# Analysis of Grid Integrated PV System as Home RES with Net Metering Scheme

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***Abstract*—To meet the increased demand of electricity, PV system is being used as home RES (Renewable Energy Source) throughout the world. In this paper, a grid integrated PV system has been proposed with net metering scheme. A home of 149 sq. meter in Dhaka city is considered whose average daily load is 11.27 kWh/day with an annual peak load of 1.21 kW. According to DESCO (Dhaka Electric Supply Company Limited), for the span of last one year (July, 2017-July, 2018) the monthly electricity usage of this home varies from 401-600 units (kWh) with a Cost of Energy (COE) of $0.1. Simulation and analysis of the proposed system shows that the Cost of Energy (COE) and Net present Cost (NPC) of the proposed system can be reduced to a great extent with the application of net metering scheme which also improves the renewable fraction of the system.**

***Keywords—RES, Net Metering, COE, NPC, Grid Integrated PV System, Optimized System, Renewable Fraction.***

## I. INTRODUCTION

Non renewable sources to generate electricity are limited. Moreover these sources are not eco-friendly and cause emissions. With the technological development, world is leaning more towards electricity. So its demand is ever growing. It's also true that, with the development of technology, problem like environmental pollution has become more drastic. That's why the world is encouraged to lean on renewable sources to meet this ever growing demand. The need for energy security and emission reduction has led developing countries like Bangladesh towards a major transition in energy sector. The solar energy has great potential within this country. In this country PV cells are being used by house hold and commercial buildings as an alternative power source. The house hold and commercial popularity of the PV power is depicted in the table I [1].

TABLE I. IMPLEMENTED SOLAR ENERGY IN BANGLADESH(2014)

| Category | Achievement |
|---|---|
| Home System (3.3 million) | 150MW |
| At roof top of Govt./non govt. building | 03MW |
| At Commercial building | 01MW |
| For new connection at roof top of buildings | 11MW |
| Solar Irrigation (193) | 01MW |

This increasing growth in PV installation is due to the policy taken by government and technological improvement which also results in reducing the installation cost. In most of the cases these PVs are not connected to the grid. Rather these act as backup power sources due to lack of system design & infrastructure. But as proposed this PV systems can significantly contribute to the total grid production being integrated to the grid through net metering. When a large PV system is integrated in the grid, it is needed to know beforehand the amount of power, system can provide to the grid. On the contrary, optimization of self-consumption is required to increase profits and decrease energy exchanges with grid in case of small system integration [2]. Net metering is a mechanism that calculates the electricity supplied by the grid and also the amount of excess electricity of the consumer supplied to the grid. This mechanism takes into account of the amount of electricity consumer supplies to the grid and takes from the grid thus, generate the resultant bill for the consumer. The electricity feed into the grid is preferably valued same as the consumed electricity from the grid [3]. In the 1980s net metering was first introduced in USA and now a days almost every states include net metering policies: simple, with buy-back, with rolling credit or with buy-back and rolling credit. later net metering has been included in many other countries [3] [4].

In this context, a typical residential home of Dhaka city has been considered while its power usage from DESCO for one year (July,2017-July,2018) is analyzed. Also power usage from grid when the PV system is integrated with the grid as the proposed net metering scheme has been simulated, analyzed and presented hereby.

The rest part of the paper is structured into five sections. Section two shows the model of the proposed system and the proposed net metering scheme. Section three shows the description of the different components of the system including their technical details. Section four depicts the data modeling necessary for the simulation and section five shows the simulations of the proposed system. Finally conclusion is drawn in section six.

## II. SYSTEM MODELING

Here a house which is connected to the grid and also equipped with PV system as home RES is taken for consideration. The capacity of the PV system is found to maintain the

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optimized COE (cost of Energy). This home PV cells when integrated to the grid facilitates self consumption of electricity and supply the excess electricity to the grid. Net metering is a bidirectional mechanism which is capable of registering imported and exported energy of the system. Here the proposed net metering scheme for grid integrated residential solar PV system is depicted by flow chart in fig. 1.

