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Case Study of Grid Connected PV System at Northern Part of Bangladesh

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Abstract— A case study of grid connected PV system analysis is done for 500 kW grid connected solar photovoltaic (PV) system at a northern location of Bangladesh. HOMER and MATLAB Programming tools and monthly average solar radiation data from NASA is used for this study. In this paper a grid connected PV power plant is designed and simulated using HOMER software, the power plant is sized to supply Rajshahi load, the simulation results showed that a high capital cost is needed and the cost of energy is 0.27 $/kWh which is still high but with incentives and decrease of the PV panels price the system will reach a feasible cost.

Index Terms— PV array, Solar energy, Power plant, solar irradiation, HOMER and MATLAB Software.

1 INTRODUCTION

World Bank reported that 2.4 billion people rely on traditional energy sources, while 1.6 billion people do not have access to electricity [1]. With an estimated world average growth rate of 2.8%, the electricity demand is expected to be doubled in 2020. During this period, the electricity demand in developing countries is projected to increase by 4.6% annually [2]. Bangladesh lacks a sufficient electricity generation capacity and there are always a huge gap between demand and supply. Figure 1.1 presents power system master plan 1995 base case power demand fore cast for the years 1995-2005 and the actual demand served and power load shedding done the said years [3].

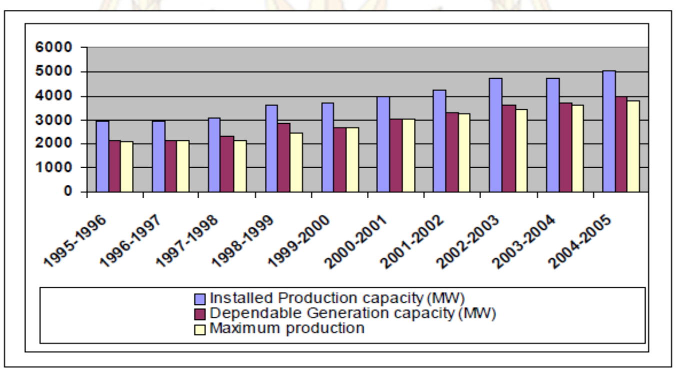

Fig. 1.1 Power Demand and Supply Graph (1995-2006) [3]

The country has been facing a severe power crisis for a decade. Power generation in the country is almost entirely dependent on natural gas, which accounts for 81.4% of the electricity generation of the installed capacity 5248 MW [3]. At the current rate of increase in consumption (10% annually), the national proven reserve of natural gas may not last more than 15-20 years [4]. Only limited amount of coal resource is available to generate electricity, although it has adverse environmental impact. On the other hand, the government of Bangladesh has declared that it aims to provide electricity for all by the year 2020, although at present there is a high unsatisfied demand for energy, which is growing by more than 8% annually. The Rural Electrification Board (REB) in its master plan of 2000 noted that it had supplied electricity services to about 31% of the total rural population. It aims to reach 97 million rural populations by 2020, which is about 84% of the total rural population. In order to address this target only fossil fuel based power plant would not be able to satisfy the demand. It needs to look for the alternative sources of energy for power generation. Renewable energy technologies would be one of the important emerging options.

This paper presents an analysis for a grid-connected photovoltaic system for Rajshahi location in northern part of Bangladesh, and energy production costs are analyzed, the system configuration is simulated using the Hybrid Optimization Model for Electric Renewable (HOMER) and output of the 500KW PV Strings analyzed by using MATLAB programming. Also the effect of the temperature and irradiance are analyzed by using MATLAB programming.

2. SITE CHARACTERISTICS

Bangladesh is situated between 20.30 and 26.38 degrees north latitude and 88.04 and 92.44 degrees east 2.2 Final Stage

Longitude, the temperature is warm in summer and moderate in winter, with temperature range of 24 to 37 C in summer and as low as 7 ^{0}C in winter. The area of Rajshahi is characterized by vast a plain area which is an ideal location for solar energy utilization. Daily solar radiation varies between 4 and 6.5 kWh/m2. Solar PV technology is an important emerging option for electricity generation. So, densely populated tropical country like Bangladesh could be electrified by PV grid system using the in exhaustible and pollution free solar energy without using any novel technologies. Compensation of electricity shortage and reduction CO2 emission would be done by introducing solar energy sources for electricity generation in mass scale.

