

Comparative Assessment of Energy Accounting Schemes in Grid Integrated Roof Top PV System for Different Load Profile

Winshy Rapheal¹, Sreenivas Parameswaran²

P.G. Student, Department of Mechanical Engineering, Govt. Model Engineering College, Thrikkakara, Kerala, India¹

Associate Professor, Department of Mechanical Engineering, Govt. Model Engineering College, Thrikkakara, Kerala, India²

ABSTRACT: Increasing energy demand potentially drive the widespread implementation of distributed generation by end-users through various technologies such as rooftop solar PV system. When they first came to market years ago, many states approved different billing systems in India to encourage the introduction of these systems. Gross metering in solar system has been set up to send the entire solar power they generated to the grid. Net metering in solar systems are set up to send energy to your household first before sending the excess energy to the grid and the consumer will be paid a rebate for supplying this power. The objective of this paper is to present an evaluation related to the possible application of the Feed-in tariff and net metering tariffs into the grid integrated roof top solar PV system in Kerala at the economy and energy perspectives for different load profile on the basis of hourly based data of solar irradiance and energy consumption profile.

KEYWORDS: Gross metering, Net metering, Feed in Tariff, Capacity Utilization Factor .

I. INTRODUCTION

With the country facing a continuous shortfall in the supply of conventional sources required to meet the increasing demand for energy in recent years, the focus is gradually shifting from conventional to renewable sources of energy. In order to reduce the current demand-supply gap for electricity within the country, the renewable energy sector has to be given high importance. With several solar PV projects coming up under the Jawaharlal Nehru National Solar Mission (JNNSM), the demand for PV cells and modules is expected to increase significantly. Moreover, the capital costs involved in setting up solar PV projects in India, along with the feasible geographical location of the country that enables it to receive around 3,000 hours of sunshine each year, makes solar PV a highly viable option for electricity generation [1]. The domestic solar PV industry has also attracted significant investments over the past few years. These factors will ensure that the market continues to exhibit steady future growth.

With recent developments, solar energy systems are easily available for industrial and domestic use with the added advantage of minimum maintenance. Solar energy could be made financially viable with government tax incentives and rebates. For 300 clear sunny days in a year, India's theoretical solar power reception, just on its land area, is about 5 Peta hour/year (i.e. = 5000 trillion kWh/yr ~ 600 Tera Watt) [2]. The daily average solar energy incident over India varies from 4 -7 kWh/m² with about 2300 - 3200 sunshine hours per year, depending upon location [3]. This is far more than current total energy consumption. For example, even assuming 10% conversion efficiency for PV modules, it will still be thousand times greater than the likely electricity demand in India by the year 2017 [4]. Exploitation of the abundant solar energy resources available in our country is therefore, being accorded a high priority by the Ministry of New and Renewable Energy. The Ministry has come forward to support Solar PV based Power Plants in big way throughout the country with a host of fiscal incentives. For encouraging investment by the private sector in power generation through renewable energy, MNRE has formed nodal agencies in all the states, and has issued a set of guidelines for their consideration.

Due to the fast-paced growth of India's economy, the country's energy demand has grown an average of 3.6% per annum over the past 30 years [5]. In December 2010, the installed power generation capacity of India stood at 165,000 MW and per capita energy consumption stood at 612 kWh. The country's annual energy production increased from about 190 billion kWh in 1986 to more than 680 billion kWh in 2006. The total demand for electricity in India is expected to cross 950,000 MW by 2030. According to a research report published by Citigroup Global Markets, India is expected to add up to 113 GW of installed capacity by 2017. Announced in November 2009, the Government of India proposed to launch its Jawaharlal Nehru National Solar Mission under the National Action Plan on Climate Change with plans to generate 1,000 MW of power by 2013 and up to 20,000 MW grid-based solar power, 2,000 MW of off-grid solar power and cover 20 million sq meters with collectors by the end of the final phase of the mission in 2020.