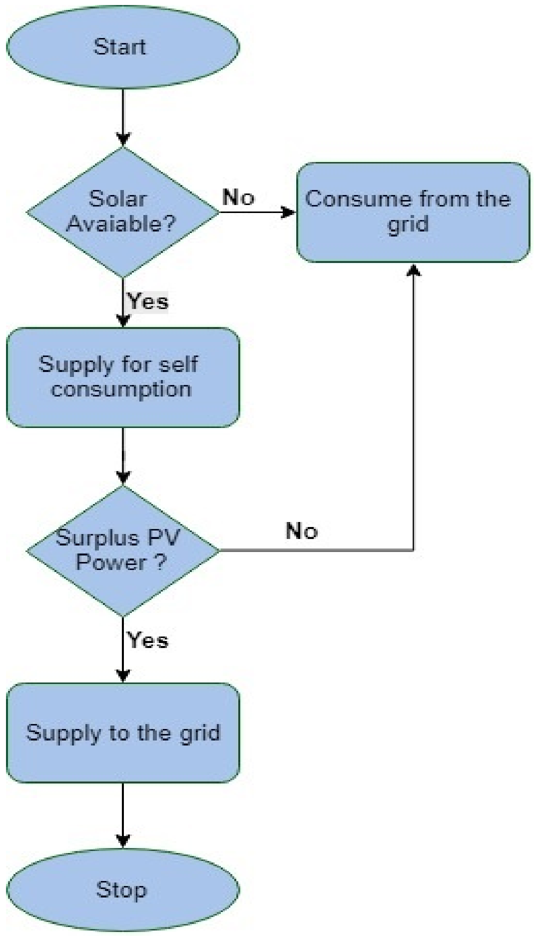


Fig. 1. Proposed net metering scheme

PV power primarily covers the home electricity demand. If installed PV power is not sufficient to meet up the home demand, electricity is consumed from the grid. On the contrary, surplus PV power if available, is supplied to the grid. Battery is used as back up source in case of emergency and load shedding. The battery is charged only from PV power and in no means from grid. And the battery never supplies power to the grid. A converter is also used to convert the generated PV power from DC to AC. The System is depicted in fig. 2. where electric load and grid is connected to the AC bus. PV module and batteries are connected to the DC bus whereas both the buses are connected to each other by a converter to convert electricity from AC to DC and vice versa. Micro-controller PIC18F4520 is used to calculate the power, energy, imported and exported tariffs where current sensor ACS712 and voltage divider circuit is used to measure the current and voltage respectively. Relays are used for automatic controlling [5].

For simulation, HOMER pro (Hybrid Optimization Model for Multiple Energy Resources) is used for enabling net metering scheme to the proposed system.

