Techno-Economical Analysis of Grid Connected PV System For A University In India

Rachit Srivastava*‡, Vinod Kumar Giri**

*Department of Electrical Engineering, Madan Mohan Malaviya University of Technology, Gorakhpur, India

**Department of Electrical Engineering, Madan Mohan Malaviya University of Technology, Gorakhpur, India

(srivastava.rachit94@gmail.com, girivkmmm@gmail.com)

‡ Corresponding Author; Rachit Srivastava, Madan Mohan Malaviya University of Technology, Gorakhpur, India

srivastava.rachit94@gmail.com

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Abstract- This study presents techno-economical analysis of grid connected photovoltaic system for powering the Madan Mohan Malaviya University of Technology, Gorakhpur situated at Northern sub-region of India. Load data of university is taken from the Substation and solar data is taken from solar resource setup at the university. The system is optimized for the load and solar data by the HOMER software. Different rating of photovoltaic panel and inverters are studded in the search space. The best feasible system is chosen according to net present cost of the system and carbon dioxide reduction. From the results, it is found that 500kW PV panel and 500kW inverter is the optimal solution for university. This system has 37% renewable fraction and cost of electricity is just about $0.1/kWh. This system will reduce the emission of CO_2 gas about 544 tones in a year.

Keywords HOMER, Grid Connected PV, Techno-economical, Optimization.

1. Introduction

The demand of electricity is increasing rapidly throughout the world as well as conventional energy resources emit toxic gases which are harmful to human and environment. At this situation renewable energy are very promising for feature. India has created an ambient program to promote and develop renewable energy such as solar energy.

Gorakhpur is situated on the northern region of India. High amount of solar radiation is received in this area. Madan Mohan Malaviya University is planning a grid connected photovoltaic system that can supply University load and excise energy will supply to grid. For this purpose techno-economical analysis is required for that system. HOMER is the best available software that is able to simulate and optimize grid connected photovoltaic system.

Many literatures reported the study of grid connected photovoltaic system using the HOMER software. Yousif El-Tous *et al.* [1] performed a case study on the effect of the tariff rate on the economic feasibility of a grid-connected PV system for a Household System in Amman using the HOMER software. Danny Li *et al.* [2] presented a study of a grid-connected PV system in Hong Kong and from the study it founded that estimated payback period is 7.9 years. H. Maammeur *et al.* [3] design a grid connected photovoltaic system for agricultural farm in Chlef at Algeria by the use of HOMER software. From analysis it is found that renewable fraction is 58% for that system. T. Nacer *et al.* [4] presented a case study for grid connected PV system for dairy farm in Mitidja at Algeria.

This paper is divided into six sections. In the second section site location of the university is described. Third and fourth section shows the input data and component used in the system. Second last section deals with the result of the system along with the comparison of emissions of gases. Last section described the conclusion of this paper.

2. Site Location

The proposed system designed to power Madan Mohan Malaviya University of Technology (MMMUT) at Gorakhpur, India. MMMUT is a reputed state University of Utter Pradesh in northern reason of India. University consists of seven department of various engineering field, nine hostels and residential quarters for faculties. The University is situated at Latitude of $26^0 43'50.41''$ North and Longitude of 83⁰26'2.8" North. The altitude of site is 59 meter above the sea. Figure 1 shows the Google Map of the Gorakhpur [5].

Fig. 1. Google Map of MMMUT

3. System Input

3.1. Load profile

One year load data is taken from the Khorabar Sub-Station of Uttar Pradesh Power Corporation Limited in Gorakhpur. Minimum load is on winter season whereas Maximum load is on summer session. Average load and peak load of MMMUT is 257kW and 502 kW respectively. Figure 2 represents daily load profile and Figure 3 represents monthly load profile.