3. SIZING OF THE PV GRID SYSTEM

3.1 Sizing of PV Panel

Our initial proposed system is for 500 KW grid connected PV system. The design criteria for PV module are as follows

TABLE 1.1
Typical Electrical Characteristic's of BP 5200 Monocrystalline PV Module

Parameter	Variable	Value
Maximum power	Pm	170 W
Voltage @ Pm	V_{mpp}	18.0 V
Current @ Pm	I_{mpp}	9.440 A
Short circuit current	I_{sc}	10 .00 A
Open circuit voltage	V_{oc}	22.00 V
Temp. coeff of Voc	β	0.073 %/^{0}c
Temp. coeff of Isc	α	0.024 %/^{0}c
Ideality factor	N	1.29
Efficiency /Module area	η	12.92 %

$$\text{No of PV module needed} = \frac{\text{total Wp}}{\text{selected PV module Wp}}$$

$= 500\times10^3 / 170$

$= 2941.177$ panels

So we consider 2944 panels.

3.2 Inverter Sizing

For grid connected systems, the inverter must be large enough to handle the total amount of Watts that is needed at one time.

TABLE 1.2
Data for EA500KTL inverter

Technical Data	EA500KTL
Max DC voltage	900Vdc
MPPT Voltage range	450~820Vdc
Max DC power	550kWp
Max input current	1200A
Nominal AC power	500KW
Nominal AC voltage	220 Vac
Nominal frequency	50Hz/60Hz
Power factor	0.9(lagging)~0.99(leading)
Max efficiency	98.7%
Net/Gross Weight	2000kg/2100kg

3.3 Total size of PV panel based on inverter ratings

No. of module parallel (N_{pg}) $= \frac{Imax}{Im} = 1200 / 9.440 = 128$

No. of module in series (N_{sg}) $= \frac{P}{\eta\times Vm\times Npg\times Im} = 23$

3.4 Matlab Output of Designed Grid Connected PV Panel

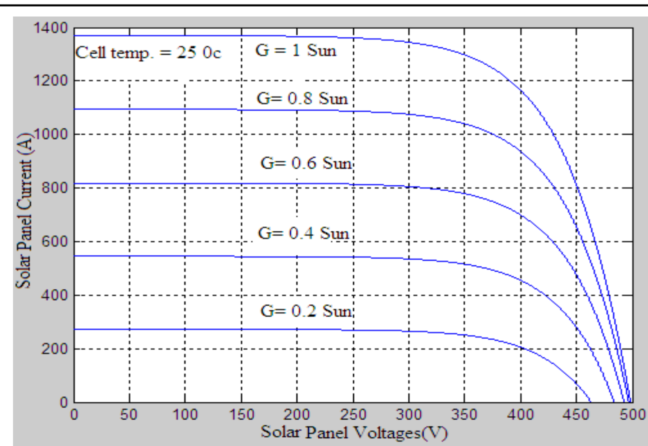

Fig. 3.1: Matlab model of Solar panel (2944 strings) I-V Characteristic curves at different insolation levels (BP 5200, G=0.2 sun, 0.4 Sun, 0.6 Sun, 0.8 sun, 1 sun)

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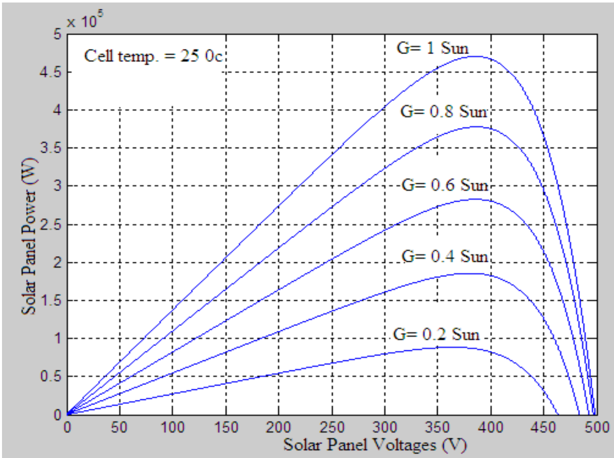


Fig. 3.2: Matlab model of Solar panel (2944 strings) P-V Characteristic curves at different insolation levels (BP 5200, G=0.2 sun, 0.4 Sun, 0.6 Sun, 0.8 sun, 1 sun)