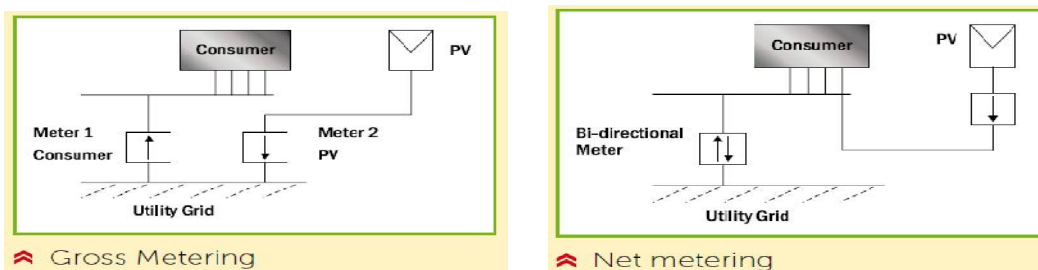
Every building whether it is home, industry, institution or commercial establishment has the potential to generate some solar power by installing PV panels on the rooftop. Some Key Benefits:-

- Photovoltaic roof-top installations at the tail-end of the grid can enhance grid-stability and reduce losses
- Savings in land requirement and costs
- Savings in development of new transmission infrastructure
- Creation of value from under-utilized /unutilized rooftops
- Good choice for distributed power generation system

As per the census report 2011, India is having 330 million houses. 140 million houses are having proper roof (Concrete or Asbestos / metal sheet) and 130 million houses are having more than 2 rooms. An average house can accommodate 1-3kWp of solar PV system and the large commercial roofs can accommodate larger capacities. As a conservative estimate, about 25000 MW capacity can be accommodated on roofs of buildings having more than 2 rooms alone if we consider 20% roofs

II. RELATED WORK

Sudhakar Sundaray explores a lucrative option on different metering arrangement on grid integrated roof top PV system [6]. In the grid interactive system metering schemes are developed on the basis of reliability of supply to the loads and the consumer needs. Gross metering arrangement doesn't affect consumer's existing electrical connections. Electricity generated from rooftop SPV system is directly fed to the grid and consumers get electricity supply from the utility grid. There are two separate energy meters to read solar energy generation and the consumer's electricity consumption from the utility grid. Net metering arrangement allows consumers to use solar electricity for meeting end use loads and surplus energy is fed to grid. In this case simple energy meter is replaced by a bidirectional meter. That means only solar energy that's not used is sent to the grid and receive a payment for that excess [7]. A net meter records the excess solar your system generates, as well as the amount of electricity your household takes from the grid.



Rodney et al developed a 100 KWp solar PV system model and done a comparative study of Fit and net metering for UCSI University North wing campus at the economy and energy perspective. It is found that the monthly energy bill cost saving for fit and net metering are 4.9% and 3.51 % respectively. Rodney et al used real recorded solar radiation and university energy consumption data for the study and found that the monthly energy bill cost saving for fit and net metering are 4.9% and 3.51 % respectively. The return of investment of solar PV implementation for fit and net metering are 11.5 and 16.1 years respectively[8].

From the bill assessment at Mar Baselios College of Engineering and Technology was found that the energy demand as well as the energy charges decreased after the installation of 100 kwp solar panel. From the economic assessment it was found that a considerable amount of savings were made and the payback period was found to be about 9-10 years and they suggests that If net metering is also taken into consideration this system will become more economically viable [9]. As reported in the literature, Kappagantu et al had done an analysis on rooftop solar PV system implementation barrier in Puducherry smart grid pilot project. A survey has been performed with electricity consumers, considering questions regarding consumption over different period, space availability for roof top PV system and users experience with this technology [10].

The self-owned and the third party owned models are evaluated by Narula et al for different SPV system sizes which are suitable for installation on residential rooftop spaces [11]. The paper compares the Internal Rate of Return (IRR) based on cash flows for different cases using a deterministic financial model. Results indicate that with the current costs, smaller systems (2.5 and 5 kWp) are suitable for self ownership, but require the existing 30% subsidy in order to be financially viable. However, the return on larger self-owned systems (10 kWp and above) is sufficiently high and does not warrant the subsidy. On the other hand, third party ownership model is financially not feasible for smaller systems, but returns on larger systems (10 kWp and above) are sufficiently high.