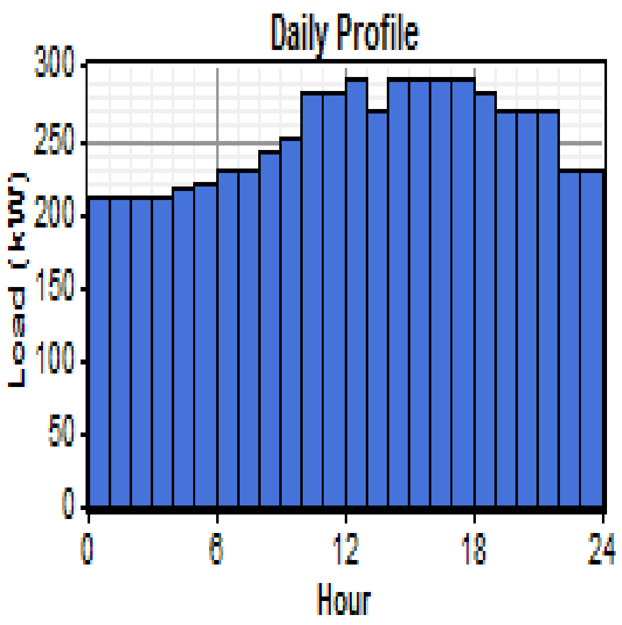

Fig. 2. Daily load Profile

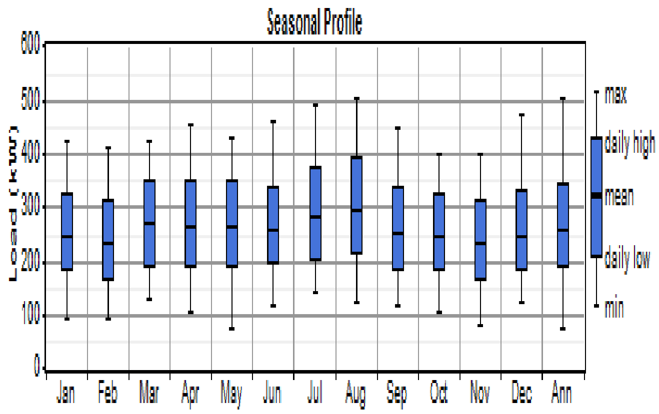

Fig. 3. Monthly Load Profile

3.2. Solar Radiation

One year solar radiation data was obtained from Solar Radiation Resource Assessment Setup commissioned by Center of Wind Energy Technology, Government of India at the roof of Electrical Department, MMMUT [6]. Global solar radiation varies from 4.00kW/m^2/Day to 7.25kW/m^2/Day and annual solar radiation is about 4.97kW/m^2/Day with the clearness index of 0.586 which is suitable for installation of photovoltaic system. Figure 4 represent one year solar radiation data.

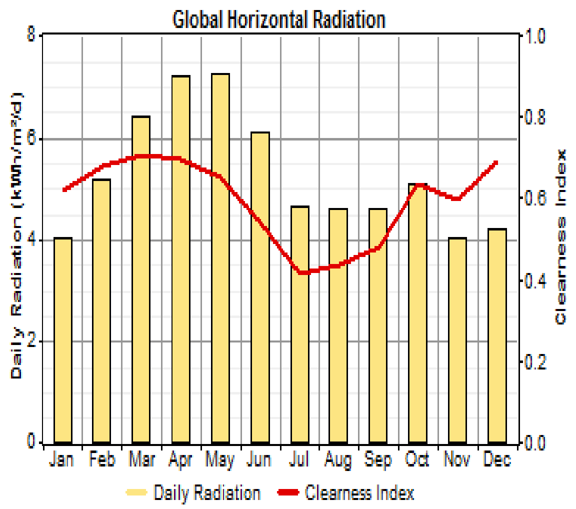

Fig. 4. Solar Radiation Data

4. System Component

Grid connected photovoltaic system consists of photovoltaic panel, inverter and grid. DC power is generated from photovoltaic panels, inverter changes the DC power into AC power which is fed to the load. Extra energy is sold to the grid and in case of insufficient solar energy power is taken from the grid. Figure 5 shows the system components on HOMER software.

