International Journal of Civil Engineering and Technology (IJCIET)
Volume 8, Issue 11, November 2017, pp. 180-190, Article ID: IJCIET_08_11_019
Available online at http://www.iaeme.com/ijciet/issues.asp?JType=IJCIET&VType=8&IType=11
ISSN Print: 0976-6308 and ISSN Online: 0976-6316

FINANCIAL VIABILITY OF SOLAR PHOTOVOLTAIC SYSTEM: A CASE STUDY

Himani Maheshwari
Centre of Excellence in Disaster Mitigation & Management,
Indian Institute of Technology Roorkee, India

Kamal Jain
Department of Civil Engineering, Indian Institute of Technology Roorkee, India

ABSTRACT

Today, energy sector of India mostly depends on nonrenewable energy sources, which generates a considerable amount of carbon footprint. In order to address the global challenges of climate change and sustainable development, there is a vital need to accelerate the development of advanced technologies for clean energy. Solar photovoltaic is a key technology options to realize the shift towards de-carbonize energy supply and is projected to emerge as an attractive alternate electricity source in the future. This paper estimates the generated solar energy production and carbon credits earned by the photovoltaic cells of multi crystalline solar photovoltaic module, used in the campus of Indian Institute of Technology Roorkee, India. Also the analysis has been done for the amount of carbon footprint and payback period. The study reveals that, the average insolation value of a campus is 6.02 kWh/m^2/day and the amount of actual energy generation is 3286605 units per year. The carbon credit in the campus is computed as 3063.12 tons/year and should be traded as USD 2871.44 as per the norms of the Kyoto protocol. The amount of CO_2 produced is calculated as 164.33 tCO_2 per year. The capacity utilization factor (CUF) is 20.6%. Additionally, the payback period for different scenarios is also evaluated.

Key words: Rooftop Solar PV, Carbon Footprint, Carbon Credit, CUF, SPP, DPP.

Cite this Article: Himani Maheshwari and Kamal Jain, Financial Viability of Solar Photovoltaic System: A Case Study, International Journal of Civil Engineering and Technology, 8(11), 2017, pp. 180-190.
http://www.iaeme.com/ijciet/issues.asp?JType=IJCIET&VType=8&IType=11

1. INTRODUCTION

The essential input for the progress of social and economic development of any country is energy. It is one of the fundamental needs and a way to increase, productivity, enhances employment opportunities and improves the quality of life of the people (Purohit & Purohit, 2009). The total annual generation of electricity in India from all sources was 1102.9 TWh in

2013 from which 59% was generated from coal, 17% from hydro, 12% from renewable energy source, 9% from natural gas, 2% from nuclear and 1% from oil. Currently, India is facing a severe scarcity of power generation capacity, even though it is the world's fourth largest energy consumer after the United States, China and Russia (Energy Statistics, 2013). This major shortage of electricity generation capacity has a direct negative impact on its industrial and economic growth. Upcoming day's power plants are inevitably dependent on highly volatile fossil fuels such as coal, which is the inescapable ensuing increase in greenhouse gas (GHG) emissions and not a viable long- term option as an energy resource. India's energy basket has a mix of all renewable and nonrenewable energy sources. The massive supply-demand imbalance in energy is tackled through renewable sources such as solar and wind energy that will help to mitigate global warming (Saidel et al., 2009). 250-300 sunshine days and 4 to 7 kWh/m^2 of solar radiation intensity depict a great potential of solar energy resource in India (Saidel et al., 2009; Prabhakant & Tiwari, 2012).

Solar energy can be captured in two ways. The more traditional approach is to capture heat using thermal devices such as solar water heater, while the other is to generate electricity directly through the use of photovoltaic panels. A french scientist Becquerel, detected in 1839 that when light is directed into one side of a simple battery cell, the current generated is increased. This is known as phenomena of Photovoltaic (PV) technology that converts sunlight directly into electricity. Later in 1950s, the crystalline silicon solar cells and in 1953 PV modules for terrestrial applications was developed. The applications of PV systems include lighting, telecommunications, vaccine refrigeration, electrified livestock fencing, water pumping and many others. The PV technology is used to generate power that reduces anthropogenic carbon footprint (ITDG, 1994).