There are two main reasons for the disappointing adoption of net-metering by the consumers: the tariff structure (a policy matter) and grid-reliability (a technical concern). Both issues are relevant for the residential, commercial and industrial segments. If the energy supplied by the consumer to the grid (selling) is at a special (usually higher and fixed for a particular contract period) tariff rate than the one at which electricity is bought from the grid (buying), then it is called a “feed-in-tariff”. However, if the selling and buying are at the same tariff-rate (usually the buying rate), then it is called net-metering. And herein lies a problem. Residential (and agricultural) tariffs are kept low (through subsidy) and only residential customers of highest consumption will be benefited as they can sell at a profit and recover their investment within a few years.

Both FiT and net metering mechanism help to reduce the energy consumption and bill by implementing renewable energy generation. However the cost and energy outcome of FiT and net metering are not identical due to the difference in its mechanism. In this paper, a comparative study of both schemes is presented at the economy and energy perspective for different load profile. For that a Matlab/ simulink model was developed to compute the outcome on the basis of real recorded solar radiation and hourly based load profile. This study is more relevant in current situation of Kerala since KSERC has not published average power purchase cost of KSEB that has to be paid for consumer for solar injection to the grid yet. This cost could vary from year to year and highly influenced by market bidding.

III. MODELLING

The capacity of a solar PV array depends 90% energy consumption of the building on and the shade-free rooftop (or other) area available.

Assumptions

- The roof (or elevated structure) area requirement per kW of solar PV modules is about 10m².
- In Kerala the typical average energy generation per installed kW of solar PV capacity is 5.8 kWh/m²/day and 300 clear sunny days in a year. (This number assumes a system capacity utilization factor of 19% and average grid availability of 95% during the daytime) [12].

With these assumptions, the recommended capacity of the solar modules array of a proposed grid-connected solar PV system can be calculated with the following equation (1) and (2)

$$\text{Capacity} = \frac{\text{shade freerooftop area (square metre)}}{10} \quad \text{or} \quad (1)$$

$$\text{Capacity} = \frac{90 \text{ of annual energy consumption (kWh)}}{1740} \quad (2)$$

Recommended Capacity: Take the lowest of the above two capacity calculation results.

PV array model is defined by the equation (3) and (4), where PV_{array} (t) is the power generated from the array, I_{mp} and V_{mp} are the individual maximum power current and voltage, N_{string} and N_{module} are the no of strings and modules connected in a string, G is the solar irradiance in W/m² and η_{inv} is the inverter efficiency.

$$PV_{array}(t) = (I_{mp} \cdot N_{string}) \cdot (V_{mp} \cdot N_{module}) \cdot G(t) \quad (3)$$

$$PV_{out} = PV_{array} \cdot \eta_{inv} \quad (4)$$

Saving by feed in tariff and net metering is given by the equation (5) and (6)

$$FiT_{savings} = PV_{gkwr} \times FiT_{tariff} \quad (5)$$

$$Net_{savings} = E - E_{PV} \quad (6)$$

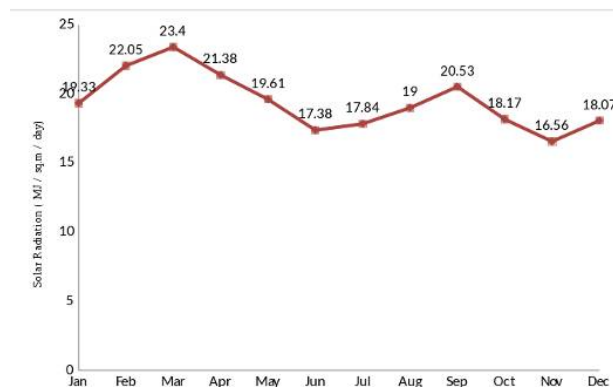
where $FiT_{savings}$ and $Net_{savings}$ are the saving by FiT and Net metering schemes, PV_{gkwr} is the Energy generated by PV and FiT_{tariff} is the tariff rate for FiT. E is the Energy cost without PV and E_{PV} is the Energy cost with PV. For the economic analysis payback period has to be considered by the following equation (7)

$$Payback\ period = \frac{Total\ investment}{monthly\ savings \times 12} \quad (7)$$

IV. SIMULATION

To investigate the outcome of two schemes, Matlab/Simulink model was developed as per the designing equation mentioned above. In this model both schemes are computed in different load profile such as domestic consumers (LT Tariff), institution or offices (HT Tariff), industrial consumers (EHT Tariff) for a month of December 2016. The simulation model for these cases consists of solar PV system, load profile and energy measuring blocks for fit and net metering.