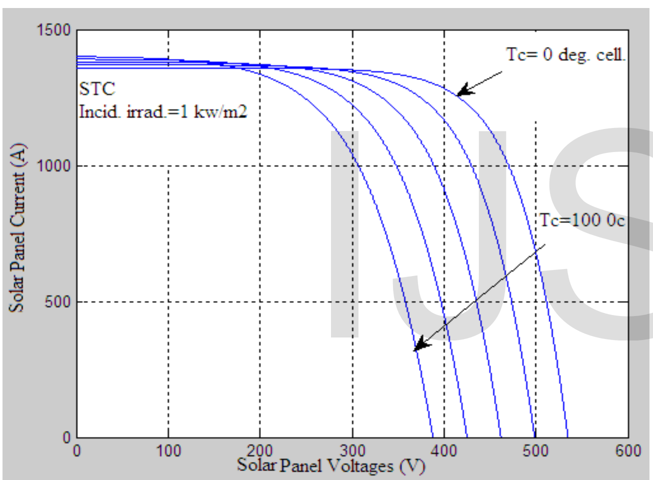


Fig. 3.3: Matlab model of solar panel (2944 strings) I-V Characteristic curves at different cells working temperature (BP 5200, Tc = 0 ^{0}c, 25^{0}c, 50^{0}c, 75^{0}c, 100 ^{0}c)

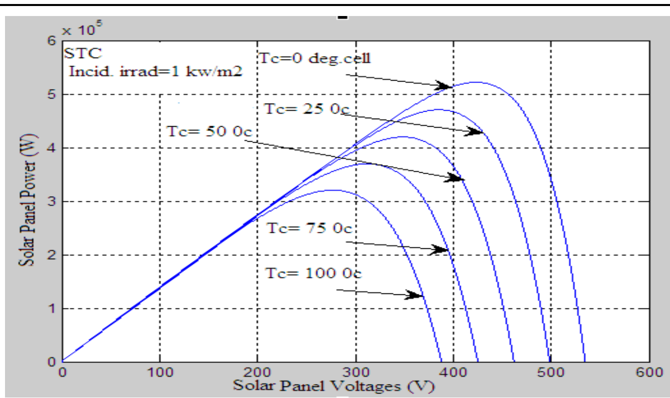


Fig. 3.4: Matlab model of solar panel (2944 strings) P-V Characteristic curves at different cells working temperature (BP 5200, Tc = 0 ^{0}c, 25^{0}c, 50^{0}c, 75^{0}c, 100 ^{0}c)

4. SOLAR IRRADIATION

The solar irradiance data were obtained from NASA Surface meteorology and Solar Energy (SSE) data set (2011) and were analyzed using HOMER the average monthly solar irradiance data for Rajshahi location is shown in Table 1.3. It can be seen from Table 1.3 that the average solar radiation in Rajshahi is very high (5.002 kWh/m^2/d), which is suitable for Photovoltaic generation, and the clearness index shows that Rajshahi is a sunny area, which predicts a promising energy production. It is shown in Figure 4.2 that the maximum solar radiation occurs in April with the irradiation of 6.240 kWh/m^2/d which is a very high value, from April to October the solar radiation exceeds 4.50 kWh/m^2/d, and the lowest average radiation is in the month of December with 3.820 kWh/m2/d. It's clear from the site analysis and solar radiation data that Rajshahi location has a great potential for a PV energy generation project [5].

TABLE 1.3
Solar radiation and clearness index for Rajshahi

Month	Clearance index	Average daily radiation (KWh/m^2/day)
January	0.643	3.960
February	0.607	4.470
March	0.660	5.880
April	0.607	6.240
May	0.556	6.170
June	0.462	5.250
July	0.428	4.790
August	0.489	5.160
September	0.530	4.960
October	0.626	4.880
November	0.661	4.420
December	0.564	3.820