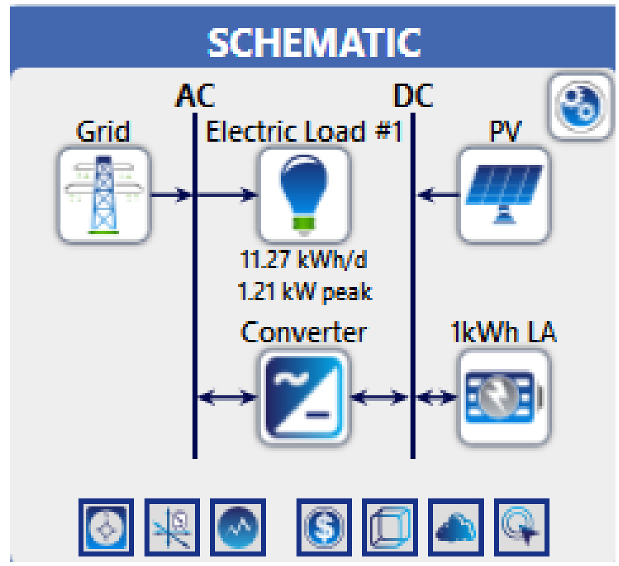


Fig. 2. Proposed grid integrated PV system with net metering

## III. Components of the Proposed System

In the proposed system PV cell is considered as home RES. Battery is also included in the system as back up power in case of emergency or load shedding. A converter is used in the system to convert the DC power to AC. For the economic analysis, technical ratings, capital cost, replacement cost , O&M (Operation and maintenance) cost are to be given input to HOMER Pro.

### A. PV Module

A generic 1 kW flat plate PV for the proposed system which costs 800$ [6] is considered. Technical details of the module is given in table II.

TABLE II. Technical Details of PV Module

| PV | |
|---|---|
| Capital Cost | 800 $/kW |
| Replacement Cost | $800 $/kW |
| Operation and maintenance cost | 10$/year |
| Lifetime | 25 years |
| Derating factor | 90% |
| Tracking system | No |

### B. Battery

Now a generic 1 kWh lead acid battery with nominal voltage of 12 V is used. The technical details of the battery is depicted in table III.

### C. Converter

A system converter with 90% of efficiency and cost of $186.66 is used. More technical details of the converter are shown in table IV [7].