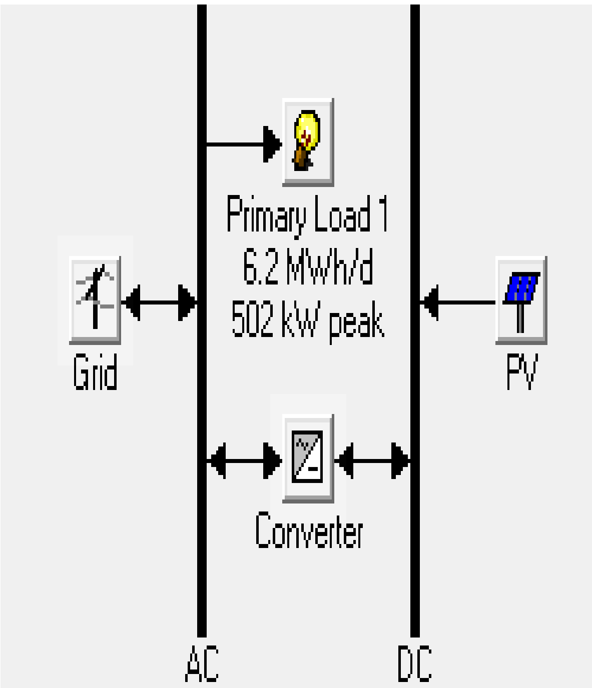

Fig. 5. Grid Connected System Components

4.1. Photovoltaic Panel

In this feasible study SU-250 photovoltaic panel is used which is made in India by Su-kam company. Selected panel power capacity is 250W and poly-crystalline technology is used in it [7]. Life time of the PV panel is 20 year and de-rating factor is 0.9 due to the loss on cables, dust and module aging. Table 1 shows the financial and technical criteria of the PV panel. Installation cost of the panel consists of mainly sum of panel cost, support structure cost and cable cost which is equal to $ 270 [8]. Ground refraction is considered 20% and slope of panel is considered 26.71^0 with 0 azimuths (sought oriented). PV panel are studied at 0, 50, 100, 150, 200, 250, 300, 350, 400, 450, 500, 550, 600, 650kW.

Table 1. SU-250 Module Specifications

Technical specification	
Rated Power	250 W
Maximum Power Voltage	30.72 V
Maximum Power Current	8.14 A
Open Circuit Voltage	37.8 V
Short Circuit Current	8.63 A
Power Tolerance	5 %
Financial Specification	
Capital Cost	$ 270
Replacement Cost	$ 240
Maintenance Cost	$ 10/ Year

*$1= 65 IND Rs.

4.2. Converter

A grid tie inverter is required for photovoltaic system to maintain flow of power between DC PV generation and AC load connected to grid. In this feasible study three phase Su-Kam grid tie inverter is used with the assumption that efficiency of inverter is 95% and lifetime is 15 years [7]. Technical and economical specifications of the inverter are shown in the table 2. Capital cost of the proposed inverter is $ 7550 and replacement cost is 90% of capital cost [8]. Rated power of the inverter is 50kW along with built-in MPPT technique. Converter are studied at 0, 50, 100, 150, 200, 250, 300, 400, 450, 500, 550, 600, 650, 700 kW.

Table 2. Inverter Specifications

Technical Specifications	
Rated Power	50 kW
Maximum DC Power	56 kW
Maximum DC Current	130 A
MPPT Range	420V-850V
Rated Voltage	400 V
Voltage Range	310V-450V
Financial Specification	
Capital Cost	$ 7550
Replacement Cost	$ 6040
Maintenance Cost	$ 100/Year

*$ 1= 65 IND Rs.

4.3. Grid

MMMUT, Gorakhpur is powered by Poorvanchal Vidyut Vitran Nigam Limited a sub division of Uttar Pradesh Power Corporation Limited, Lucknow [9]. Tariff rate for MMMUT is $ 0.103 (6.75 IND Rs.) under the commission of Tariff Order FY2015-16 [10]. Tariff rate is same for university throughout the day.

5. Result

HOMER simulate the system under the given search space for a year and provide a set of feasible system accordance with the increasing Net Present Cost. Set of proposed system is shown in the figure 6. From the result it is found that 300kW PV and 250kW inverter has the minimum NPC but does not meet the university load. System with 500kW PV and 500kW inverter is the optimal solution for our system with the renewable fraction of 37%. Suggested system has the initial capital cost $ 617,500, operating cost $183,193 and cost of electricity is $ 0.103, payback time of estimated system is about 11.2 year on the current electricity tariff rate. Monthly electricity production by the proposed system is shown in the figure 7. Total electricity production by the photovoltaic system in a year is 2,250,226kWh (95%) and grid sale power in a year is 129,740kWh (5%).