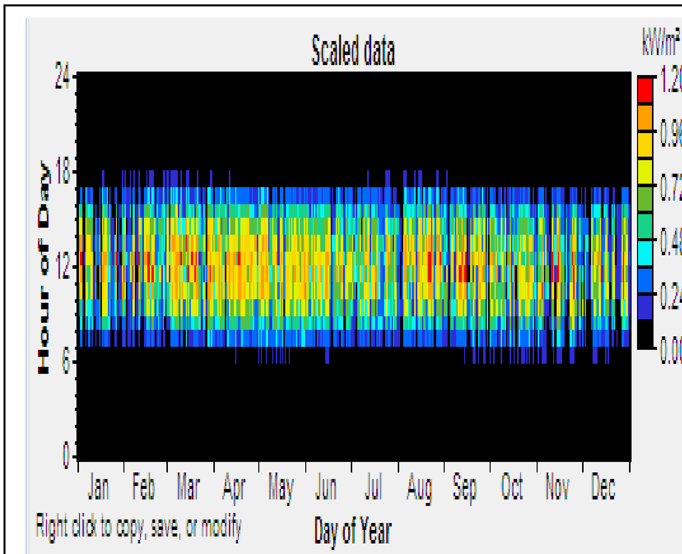


Fig. 4.1 Solar radiation with scaled data

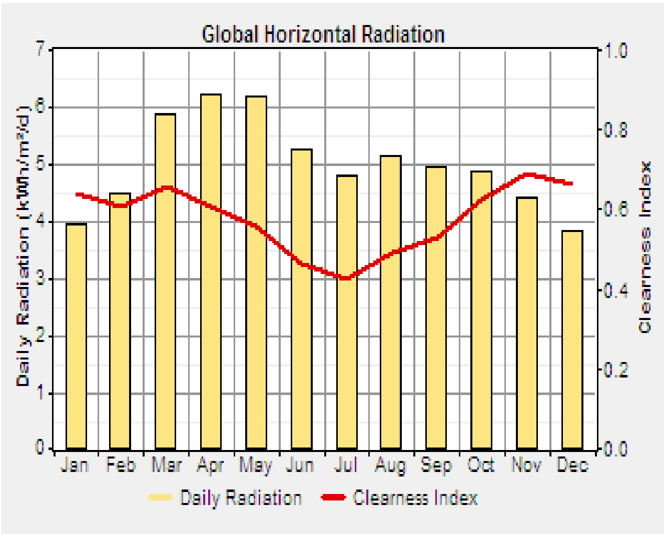


Fig. 4.2 Solar radiation and clearness index for Rajshahi

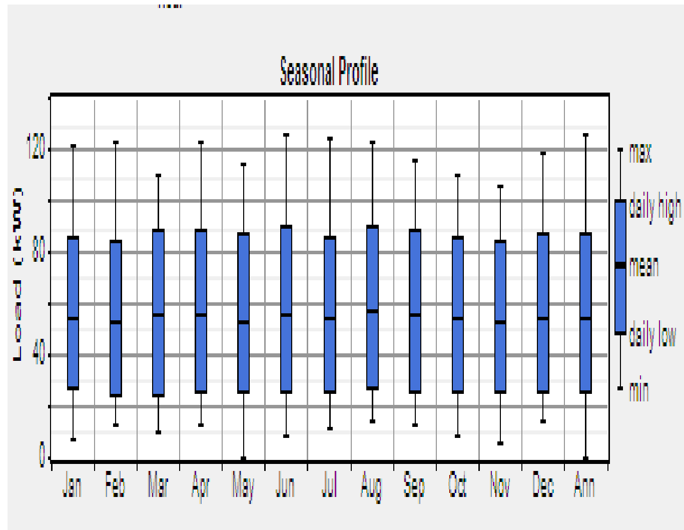


Fig. 5.2 Seasonal load profile of the small household area

5. THE LOAD PROFILE

The small household appliance is estimated to accommodate 70 small families with total peak load of 126kW. With added consideration for demand variation of 2% for day to day and hour to hour, the peak load is estimated to be 126kW. Figure 5.1 shows the daily load profile of the interest area. The load demand starts to peak after 8am. The load drop occur at 8 pm too much of the day. Further looking at the variations over the months of a year at Figure 5.2, the load is higher for the middle2 quarters and last 4 quarters of the year, which is from January to February and April to August, because most household appliances are in maximum operation during this period.