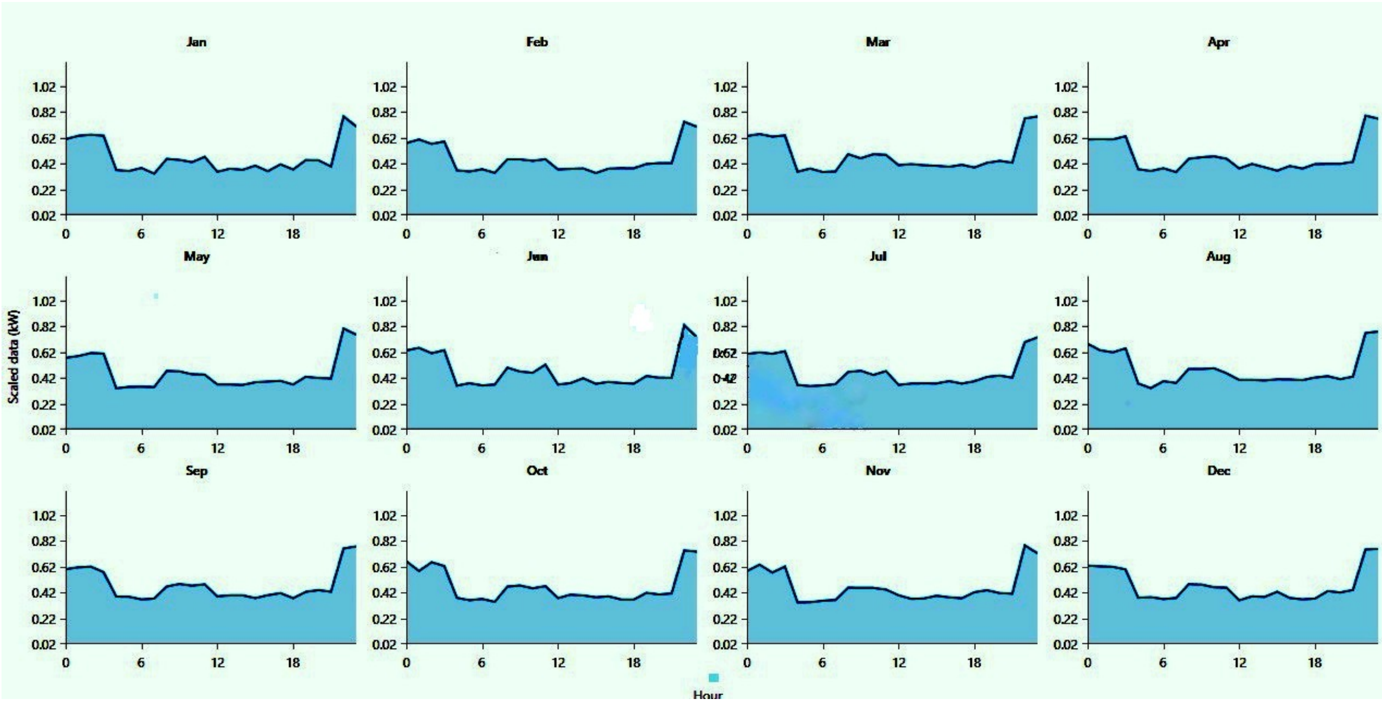


Fig. 3. Scaled data daily profile

TABLE III. TECHNICAL DETAILS OF BATTERY

| Battery | |
|---|---|
| Nominal Voltage | 12 Volt |
| Nominal capacity | 1 kWh |
| Maximum charge current | 16.7 A |
| Round-trip efficiency | 80% |
| Maximum discharge current | 24.3 |
| Capital cost | $300 |
| Replacement cost | $300 |
| Operation and maintenance cost | 10$/year |

TABLE IV. TECHNICAL DETAILS OF CONVERTER

| Converter | |
|---|---|
| Capital Cost | 186.66$/kW |
| Replacement cost | 125$/kW |
| Lifetime | 10 years |
| Efficiency | 90% |
| Rectifier capacity | 95% |
| Rectifier efficiency | 85% |

## IV. DATA MODELING

A home of 149 sq. meter which is located in Dhaka city is considered. This home mostly consists of one TV, two air conditioners, one computer, two refrigerators and 6 rooms each having two florescence light and one fan. According to DESCO, this house used 400-600 units of electricity each month from July 2017- July 2018. Now analyzing its load data to create the hourly load profile with daily randomness of 10% and noise of 15%. HOMER Pro is used to synthesize the given hourly load to produce scaled data daily load profile and monthly load profile which are depicted in the fig. 3 & fig. 4 respectively. Average daily load of the house is 11.27 kWh/day with an annual peak load of 1.21 kW.

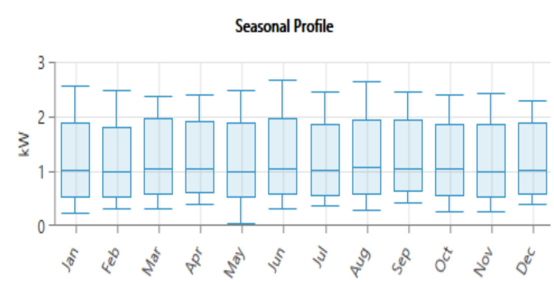


Fig. 4. Monthly load profile

For economic analysis data for per unit electricity price is needed. As the considered home is situated in Dhaka city, let's consider the tariff rates of DESCO (2018) for residential consumption which are depicted in table V.

TABLE V. PER UNIT PRICE OF ELECTRICITY FOR RESIDENTIAL CONSUMPTION(DESCO)

| Consumer Groups | Unit-price |
|---|---|
| First : 1-75 units | 0.0475 $/kWh |
| Second : 76-200 units | 0.0642 $/kWh |
| Third : 201-300 units | 0.0670 $/kWh |
| Fourth : 301-400 units | 0.0704 $/kWh |
| Fifth : 401-600 units | 0.1090 $/kWh |
| sixth : More than 600 units | 0.1247 $/kWh |

The home is in the range of fifth group, so 0.1090 $/kWh is used as per unit price both for consumption from the grid and sell back.To know the PV power generation of the system, the solar radiation on the home must be known. HOMER uses the location of the home (23.8223°N and 90.3654°E) to find the solar radiation from clearness indices. The monthly average global radiation data from NASA (National Aeronautics and Space Administration) which is given input to homer is analyzed to synthesize solar radiation values for 8760 hours/year with Graham algorithm [8]. The annual average solar radiation for this system is 4.80 kWh/$m^2$/day & average clearness index is 0.5269. Fig. 5 shows the monthly average solar GHI (Global Horizontal Irradiance).