A) PV SYSTEM : The PV system is modeled as per the above equations and it gives the simulated PV array power generation output. The figure (a) is showing the annual monthly global solar radiation exposure (MJ/m²/day) over Kerala and annual average global solar radiation exposure is about 19.45 MJ/m²/day.



The solar radiation data for the hourly based analysis is obtained from the Kerala State Electricity Board, Banasuradasagar dam, Wayanadu, and recorded in workspace of simulation platform as shown in the figure (b) for every 30 minutes in the month of December 2016. For this study, 2 kWp, 30 kWp and 100kWp solar PV system are designed for domestic (LT), institution (HT), and industry (EHT) customers respectively. Solar PV modules considered for the analysis is of poly crystalline silicon type, manufactured in India. 3 kWp PV array was modeled using 10 pieces of 300 Wp PV module from Titan, M6-60 with RFID tag for LT domestic consumers and 30 kWp PV array was modeled using 100 pieces of PV module for HT institution/offices type consumers and 100kWp PV array was modeled using 334 pieces of PV module for EHT industry type consumer with inverter efficiency of 95%.

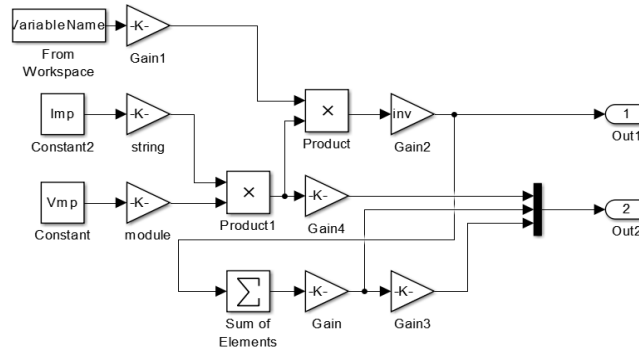


Fig. (b) Solar PV output sub block

B) ENERGY CONSUMPTION PROFILE: To analyse the impact of grid integrated roof top PV system in a LT sector, a domestic consumer with 240 unit monthly consumption is considered for the study and 2 kWp PV array was modeled for them. The figure (c) shows the load profile of domestic consumer and found that the energy consumption is at higher rate in day time in Saturday and Sundays compared to other working days.

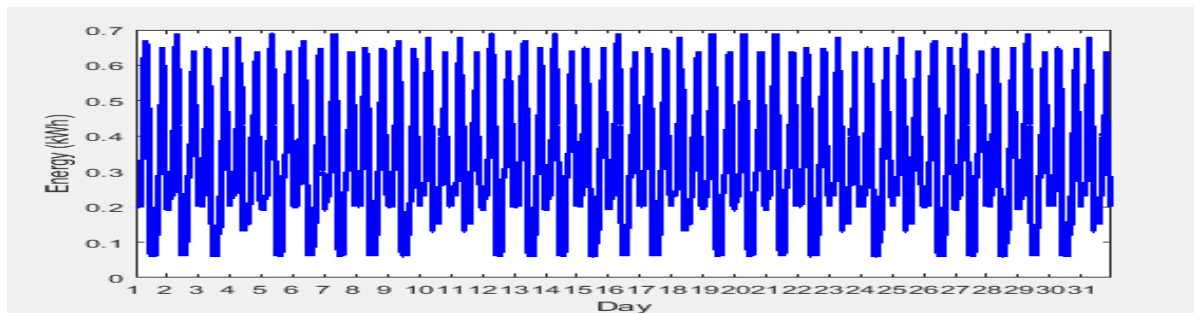


Fig (c) KWh consumption LT consumer (December 2016)

Currently, Govt Model Engineering College has taken an initiative to install a 30kW roof top solar power plant in the college as first phase of the project. This institution is a HT (II A) consumer and monthly consumption is around 1700 units and has a contract demand of 150 KVA. In this figure (d) it can be observed that the trend of the consumption for month of December is comparatively lower than average monthly consumption since it was examination and vacation time for students.

