4	39,831
2020	8.50	4916.7	41,792
2021	9.00	4867.5	43,807
2022	9.54	4818.8	45,971
2023	10.11	4770.6	48,231
2024	10.71	4722.9	50,582
2025	11.35	4675.6	53,069
2026	12.03	4628.8	55,685
2027	12.75	4582.5	58,427
2028	13.51	4536.6	61,290
2029	14.32	4491.2	64,314
2030	15.17	4446.3	67,450
2031	16.08	4401.8	70,781
2032	17.04	4357.8	74,256
2033	18.06	4314.2	77,914
2034	19.14	4271.0	81,748
2035	20.28	4228.2	85,750
2036	21.50	4185.9	89,997
2037	22.79	4144.0	94,442
2038	24.15	4102.5	99,076
Total**25**Yrs			14,77,286

[It is considered that per unit Electricity bill is increasing at a rate of 6% and also the power generation of the solar panel is reducing at a rate of 1%.
Practically it will be approximately linearly as mentioned above. It is only our pre- assumption.]



Graph 6: Variation Economical Status with respect to year

FUTURE SCOPE OF THIS PROJECT WORK

There are some points ,which are important considering the long term perspective on the growth of the country, mentioned here which support the recommendations for installing PV modules for electricity generation and cost-effective.

❖ The price of the solar panels has declined in recent years. So in future solar panel installation cost will be reduced.

❖ Excess electricity also may be sold back to the grid (local power company) or in the case of net metering can flow to the grid with the sum used to offset electricity used during other times.

❖ Grid-tied system are the most common when a load is connected to the both the Solar PV system and Conventional electric grid. Batteries can be added to the grid connected system to give backup power during an outage.

❖ Multi junction III-V Concentrator Photovoltaic (CPV) cell have the highest energy conversion efficiency of any solar cell technology, with several different types of cell architecture reaching over 40% efficiency since 2006. The third generation concentrator photovoltaic system can become the lowest cost option for solar electricity, competing with conventional power generation without government subsidies. Higher efficiency is one of the few effective ways to reduce the fundamental module packaging and support cost of solar electricity. A 10% efficient module technology required 10m2 worth of materials to generate 1KW of electricity under 1000W/m2 incident intensity, where as 25% efficient module requires 2.5 time less, or only 4m2. As a result the lower cost of CPV system with highest efficiency must be cost-effective. Hence the installation cost will be reduced and the Payback Period must be reduced.

❖ Rooftop solar PV is connected to the distribution system and ingestion of power is into a load centre thereby avoiding transmission and distribution (T&D) losses incurred in the case of centralized, larger plants. This is a strong rationale for rooftop solar projects in India, where the national average of T&D losses hover at close to 30%.

❖ produced in next GA generations. The optimal solution will then be subject to the process of crossover and mutation, it produces the next generation have been reached. The iteration will continue when convergence criterion satisfy.

In the design and planning of stand-alone renewable energy systems, the optimal sizing is an important and challenging task as coordination among renewable energy sources, generator, storage capacity and its complicated load. Genetic algorithm (GA) is a population based search and optimization technique. It has been developed to imitate the process of natural evolutionary of genetics. GA takes selection, crossover and mutation to imitate evolution processes. The selection evaluation is to determine the chosen chromo some, each chromosome consists of two genes. Specific values of Loss of Load Hour (LOLH) with allocation of PV and Battery (BTY) in a LOLH table pass the se-lection evaluation via the fitness cost function. If the evaluation of qualified chromosome has a lowest total cost of a SPV system than the cost obtained at the previous iterations, the size of PV/BTY allocation was considered to be the optimal solution for the constrained optimization in this iteration which can be shown by a flow chart.

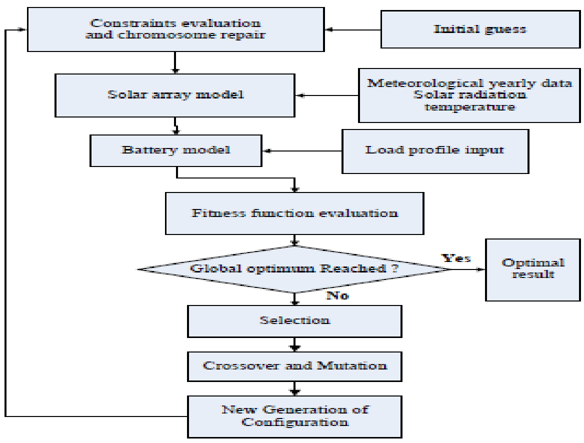


Figure 2: Flowchart of the optimal sizing model using GA.

If any of the initial population chromosomes violates the system constraint, it is replaced by a new chromosome. The PV array current output is calculated according to the PV system model by using the specifications of the PV module, ambient temperatures and solar radiation conditions. The battery capacity is permitted to discharge up to a limit defined by the maximum depth of discharge, which is specified by the system designer at the beginning of the optimal capacity process. The GA was implemented by Matlab and employed the operators of roulette-wheel selection, single-point crossover, single-bit mutation, and elite replacement.

The optimal size of a SPV system is found efficiently by a GA optimization technique. Global optimum with relative computation simplicity has been attained. The simulation result of this paper is believed to be a worthy reference for decision-making can be considered as important references of the photovoltaic generation installation.

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