PV modules provide an independent, reliable electrical power source at the point of use, making PV particularly suited to remote locations. In the form of rooftop solar PV system, it is increasingly being used in offices, colleges and homes for electricity to replace grid power. PV cells, in panels, convert free daylight into electricity, but they are expensive to install and can take many years to achieve payback. PV can be the most cost-effective power source in remote areas where grid connection is costly (ECREHSB, 2007). The several benefits of SAPV system are: no fuel requirements, modular design, reliability of PV modules, easy to maintain, long life, national economic benefits, environmentally benign (REIHRD, 2011).

Uttarakhand lies under micro-climatic zone. Their hilly areas are sometimes 'cold and cloudy' and 'cold and sunny' climatic zones. However, some locations in the plains of the state like Roorkee lie in the composite climatic zone (Purohit & Purohit, 2009). Roorkee town has vast potential of solar energy and hence a case study has been chosen covering an educational institution, Indian Institute of Technology Roorkee (IITR) in the town. The Government of Uttarakhand (GOU) is keen to tap such natural resource. The state would support efforts for setting up grid connected solar based power projects for generating electricity. The Ministry of New and Renewable Energy (MNRE) approved the non-polluting solar PV power projects for renewable energy tariff. The capital cost of the Solar PV power projects is 1000 lakhs per megawatt in the fiscal year 2012-13 under Regulation 57 (IECU, 2009).

According to CERC (2013), the total project cost of solar PV system includes PV modules cost (40.9%), land cost (2.1%), additional module cost (1.2%), civil and general works (11.9%), mounting structures (13.2%), power conditioning units (7.5%), evacuation cost (13.2%) and preliminary &pre-operative expenses cost (10%). The major benefit of allowing the right of use to one's rooftop would generate a source of income in future to the owner. The average rental value varies in different locations.

Like wind energy systems, hydro energy systems, solar energy produces virtually no greenhouse gas emissions, which considered it the best option for power generation. The implementation of solar PV energy systems can dramatically reduce carbon footprint, but it is also true that their manufacturing process requires the use of potentially toxic metals such as lead, mercury and cadmium and produces carbon dioxide but this is very less compared to using conventional fossil fuel technologies (Whitney, 2010).

ROOF TOP SOLAR PHOTOVOLTAIC SYSTEM

A campus of IITR (29° 51' 52″ N, 77° 53' 47″ E) which has spread over an area of 356 acres landscaped lush greenery and within this there are several heritage buildings, modern academic departments, hostels, messes, hospital, school, banks, community centre, indoor and outdoor sports facilities which include three sports stadiums, a modern swimming pool, yoga bhawan, dairy, students' clubs and several activity centers and other buildings (SIITR, 2011).

These buildings have regular grid electricity supply and in the unlikely event of a grid failure, backup DG sets are present in these buildings. Their electrical load is given in table 1:

Table 1 Electricity consumption at different Departments and Centers of campus (SIITR, 2011)

S.No.	Department Electrical consumption	Electrical consumption (kWhp.a.)
1	Alternate Hydro Energy Center	3,00,803
2	Department of Biotechnology	1,90,693
3	Department of Civil Engineering	5,50,866
4	Department of Chemistry	2,02,334
5	Department of Chemical Engineering	2,89,226
6	Department of Management Studies	1,94,984
7	Department of Earthquake Engineering	3,56,318
8	Department of Earth Science	2,92,188
9	Institute Computer Center	4,96,205
10	Water Resource Development & Management	2,57,023
11	Department Of Electronics &Computer Engineering	6,05,201
12	Department Of Humanities And Sciences	68,620
13	Department Of Mathematics & Physics	5,04,502
14	Institute Instrumentation Center	2,22,698
15	Department of Mechanical Engineering	4,79,078
16	Mahatma Gandhi central Library	1,66,343
17	Lecture Hall	4,79,078
18	Others	NA
	Total	56,56,160

Table1 shows the observed electricity consumption on campus, which was relatively large and the electricity requirement of the above shown buildings peaks in the afternoon due to usage of fans, air-conditioners, computers, water coolers etc. These buildings represent the ideal site for installation of solar PV systems on campus because during this time the performance of the PV system is optimized due to maximum insolation. The most efficient solar technology available is rooftop solar plant because it is not prudent to use ground level land for installation of these systems as the insolation received would be low. Hence a fixed solar PV grid connected system without tracking is used in the rooftops of buildings within the campus. The total number of modules is 7910 having a total capacity of 1.8192 MW (table 2).