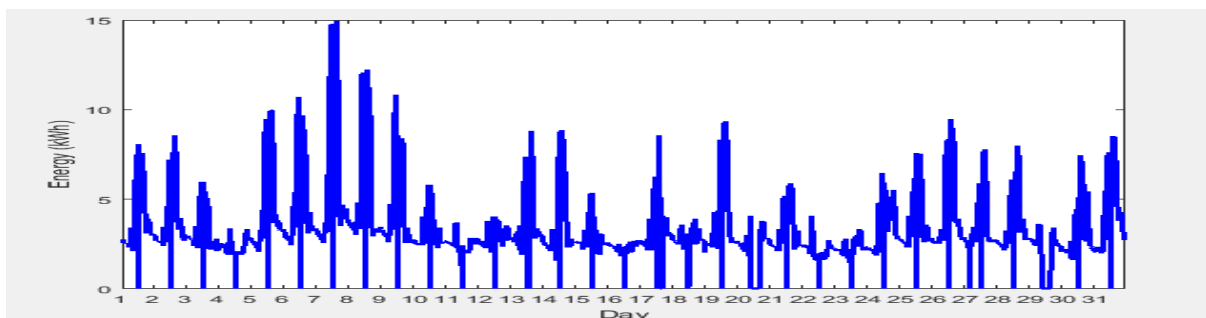


Fig (d) KWh consumption HT consumer (December 2016)

Hindalco Industries Ltd, Kalamassery, aluminium and copper construction company is considered for analysis in EHT tariff with 100kWp PV plant. Hindalco Industries Ltd consumes an average of 9.8 MWh of electricity, every

month with an open access of 3.75MVA from Power trading corporation. In this figure (d), it is observed that the consumption is comparatively high irrespective of day and night.

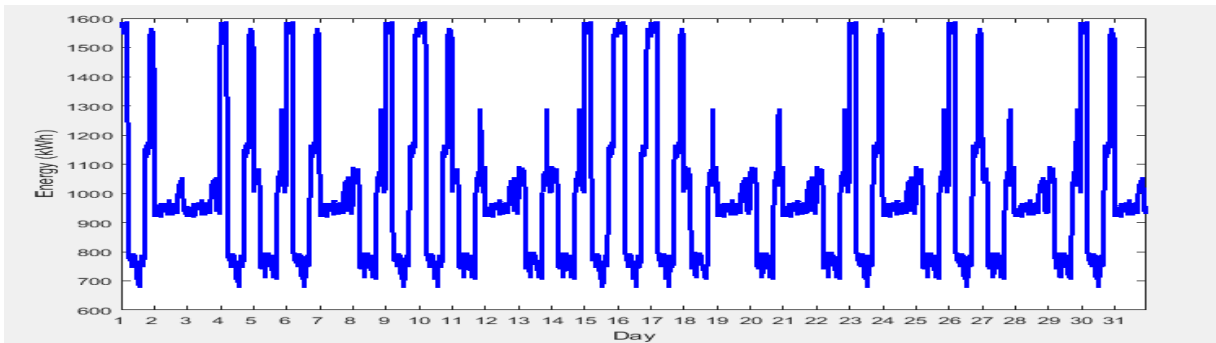


Fig (d) KWh consumption EHT consumer (December 2016)

V. RESULT AND DISCUSSION

The schedule of tariff, terms and conditions for retail supply of electricity by Kerala State Electricity Board with the effect from 16.08.2014 is utilized for the analysis. For solar photo voltaic energy generation projects levelised tariff is Rs. 6.86 / unit for 25 years (Kerala state electricity regulatory commission (annexure F(2015-16)) and net metered tariff is similar to that of energy consumption tariff. As per the data available from MNRE the investment cost is assumed to be Rs. 75000/kWp capacity plant without battery backup.