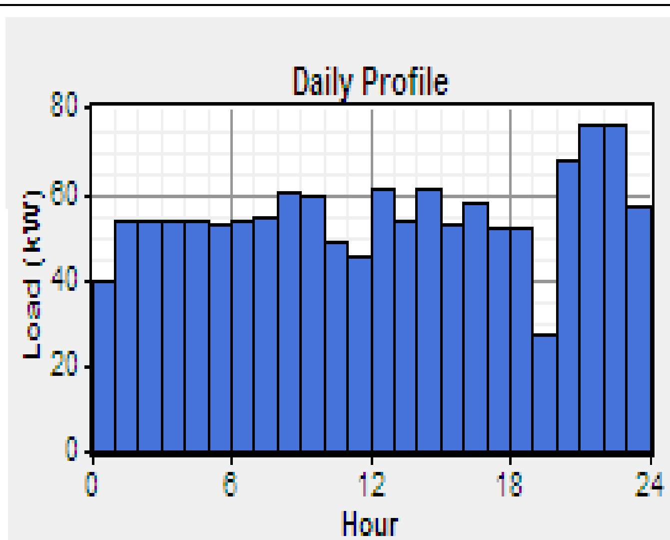


Fig. 5.1 The daily load profile of the small household area

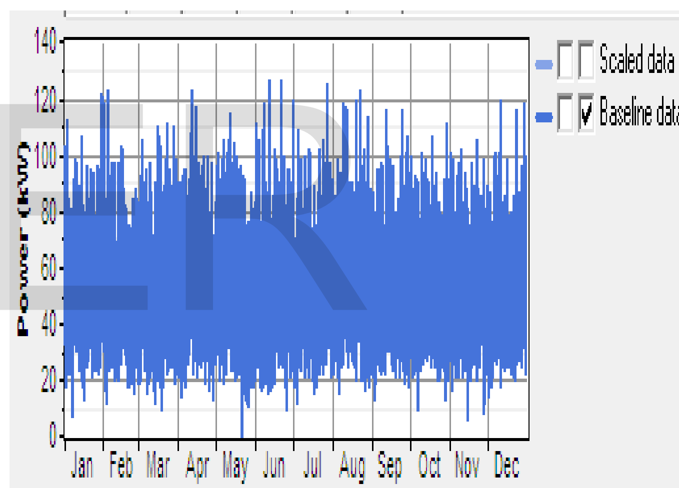


Fig. 5.3 Seasonal load profile of the small household area

Parameter	Value
Average load (kWh/d)	1312
Average load (kW)	54.7
Peak load (kW)	126
Load Factor	0.433

6. SYSTEM CONFIGURATION

The grid connected system was modeled using HOMER and MATLAB program Figure 6.1 shows the system configuration used in this paper. The system is composed of 500 kW of PV and 500 kW converters with the load of an average consumption of 1.312 MWh/d and peak demand of 126 kW, Table 1.4

summarizes the components sizes and cost used in the system simulation. The cost of electrical energy purchase rate from the grid is set to 0.10 US$ while the sellback price is 0.05 US$ with Net metering for the project.

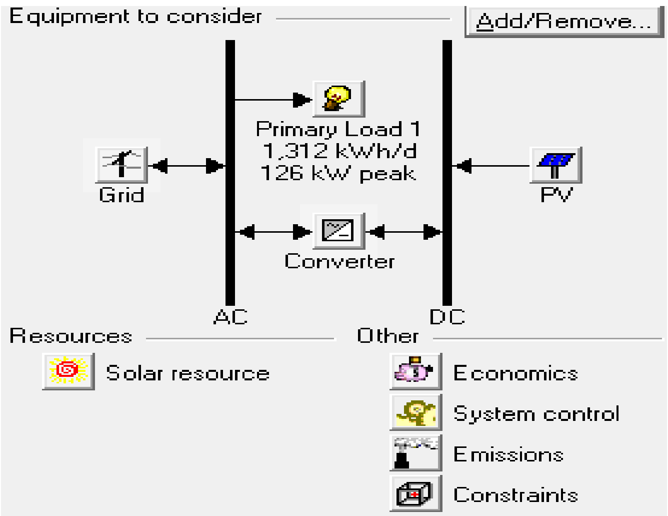


Fig. 6.1 The grid connected PV system configuration

TABLE 1.4
Components sizes and cost used in the system simulation

Com ponent	Qu antity	Size (kW)	Capital Cost ($/kW)	Mainte- nance and operation cost ($/year)	Total capital cost($)
PV panels	2944	500	2920	0	1460000
Inverter	1	500	250	313	125000