Table 2 Number of solar PV modules installed on roof of different buildings in the campus and the total 1.8192 MW peak PV capacity

Sl. No.	Roof of Different Building Blocks	Capacity (Wp)	Quantity	Total (kWp)
1	MCA	230	66	15.1800
2	Lecture Hall- 1 & 2	230	36	8.280
3	OP Jain Auditorium	230	92	21.16
4	Institute Instrumentation Center	230	96	22.08
5	Department Of Hydrology	230	115	26.45
6	Department Of Earth Science	230	135	31.05
7	Institute Computer Center	230	140	32.20
8	Department Of Biotechnology	230	140	32.20
9	Department Of Humanities And Sciences	230	154	35.42
10	Alternate Hydro Energy Center	230	184	42.32
11	Mahatma Gandhi Central Library	230	184	42.32
12	Water Resource Development & Management	230	188	43.24
13	Research Scholar Wing	230	201	46.23
14	Industrial Block	230	210	48.30
15	Department Of Management Studies	230	261	60.03
16	Department Of Chemistry	230	267	61.41
17	Hafiz Mohd Ibrahim Building	230	267	61.41
18	Department Of Architecture & Planning	230	289	66.47
19	Department Of Earthquake Engineering	230	289	66.47
20	Department Of Mathematics & Physics	230	345	79.35
21	Lecture Hall Complex	230	368	84.64
22	Department Of Mechanical Engineering Building	230	436	100.28
23	Department Of Electronics &Computer Engineering	230	496	114.08
24	Department Of Chemical Engineering Building	230	518	119.14
25	Department Of Electrical Engineering Building	230	741	170.43
26	Department Of Metallurgy Building	230	822	189.06
27	Department Of Civil Engineering	230	870	200
	Total		7910	1819.2

Table 3: Details of a PV Module

SI No.	Components	Data Used
1	System type	Solar Photovoltaic Grid connect System
2	Type of module	Multi Crystalline silicon solar photovoltaic module
3	Module size (L*W*H)	1667 mm *1000 mm * 30 mm
4	Series Cells (No's)	60
5	Module efficiency (%)	13.8
6	Single solar panel output	230Wp
7	Solar Array capacity	1819.2 kWp (1.8192MW)
8	Life Span	25 years

Figure 1(a) Figure showing the civil engineering building roof with solar photovoltaic setup at campus.

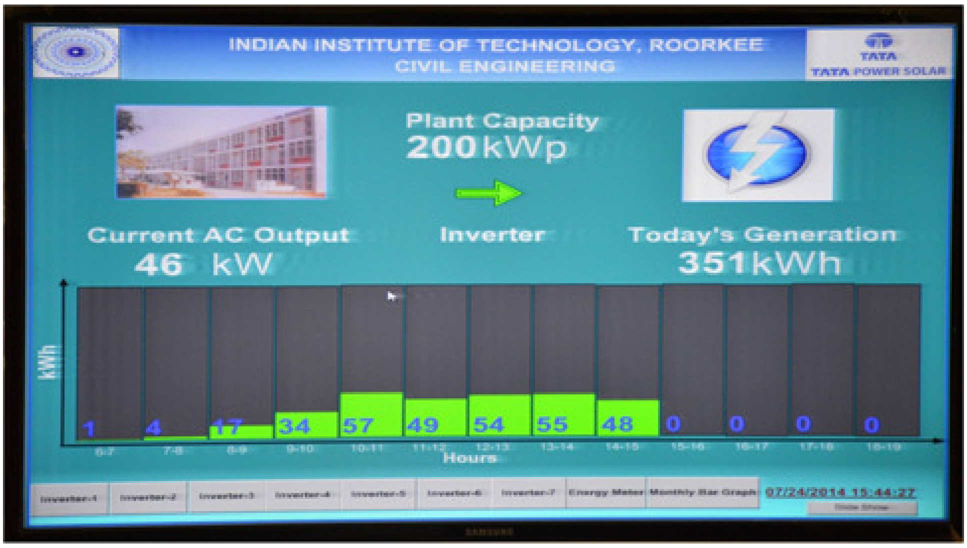

Figure 1(b): Figure showing the power generation with solar photovoltaic of civil engineering building at campus.