CASE 1: The simulation model for a home of connected load of 3.335 kw is shown in the fig (e). The study reveals that 2 KW panel produce around 293 units of electricity and load consumption is around 240 units for one month. In this situation energy cost calculation is done in accordance with telescopic billing(rate goes up in each slab). If the usage is above 250 units, nontelescopic(flat rate for every unit consumed) billing is following for the analysis.

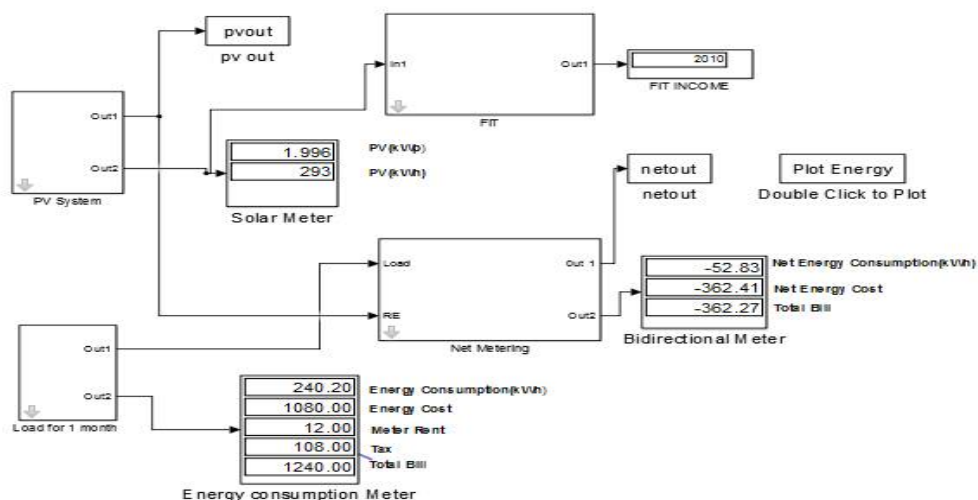


Fig (e) Simulation model for LT consumer

In gross metering the monthly savings will be around Rs.2010 and that will be Rs.1442 for netmetering scheme for the same tariff rate of Rs. 6.86/ kWh is considering. But unfortunately the subsidy tariff rates offered by Government are lesser than Fit rates tariff rate. In this present scenario, since the selling and buying are at the same tariff-rate, the savings will be negligible in these low consumption LT consumers. The figure(f) shows the energy variation with and without PV for 31 days. In day time the major part of unused solar energy can be sold to grid and that can be recovered

Department of Electrical & Electronics Engineering, College of Engineering Perumon, Kollam, Kerala – 691601, India

their investment within a payback period of 6.21 years in gross metering and 8.67 years in net metering. Fixed charges meter charges and other duty charges are not included in the economic analysis.

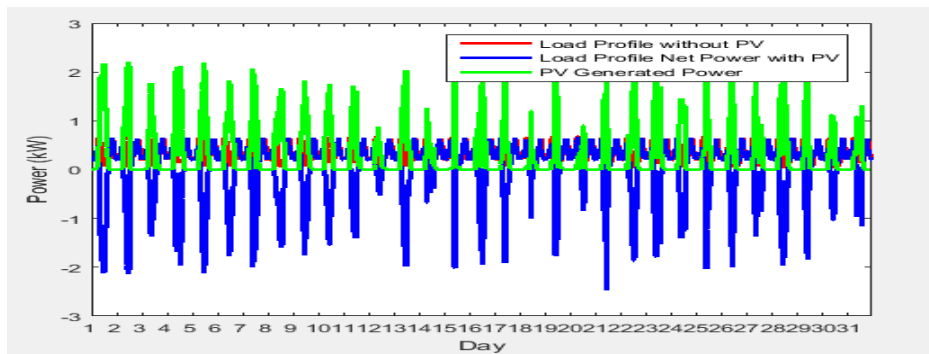


Fig (f) Energy plot for LT consumer

CASE 2: The simulation model for an institution or office is shown in the fig (g). Here Govt. Model engineering college, Thrikkakara (HT II consumers) of connected load of 165 kW is considered for the analysis. The ToD based tariff structure used for the calculation of energy cost and demand charge, surcharge (2.5%) and additional duty charge (10%) are also considered for this calculation.