PV (kW)	Conv. (kW)	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.
500...	450	1000	$ 609,750	182,943	$ 2,948,377	0.102	0.37
100...	200	1000	$ 139,000	220,104	$ 2,952,674	0.103	0.08
450...	600	1000	$ 579,000	185,707	$ 2,952,960	0.103	0.34
200...	450	1000	$ 285,750	208,708	$ 2,953,736	0.103	0.16
300...	150	1000	$ 347,250	204,233	$ 2,958,027	0.103	0.23
500...	500	1000	$ 617,500	183,193	$ 2,959,319	0.103	0.37
200...	100	1000	$ 231,500	213,404	$ 2,959,517	0.103	0.15
400...	200	1000	$ 463,000	195,333	$ 2,960,010	0.103	0.30
100...	50	1000	$ 115,750	222,588	$ 2,961,178	0.103	0.08
		1000	$ 0	231,773	$ 2,962,839	0.103	0.00
100...	250	1000	$ 146,750	220,365	$ 2,963,754	0.103	0.08
200...	500	1000	$ 293,500	208,968	$ 2,964,815	0.103	0.16
500...	550	1000	$ 625,250	183,453	$ 2,970,397	0.103	0.37
0.25	50	1000	$ 8,020	232,002	$ 2,973,783	0.103	0.00
550...	350	1000	$ 648,250	181,922	$ 2,973,819	0.103	0.40
100...	300	1000	$ 154,500	220,625	$ 2,974,833	0.103	0.08
200...	550	1000	$ 301,250	209,229	$ 2,975,895	0.103	0.16
550...	400	1000	$ 656,000	181,614	$ 2,977,639	0.104	0.40
500...	250	1000	$ 578,750	187,791	$ 2,979,354	0.104	0.36
500...	600	1000	$ 633,000	183,714	$ 2,981,476	0.104	0.37
0.25	100	1000	$ 15,770	232,262	$ 2,984,862	0.104	0.00
550...	300	1000	$ 640,500	183,435	$ 2,985,409	0.104	0.40
100...	350	1000	$ 162,250	220,886	$ 2,985,913	0.104	0.08

Fig. 6. Optimization Result

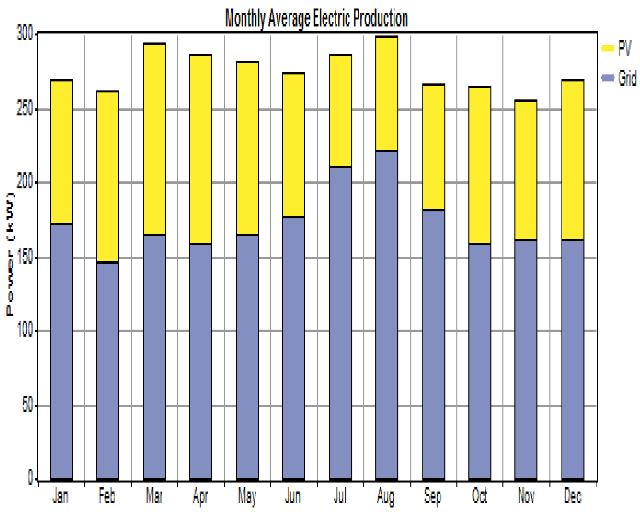

Fig. 7. Energy Production by Optimized System

In 25 years economical analysis it is found that $ 617,500 will be required as startup cost. After that grid purchase price will be required continously though out the period. Replacement cost of the inverter will be required after 15 years and PV replacement cost will be required after 20 years. Gain of 47,460 will be found on 25th year. Figure 8 presents the cash flow during the 25 years by the grid connected photovoltaic system. 7.92 % of the initial cost will be returned by the proposed system with the comparison of grid connected system.

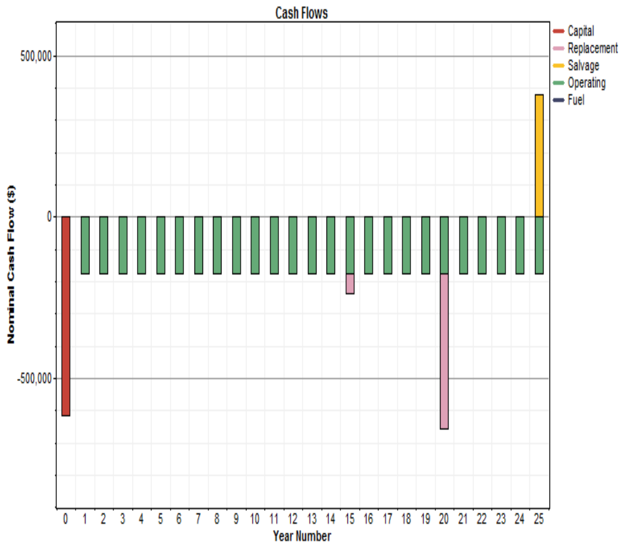

Fig. 8. Cash Flow in 25 Years

Table 3 shows detailed electric flow from grid to system and vice versa in all months. It is found that maximum electricity will be purchased in the Augest month due to high electricity load . Maximum energy will be sold in the March due to sufficient amount of solar radiation and low energy required.