Figure 2 Figure showing the Geomatics Engineering Building roof with Solar Photo Voltaic setup and Power Generation at Campus.

3. AMOUNT OF ACTUAL ENERGY GENERATION

The net installed capacity is proposed to be 1.8192 MW but this is only a benchmark and should not be considered as the actual output for a given location. The amount of actual energy generated from a rooftop solar power plant in a year depends on both internal and external factors. External factors are beyond the control of a solar developer which includes the number of sunny days, solar irradiation, day temperatures and air mass and internal factors, all of which are within the control of a solar developer which includes plant location, panel efficiency, orientation of the roof, quality of equipment used and operational and maintenance activities (http://www.solarmango.com/faq/5; Mukherjee & Ghosh, 2009).

The calculation of solar energy generation is done in the campus based on a module which is having 60 cells of each size is 1667 mm × 1000 mm. The module efficiency is 13.80% with a life span of 25 years.

The output power is then computed as:

Considering, the area of the module having 60 cells = 1667 mm × 1000 mm = 1.667m^2

The average solar radiation in the campus is 6.02 kWh/ m^2 in a day.

Power output = Efficiency × average rate of solar radiation × area

= 0.138 × 6.02× 1.667 kWh/day

= 1.385 kWh/day

On considering 300 clear days in a year, the power production would be 1.385 × 300 kWh/year

= 415.50 kWh/year

Total no of modules= 7910 (Table 2)

Total power production in a year = 7910 × 415.50 kWh/year

=3286605 kWh/year

=3286.61MWh/year

During 25 years, the power output of a module becomes = 25 × 415.50 kWh

= 10387.50 kWh

= 10.3875 MWh

4. CAPACITY UTILIZATION FACTOR

To get the performance of solar power plant the best method is available is Capacity Utilization Factor (CUF) or Plant Load Factor (PLF) which states that the ratio of actual energy generated for a given period of time to the maximum theoretical possible generation of a power system (CERC, 2011). The standard notation for calculating CUF is as shown below:

$$\text{Capacity Utilization Factor (CUF) in \%} = \frac{\text{Energy measured (MWh)} \times 100}{365 \times 24 \times \textit{installed capacity of the plant}}$$

= (3286.61 × 100) / (365×24×1.8192)

=328610/15936.192

=20.6%

5. EVALUATION OF CARBON CREDIT

Solar PV systems help in reducing the carbon emissions and enhance the carbon credits. The carbon dioxide emission reduction per MWh of electricity produced is 0.932 tons (Prabhakant & Tiwari, 2012).Taking this average, the total CO_2 emission reduction =3286.61× 0.932= 3063.12 tons/annum. If carbon dioxide emission reduction is at present being traded at the rate of 0.7 Euro/tons(http://institute-of-solar-technology.blogspot.in/2014_02_01_archive.html), then total reduction by solar PV system = €3063.12×0.7

= €2144.18

= USD 2871.44 {1€= 1.34 USD (2014)}

6. AMOUNT OF CARBON DIOXIDE GENERATION

There are no GHG emissions associated with generating electricity from solar energy, while there are emissions associated with other stages of the solar life-cycle, including manufacturing, materials transportation, installation, maintenance, and decommissioning and dismantlement. Most estimates for concentrating solar power range from 31.75 to 90.72 grams of carbon dioxide equivalent per kilowatt-hour. This is far less than the lifecycle emission rates for coal: 0.635-1.632 kilograms of CO_2e/kWh (IPCC, 2011). So on average 50 g of CO_2 per kilowatt-hour is emitted for photovoltaic systems. The amount of carbon footprint generated from total power production of 3286605 kWh/year = 50×3286605 g of CO_2

= 164330250 g of CO_2

=164.33 tons of CO_2

7. PROJECT ANALYSIS

7.1. Simple Payback Period (SPP)

The most common and easiest method to evaluate the economic value of a project is SPP. The SPP is the minimum amount of time in years required for the positive cash flows to surpass the initial investment, with no use of time value of money (Kaplan, 1983). The payback period is the ratio of the investment required for a project (or capital cost) to the annual cost savings (or net annual cash flow).