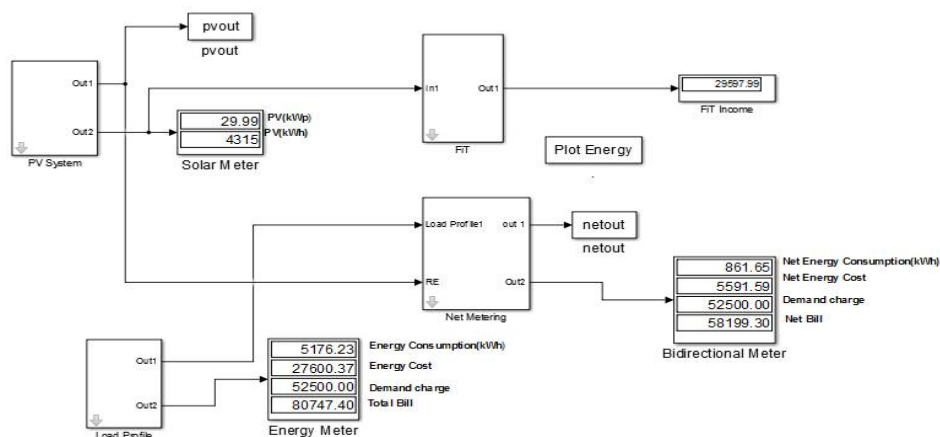


Fig (g) Simulation model for HT consumer

The study reveals that 30 KW panel produce around 4315 units of electricity and load consumption is around 5176 units for the month of December. In gross metering the savings will be around Rs.29595 and that will be only Rs.22548 for netmetering scheme for the same tariff rate of Rs. 6.86 / unit is considering. The figure (h) shows the energy plot for 31 days with and without PV. In day time the net power is negative even though total power consumption is higher than generation. So through this implementation the initial investment can be recovered within a payback period of 6.33 years in gross metering and 8.3 years in net metering.

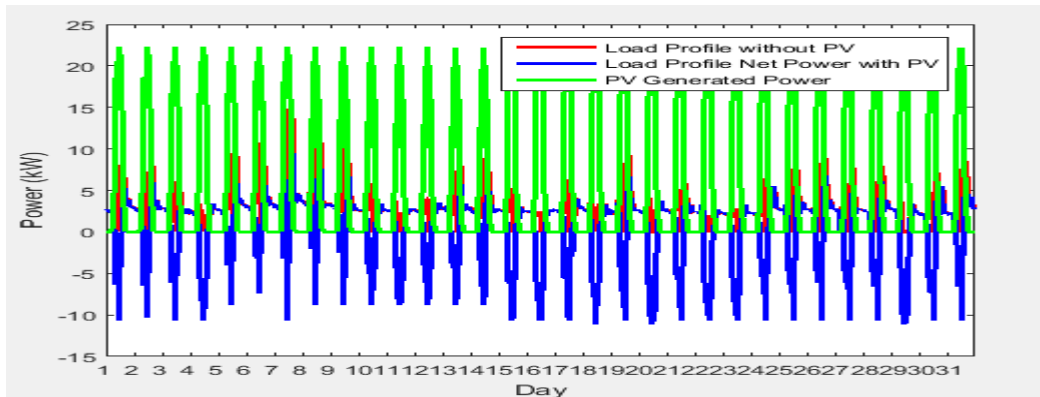


Fig (h) Energy plot for HT consumer

CASE 3: The simulation model for Hindalco Industries Ltd, Kalamassery a aluminium and copper construction company (EHT consumers) is shown in the figure (i) which has a similar load profile throughout the day.