Table 3. Power Flow in Optimized System

Month	Energy Purchased (kW)	Energy Sold (kW)	Net Purchase (kW)	Energy Charge ($)
Jan	128,012	12,956	115,056	13,086
Feb	97,856	16,013	81,842	9,956
Mar	122,242	16,092	106,151	12,467
Apr	114,567	14,347	100,220	11,690
May	122,464	9,797	112,667	12,538
Jun	127,407	6,957	120,450	13,069
Jul	157,080	2,919	154,161	16,157
Aug	164,543	3,506	161,036	16,921
Sep	130,492	6,610	123,881	13,390
Oct	117,612	12,498	105,114	12,018
Nov	116,269	15,215	101,054	11,859
Dec	120,290	12,830	107,460	12,291
Annual	**1,518,832**	**129,740**	**1,389,091**	**155,442**

5.1. Sensitive Results

Sensitive analysis helps in removing any possible infusibility in the proposed system. HOMER software allows us to check performance of our system on increased or decreased value of different parameters. In the HOMER software different variable can be vary such as load demand, solar radiation, cost of grid power, renewable fraction of the system, inverter efficiency, inverter lifetime, PV lifetime and different constraints.

In our study sensitive analysis is done on different values of cost of grid electricity and different values of average load of University. This study is done because cost of the electricity is increasing day by day and in feature price of electricity will be definitely increase. Also due to upcoming new departments in the University load of the University will also increase. In our study 5 different values of cost of electricity and 5 different values of average load of University is simulated. Hence, total 25 sensitive results are studied.

The surface plot for the levelized cost of energy is presented in Figure 9. The price of power is depicted on the x-axis and load on the y-axis. This shows that cost of energy is lower when load is lower.

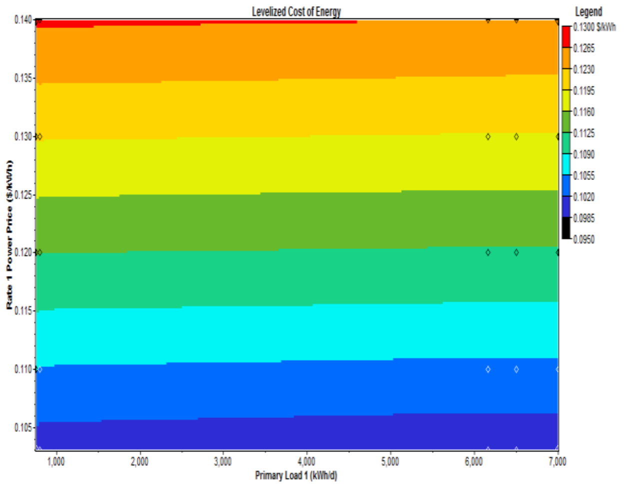

Fig. 9. Surface Plot of Cost of Electricity

The surface plot for the renewable fraction is presented in Figure 10. The price of power is depicted on the x-axis and load on the y-axis. This shows that renewable fraction is minimum when load of the system is maximum and price of power is minimum where as renewable faction is maximum when both power price and load is maximum.

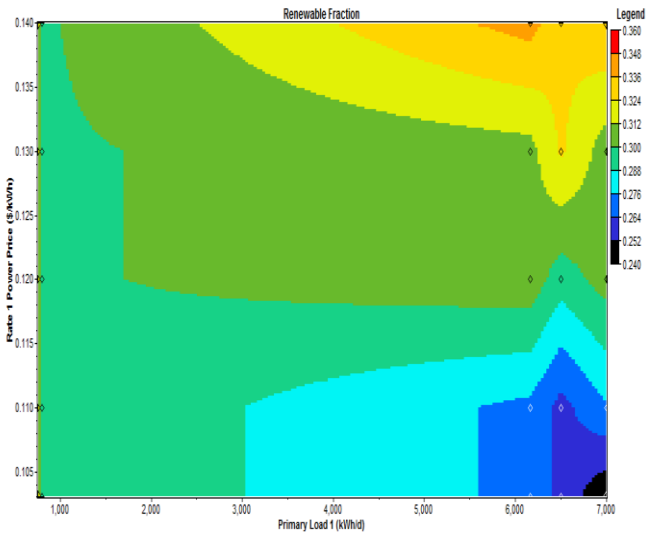

Fig. 10. Surface Plot of Renewable Fraction

The surface plot for the net present cost is presented in Figure 11. The price of power is depicted on the x-axis and load on the y-axis. This shows that net present cost is low when load is low and vies versa.