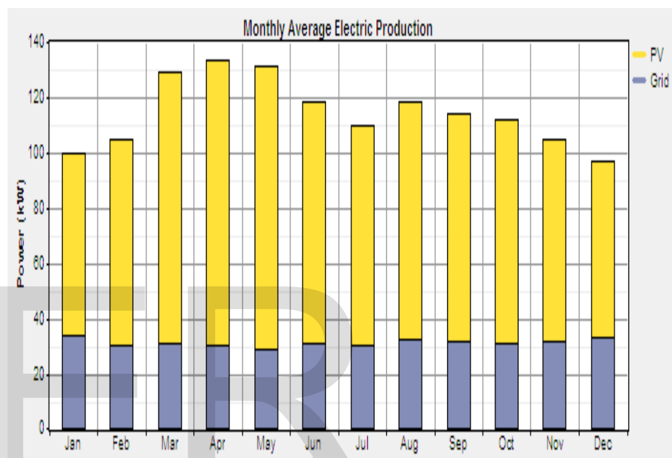
TABLE 1.5
Components sizes and cost used in the system simulation

PV mod- ules (BP 5200)	PV mod- ule Di- men- sion (m2)	Total mod- ules area (m2)	Capital Cost ($/kw)	Re place ment Cost ($)	Opera- tion & Main tenance cost($)	Life time (years)
170 w	1.319	3883	2920	730	0	20

7. Results and Discussion

After running the data through HOMER the optimal results data for the system in Rajshahi is shown in Table 1.6, the 73 percent of the load fraction is supplied by the PV system and the other 27 percent is supplied from the grid, the 48 percent of the load is sold back to the grid and that happens when the PV supply is greater than the demand and that occurs in the midday period when the sun is high in the sky. Figure 7.1 shows the monthly electric production by the PV system and by the grid, the chart shows that the PV production increases in summer months namely (March, April, May), and least in the winter months.

Table 1.4 shows the costs associated with the system, the highest part of the system is due to the PV panels but has no or low maintenance and operation costs on the other hand the converters and grid connection has a relatively low capital cost but it contribute to the total cost by the maintenance and operation cost.



7.1 Monthly average electric production for grid connected PV system

TABLE 1.6
Electrical simulation data

Component	**Production** (kwh/yr)	**Fraction** %
PV array	729,749	73
Grid Purchases	273,051	27
Total	1,002,800	100
Load	**Consumption**	**Fraction**
AC primary load	478,881	52
Grid sales	450,944	48
Total	929,825	100

System		
Quantity	kwh/yr	%
Excess electricity	0.00	0.00
Unmet electric load	0.00	0.00
Capacity shortage	0.00	0.00

Quantity	Value	Units
Rated capacity	500	kW
Mean output	83	kW
Mean output	1,999	kWh/d
Capacity factor	16.7	%
Total production	729,749	kWh/yr

Quantity	Value	Units
Minimum output	0	kW
Maximum output	473	kW
PV penetration	152	%
Hours of operation	4,380	hr/yr
Levelized cost	0.174	$/kWh

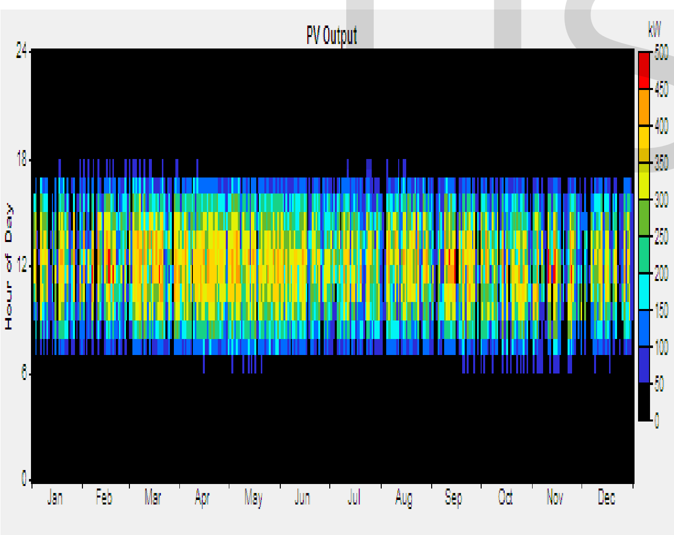


Fig 7.8 Monthly Output of PV Panel

8. CONCLUSIONS

Rajshahi is very rich in the solar resources and has a great potential for PV powered projects, in this paper a proposed PV power plant is planned to meet the load of Rajshahi, the system is sized and simulated using HOMER, and the resulted system is composed of 500kW of PV and 500 kW converter with the load of an average consumption of 1.312 MWh/d and peak demand of 126 kW, the total capital cost is high which is typical for PV system, and the cost of energy is 0.27 $ which is still a high cost, the system is still unfeasible without the incentives but prices trends are decreasing.

9. ACKNOWLEDGEMENTS

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