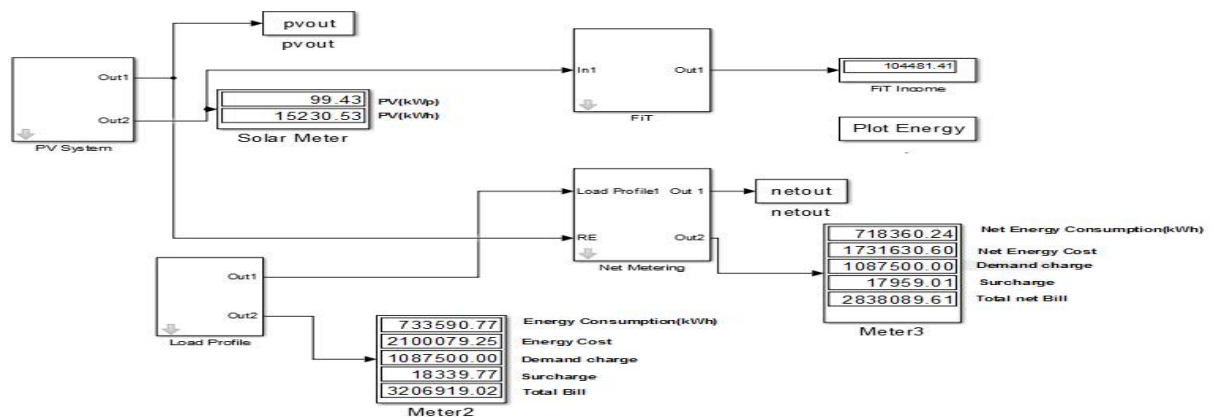


Fig (j) Simulation model for EHT consumer

This simulation study reveals that the energy consumption during day time only reduces the normal tariff consumption and there will be Rs. 104481 by gross metering and Rs. 368830 saving by net metering for one month. For gross metering fit tariff is considered is Rs. 6.86/ KWh and for net metering tod based tariff which is similar to buying rate tariff is used. The payback period for this system is 5.98 yrs for gross metering and 1.7 yrs for netmetering schemes.

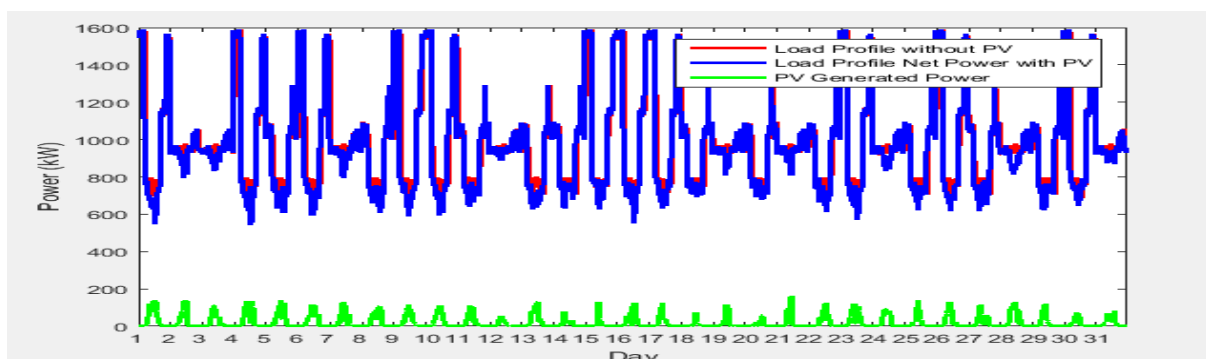


Fig (k) Energy plot for EHT consumer

VI. CONCLUSION

In essence, consumers are seeking better incentives and a resolution of technical obstacles before they invest in residential solar PV systems. Policy makers, meanwhile, are coming up with multiple mechanisms to incentivize net-metering adoption from both sides to help utility and consumer by improving the financial health and reliable energy supply. This study reveals that if the selling and buying rates are same for net metering, it will adversely affect on the implementation in the domestic consumers which has low consumption rate. In the case of institution and industry net metering is recommendable and it is a good choice for the energy security.

New and Renewable Energy department has been making serious efforts in promoting renewable in various sectors including houses. In this paper critical energy metering factors for Roof Top Program and Implantation in Kerala state are mentioned. The pace of development of solar energy systems with grid connected requires special enabling environment for success. Hopefully state government will be prepared to exploit the opportunity provided the challenges which are described here are addressed quickly and appropriately.

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