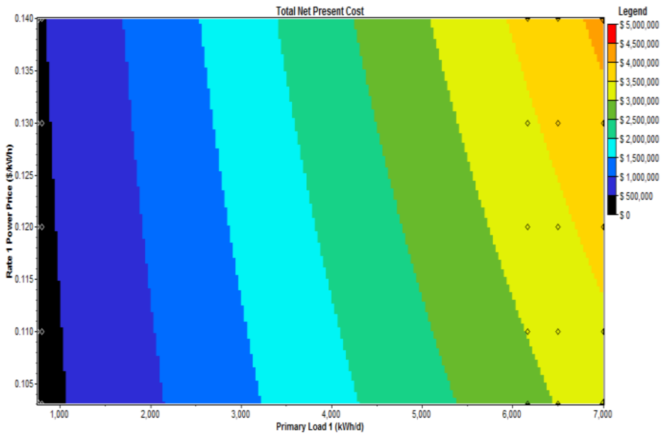

Fig. 11. Surface Plot of Net Present Cost

5.2. Emission

A comparative study is performed to compare emissions of gases by grid connected photovoltaic system and grid only system. Table IV represent reduction by the proposed system compared with grid only system. 544,236 Kg/year carbon dioxide will be reduced by the optimized system. Sulpher dioxide and nitrogen oxide reduction is 2,360 Kg/year and 1,154 Kg/year respectively.

Table 4. Emission by Grid Connected PV and Grid Only System

Pollutant	Emissions By Grid connected PV System (kg/yr)	Emissions by Grid (kg/yr)	Emission Reduction (kg/yr)
Carbon dioxide	877,906	1,422,142	544,236
Sulphur dioxide	3,806	6,166	2360
Nitrogen oxides	1,861	3,015	1,154

6. Conclusion

Grid connected photovoltaic system for MMMUT, Gorakhpur is optimized using the HOMER software. Load data of the university is taken from the substation and solar data is taken from the solar resource assessment center.

500kW photovoltaic panels and 500kW inverter are the optimal solution for the university based on the university load and net present cost. All the proposed components are easily available in the Indian market and system can be easily implemented on the university. It is found that cost of electricity by the proposed system is about 0.1 $/unit, payback time of the system is just 11.2 years. 544 tones of emission of carbon dioxide will be reduced by the system.

Reference

[1] Yousif El-Tous *et al.*, “A Study of a Grid-connected PV Household System in Amman and the Effect of the Incentive Tariff on the Economic Feasibility”, *International Journal of Applied Science and Technology*, vol. 2(2), pp. 100-105, Feb. 2012.

[2] Danny Li *et al.*, “A study of grid-connected photovoltaic PV system in Hong Kong”, *Applied Energy*, vol. 90, pp. 222-227, 2012.

[3] H. Maammeur et al., “Energy intake of a PV system from grid-connected agricultural farm in CHLEF (ALGERIA)”, Energy Procedia, vol. 36, pp. 1202-1211, 2013.

[4] T. Nacer et al., “Feasibility study and electric power flow of grid connected photovoltaic dairy farm in Mitidja (Algeria)”, Energy Procedia, vol. 50, pp. 581-588, 2014.

[5] Google Map , Madan Mohan Malaviya University of Technology [Online] Available www.google.co.in/maps

[6] Real time monitoring of solar irradiation and other meteorological parameters in India [Online] Available http://www.cwetsolar.com

[7] Sukam Power system Pvt. Lt., India [Online] Available http://www.su-kam.com

[8] Urjakart.com, Buy solar panel, solar power plant online in India [Online] Available http://www.urjakart.com/solar

[9] Poorvanchal Vidyut Vitran Nigam Limited [Online] Available http://puvvnl.up.nic.in/

[10] Rate Schedule for FY-2015-16, Utter Pradesh Corporation Limited, Utter Pradesh Government Undertaking, 2015-16.