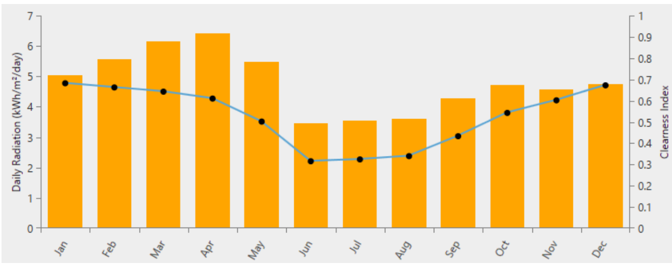


Fig. 5. Monthly average solar GHI

## V. Simulation and Result

HOMER Pro for the simulation is being used of the proposed- grid integrated PV system with net metering. After conducting hours of simulations through HOMER Pro using different capacity of PV modules and different solar radiations at different times, the optimized system is found. Simulation shows that, a PV module of 11.5 kW integrated to grid with net metering scheme gives the most optimized solution with lowest COE of $0.00396 and yearly sell back of 11,839 kWh/year to the grid. A COE of only $0.00396 with the proposed system has been achieved which is now $0.1 when consumption is only from grid. When the home is feed from grid only, the renewable fraction is 0%. But the renewable fraction of the proposed system is improved to 84.9%. An annual sell of 11,839 kWh of energy is also earned which was zero earlier. Simulations also show that, total production of the proposed system is 16,243 kWh/year and it purchases only 2406 kWh/year from the grid. This is a great improvement as being connected only to grid the home has to buy around 6,000 kWh/year. One year cost summary of this system is shown in figure 6.

Total investment in the system is $13,825.84 and after one year the total sell back is $12,194.15. This shows that, percentage of return after the first year is 88.198%. Monthly average electric production is depicted in the fig. 7. This shows that, in every month of the year system consume a constant power from the grid even though PV power production is different in different month due to change of solar radiation. PV power generation is highest in the month of March and lowest in the months of June & July.

On the contrary, When the same simulations for home PV system is conducted without net metering, the optimized COE becomes $0.107 with an NPC of $5665. Part of the optimized result of the proposed system is shown in the fig. 8. and fig. 9 shows the part of the simulation result of the system without