The SPP is given as:

$$SPP = \frac{\text{InitialInvestmentforaproject}}{\text{NetCashInflow per Period}}$$

If the payback period of a project computed by the above formula is shorter than or equal to the management's maximum desired payback period, the project is accepted or otherwise rejected (Baker & Powell, 2005).

A. SPP on total investment without any subsidy and tax: The benchmark cost of a solar power project is INR1000 lakhsper megawatt. The total initial investment is INR 1000 lakhs × 1.8192= Rs 181920000= USD 2992584 {USD/INR=0.016450 (2014)}

The prevailing unit cost of electricity in campus is USD 0.06 (INR 3.5). The annual savings that the installation of the proposed system may result in from electricity generation have been = USD 0.06 × 3286605= USD 197196. Then SPP = 2992584/197196 = 15.17 years = 15 years 2 months.

B. SPP according to Jawaharlal Nehru National Solar Mission (JNNSM) subsidy: The major scheme of the Indian government and state governments to endorse India as a worldwide national leader in solar energy is the JNNSM which is also known as the national solar mission. It is a major initiative by India to meet the challenges of global climate change. To overcome the huge demand of electricity in the whole country, Phase II promotes both off-grid and grid connected rooftop PV systems. As regards grid connected rooftop solar PV systems, the capital subsidy of 90% of the benchmark cost would be available for special category states, viz. NE, Sikkim, J&K, Himachal Pradesh and Uttarakhand (MNRE, 2012).

As per the annual report of MNRE 90% subsidy is given by this scheme, then the maximum subsidy that can be availed = USD 2693325.60. Then the actual capital cost becomes USD 299258.4.

SPP=299258.4/197196=1.52 years = 1 year 6 months

As a result, due to the JNNSM subsidies, the financial viability of the solar rooftop project is extremely good.

C. SPP according to the Central Electricity Regulatory Commission (CERC): In this project we are taking the maximum leverage, mean minimum required equity and maximum loan can be taken for the project as per the CERC New Delhi, India that is 30:70 (Equity/Owner capital: Debt/Borrowed capital) (CERC, 2014; CERC, 2011).

Total Investment= USD 2992584

Rate of Interest= 12.7 % p.a

Repayment Period = 9 years

Equity Capital= USD897777.20

Debt Capital= USD 2094808.80

Levelised Tariff = INR 7.65/unit= USD 0.13

Monthly installment (EMI) = USD 32640.56

Yearly Installment USD 32640.56 × 12 = USD 391686.71

Total Interest= USD 1430371.55

Total Amount (Principal + Interest + Equity) = USD 4422955.55

Cash Flow=USD 0.13* 3286605 =USD 427258.65

SPP =4422955.55/427258.65=10.35 years = 10 years 4 months

Discounted Payback Period (DPP)

The main drawback of the SPP is that it ignores the time value of money. To overcome this limitation, an alternative procedure called discounted payback period (DPP) may be followed, which accounts for the time value of money by discounting the cash inflows of the project. The standard formula for discounted cash inflow for each period is (Baker & Powell, 2005):

$$Discounted\ Cash\ Inflow = \frac{\mathrm{CI}}{(1+\mathrm{i})^{\mathrm{n}}}$$

Where CI= actual cash inflow

i= discount rate and

n= period to which the cash inflow relates

The discounted cash flow is the product of actual cash flow and present value factor. The DPP is calculated using the formula (http://accountingexplained.com/managerial/capital-budgeting/ discounted-payback-period):

DPP = X+Y/Z

Where,

X = Last period with a negative discounted cumulative cash flow Y= Absolute value of discounted cumulative cash flow at the end of the period X Z = Discounted cash flow during the period after X

DPP on total investment without any tax and subsidy:

As per above calculation energy generated per year is 3286605 units and the cost of electricity, according to CERC is USD 0.13 per unit then net cash flow= USD427258.65. The value of depreciation and tax are not considered here. In Table 4, it can be seen that payback is between the thirteen and fourteen years. Till the thirteen year, only USD 2911340 is recovered. To cover the balance of USD 81244 it takes another ten months [(12/101687.60)*81244]. Hence, the discounted payback period is thirteen years and ten months.