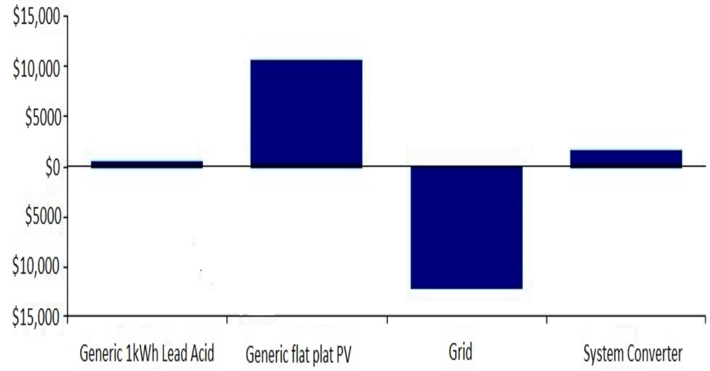


Fig. 6. Cost summary of the proposed system

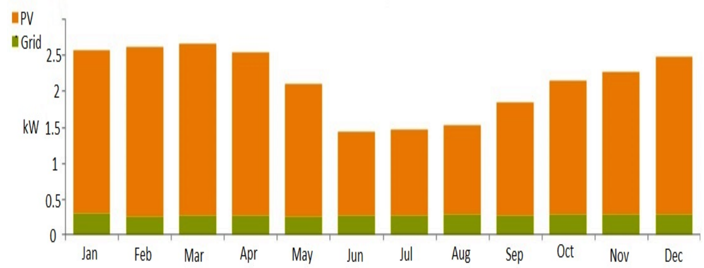


Fig. 7. Monthly average electric production

net metering. It is noticeable that, this COE is more than that of the resulting per unit price of electricity from grid. This is because, energy is not sold back to the grid rather a considerable amount of money is invested to the system which is used only for backup purposes and charging of the battery. So considerable decrease is possible in the COE by integrating the home PV system to the grid with net metering scheme.

Percent change of COE =

$$\frac{COE\ without\ net\ metering - COE\ with\ net\ metering}{COE\ without\ net\ metering}$$

$\times 100\%$

$$= \frac{0.107 - 0.00396}{0.107} \times 100\%$$

$$= 96.30\%$$

This clearly suggests that, COE increases by 96.30% when net metering scheme is not considered in home PV system. Moreover, without the net metering scheme in the proposed system, the renewable fraction of the energy usage gets down to only 21.9% whereas it was 84.9% for PV integrated to grid with net metering.

Moreover, simulations show that, the COE of the proposed system becomes only $0.000748 when no energy storage device like battery is considered in the system. But considering the issue of load shedding and emergency purposes battery is considered in the system as a backup source.

| Architecture | | | | | | | | | System | | PV | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PV (kW) | 1kWh LA | Grid (kW) | Converter (kW) | Dispatch | NPC ($) | COE ($) | Operating cost ($/yr) | Initial capital ($) | Ren Frac (%) | Total Fuel (L/yr) | Capital Cost ($) | Production (kWh/yr) |
| 11.7 | | 10,000 | 6.00 | CC | $155.45 | $0.000748 | -$795.90 | $10,444 | 85.0 | 0 | 9,324 | 16,505 |
| 11.5 | 1 | 10,000 | 6.00 | CC | $815.85 | $0.00396 | -$756.54 | $10,596 | 84.9 | 0 | 9,176 | 16,243 |
| | | 10,000 | | CC | $5,317 | $0.100 | $411.30 | $0.00 | 0 | 0 | | |
| | 1 | 10,000 | 0.0417 | CC | $5,987 | $0.113 | $439.33 | $307.78 | 0 | 0 | | |

Fig. 8. Optimization result of the proposed system

| Architecture | | | | | Cost | | | | System | | PV | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PV (kW) | 1kWh LA | Grid (kW) | Converter (kW) | Dispatch | NPC ($) | COE ($) | Operating cost ($/yr) | Initial capital ($) | Ren Frac (%) | Total Fuel (L/yr) | Capital Cost ($) | Production (kWh/yr) |
| 0.779 | | 10,000 | 0.458 | CC | $5,006 | $0.0942 | $332.46 | $708.38 | 21.9 | 0 | 623 | 1,103 |
| | | 10,000 | | CC | $5,317 | $0.100 | $411.30 | $0.00 | 0 | 0 | | |
| 0.777 | 1 | 10,000 | 0.463 | CC | $5,665 | $0.107 | $360.25 | $1,008 | 21.9 | 0 | 621 | 1,100 |
| | 1 | 10,000 | 0.0417 | CC | $5,987 | $0.113 | $439.33 | $307.78 | 0 | 0 | | |

Fig. 9. Simulation result without net metering

## VI. Conclusion

Simulations show that, The proposed grid integrated PV system with net metering is the most viable and optimized system which consists of PV module of 11.5 kW, 6 kW converter and one lead acid battery of 1 kWh. The COE of the system is $0.00396 and NPC is $815.85. Renewable fraction of the proposed system is 84.9% with a sell back of 11,839 kWh/year to the grid. The COE of the system can be brought down further to a lower level if no battery is used in the system. But being practical a battery is used in the system as back up source and for emergency purposes.

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