Table 4 Discounted and cumulative cash flow considering @10.81%

Years	Present Value of USD 1 @10.81%	Present value of cash flows	Discounted present value of cash flows	Cumulative present value of cash flows
0	-	-2992584	-	-
1	0.902	427258.65	385387.30	385387.30
2	0.814	427258.65	347788.50	733175.80
3	0.735	427258.65	314035.10	1047211.00
4	0.663	427258.65	283272.50	1330483.00
5	0.599	427258.65	255927.90	1586411.00
6	0.54	427258.65	230719.70	1817131.00
7	0.488	427258.65	208502.20	2025633.00
8	0.44	427258.65	187993.80	2213627.00
9	0.397	427258.65	169621.70	2383249.00
10	0.358	427258.65	152958.60	2536207.00
11	0.323	427258.65	138004.50	2674212.00
12	0.292	427258.65	124759.50	2798971.00
13	0.263	427258.65	112369.00	2911340.00
14	0.238	427258.65	101687.60	3013028.00
15	0.215	427258.65	91860.61	3104889.00

8. CONCLUSIONS

Globally, eighty nine percent of primary energy consumed comes from fossil fuels, and in doing so, produces one-third of global CO_2 emissions while solar energy technology generates far lower or near-zero emissions of GHGs compared with fossil fuels and by reducing carbon footprint in the environment also gaining carbon credits (ASME, 2009). The carbon credit trading is a permit table scheme which helps in gaining economic incentives for achieving reductions in the emission of pollutants. Carbon credit earned is proportional to the actual energy generated and is directly deductible from the cost of electricity produced. The actual solar energy generated by a PV module is numerically equal to the product of module efficiency, the average rate of solar radiation and cell area. The campus being located in the northern part of the country receives a considerable intensity of solar radiation and there are about 250-300 clear sunny days in a year. The average insolation value of solar energy in the campus is 6.02 kWh/m^2/day. This paper presents the actual solar energy generated by rooftop solar PV plant in IITR campus, Roorkee, India. The rooftop solar PV plant having 7910 modules and each module has 60 cells having a total capacity of 1.8192 MW. The computations of the carbon credit earned by solar grid connect system for the Campus as per the norms of the Kyoto Protocol and the amount of CO_2 generated as per the guidelines of the International panel of climate change (IPCC) has also been carried out. Additionally, the CUF, SPP and the DPP have also computed.

The following conclusions have been drawn from the above analysis:

1. This can generate 3286605 kWh electricity in a year having 20.6% capacity utilisation factor.
2. The cost of power generated by the rooftop solar PV system is USD 2992584.
3. The amount of carbon footprint generated from total power production is 164.33 tons of per year.
4. The carbon credit earned by rooftop solar PV on campus is USD 2871.44 annually.
5. The simple payback period are analysed for three different cases, namely: SPP on total investment without any subsidy; according to JNNSM; according to CERC and their payback periods are calculated as 15 years 2 months; 1 year 6 months; 10 years 4 months respectively.
6. The discounted payback period in total investment is 13 years 10 months.

ACKNOWLEDGEMENT

The authors are greatly indebted to Department of Alternate Hydro Energy Centre (AHEC) of IIT roorkee who contributed their information and PV system data for this publication. The authors are also grateful to Yadwinder Paul Singh and Sourabh Kumar for their valuable contribution and guidance to the analysis.

REFERENCES

[1] ASME (American Society of Mechanical Engineers), 2009. Technology and policy recommendadations and goals for in the energy sector.

[2] Baker K.H. and Powell E.G., 2005. Understanding Financial Management: A Practical Guide, Blackwell publishing.

[3] CERC (Central Electricity Regulatory Commission), 2011. Performance of solar power plants in India.

[4] CERC (Central Electricity Regulatory Commission), 2014.

[5] ECREHSB (Energy conservation and renewable energy for householders and small businesses), 2007. Directorate of Environment and Regeneration, Local Planning Services, Issue: 2.

[6] Energy Statistics, 2013. Central Statistics Office (CSO), National Statistical Organisation, Ministry of Statistics and Programme Implementation, Government of India. URL: www.mospi.gov.in.

[7] IECU (Impact of energy conservation act in Uttarakhand), 2009. Uttarakhand Renewable Energy Development Agency (UREDA). URL: www.ureda.uk.gov.in.

[8] IPCC, 2011: IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation. Prepared by Working Group III of the Intergovernmental Panel on Climate Change. O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer, C. von Stechow (eds)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1075 pp. (Chapter 7 & 9).

[9] ITDG (Intermediate Technology Development Group), 1994.Solar Photovoltaic Energy. URL: www.autonavzduch.cz/dokumenty/Solar_Photovoltaic_Energy.pdf (Last accessed July 09, 2014).

[10] Kaplan S., 1983. Energy economics: quantitative methods for energy and environmental decisions. New York: McGraw-Hill.

[11] MNRE (Ministry of New and Renewable Energy), 2012. Phase II.

[12] Mukherjee S. and Ghosh P.B., (2009). Estimation of carbon credit and direct carbon footprint by solar photovoltaic cells in West Bengal, India. Int J Low Carbon Technol, 4: 42–51.

[13] Prabhakant Y.N. and Tiwari G.N., 2012. Evaluation of carbon credits earned by energy security in India. Int J Low Carbon Technol, 0: 1–4.

[14] Purohit G. and Purohit I., 2009. Prospects of solar drying in Uttarakhand 3, Issue 2: 30-34.

[15] REIHRD (Renewable Energy for India's Human Resource Development), 2011. Renewable Energy Occasional Paper Series. URL: www.climateparl.net.

[16] Saidel M.A., Reis T.M. and Prado Jr. F.a.a., 2009. Carbon Credit and Energy Efficiency. International Journal of Green energy, 6: 312-319.

[17] SIITR (Solarification of IIT Roorkee Campus), 2011. URL: http://www.ahec.org.in (Last accessed July 09, 2014).

[18] Swapnil Shende, Sankalp Pund, Pratik Suryawanshi, Shubhankar Potdar, Analysis of PI Controller's Manual Tuning Technique for Residential Loads Powered by Solar

Photovoltaic Arrays. International Journal of Electrical Engineering & Technology, 7(6), 2016, pp. 75–80.

[19] Indulekha Sajeev and Shemi P A, Bidirectional Full-Bridge Dc-Dc Converter with Flyback Snubber For Photovoltaic Applications, Volume 5, Issue 12, December (2014), pp. 233-239, International Journal Of Electrical Engineering & Technology.

[20] Sofia Lalouni, Djamila Rekioua, Control of Photovoltaic Water Pumping System with Battery Storage, Volume 4, Issue 1, January- February (2013), pp. 190-199, International Journal of Electrical Engineering and Technology.

[21] Yogesh S Bijjargi, Kale S.S and Shaikh K.A., Cooling Techniques for Photovoltaic Module for Improving its Conversion Efficiency: A Review. International Journal of Mechanical Engineering and Technology, 7(4), 2016, pp. 22–28.

[22] Shobha Rani Depuru, Muralidhar Mahankali and Navya Sree S, Design and Control of Standalone Solar Photovoltaic Powered Air Cooling System, International Journal of Mechanical Engineering and Technology 8(7), 2017, pp. 1144–1158.

[23] Nishanur Rahman, Sanjana Kumari, Anukul Prakash Anurag and Ajeet Kumar Rai, Design of Photovoltaic System for School Library: A Case Study. International Journal of Advanced Research in Engineering and Technology, 7(5), 2016, pp 07–17

[24] URL: http://accountingexplained.com/managerial/capital-budgeting/discounted-payback-period. (Last accessed July 09, 2014).

[25] URL: http://institute-of-solar-technology.blogspot.in/2014_02_01_archive.html.

[26] URL: http://www.solarmango.com/faq/5 (Last accessed July 09, 2014).

[27] Whitney J., 2010. Solar PV energy by clean energy action project.