Techno Economic Feasibility Study of Roof Top PV System in India

Mehebub Alam[1]

[1]National Institute of Technology (NIT) Durgapur, Durgapur-713209, West Bengal, India

Abstract

The thermal power plants generate major part (approximate 65%) of the total energy produced in India. However, it has become urgent need to switch over from fossil fuel based generation to the renewable sources based generation considering the environmental aspect and sustainable future. Among the renewable generations, the solar energy is most promising but due to the land availability issue the roof top PV (RTPV) system gained the popularity. In this paper, the techno economic feasibility study of the off grid RTPV system is analyzed. Moreover, the environmental benefit is also highlighted by showing the emission reduction of 102.45 tons considering 25 year life cycle period. The financial benefit is discussed through the simple payback period which is found around 8 year considering a typical case study. Furthermore, the technical parameters related to the off grid RTPV system are also discussed. This study will be helpful to the utility and planners for possible adoption of the off grid solar PV system in residential as well as commercial building.

Keywords

Roof top PV (RTPV); simple payback period; emission reduction

1. Introduction

Energy plays a vital role to accelerate the economic growth in any country. There is a direct correlation between the growth in energy produced and the growth in the economic development in any country. The solar thermal and photovoltaic (PV) are basically two ways for harvesting solar energy. The solar thermal system basically works on the principle of harvesting energy from solar radiation and the energy is used for water heating, space heating. The PV system is widely used around the world and the electricity is generated through conversion of solar energy into direct current (DC) electricity utilizing the PV effect. The PV system generally composed of the modules or PV panels according to the requirement or design specification. Solar PV system is basically categorized into two types i.e., off grid PV system and grid connected PV [1]. One attractive feature of the off grid PV system is the reduction of peak load.

Generally, the consumer receives power from utility at predetermined tariff. However, in case of shortfall of energy the utility is bound to adopt the load shedding option and the power cut to the end consumers is still happening in rural areas. In this context, the reliable and uninterrupted power supply is an urgent need. This can be accomplished through off grid roof top PV (RTPV) system. However, the installation of RTPV system requires the initial investment. Therefore, proper justification is required in terms of economic viability for possible adoption of this technology. A normal customer does not have sufficient knowledge about the technical and financial parameters of the RTPV system. Therefore, a proper guideline is required in this regard so that the customers can easily understand the techno economic viability of the RTPV system. In this context, the work in this study will serve as a

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EMAIL: mehebubjgec1990@mail.com (A. 1);

guideline to the electricity consumers, factories small and medium utilities for possible adoption of the RTPV technology.

2. Fundamental Idea of RTPV and Indian Scenario

The PV modules are installed on the roof top of the buildings. It is possible to become self-reliant if the PV panels are installed by proper matching the electrical load. The off grid RTPV system is composed of the components like PV modules, solar charge controller, battery bank, inverter etc.It is very interesting to note that major portion of India receives good irradiation throughout the years. On an average, 7 hr per day the good irradiation is received. The annual average monthly irradiation in Kolkata, West Bengal, India (Latitude: 22.55; Longitude: 88.35) irradiation is 4.12 KWh/m^2/day. The 58% land of India receives average irradiance of 5 KWh/m^2/day [2].

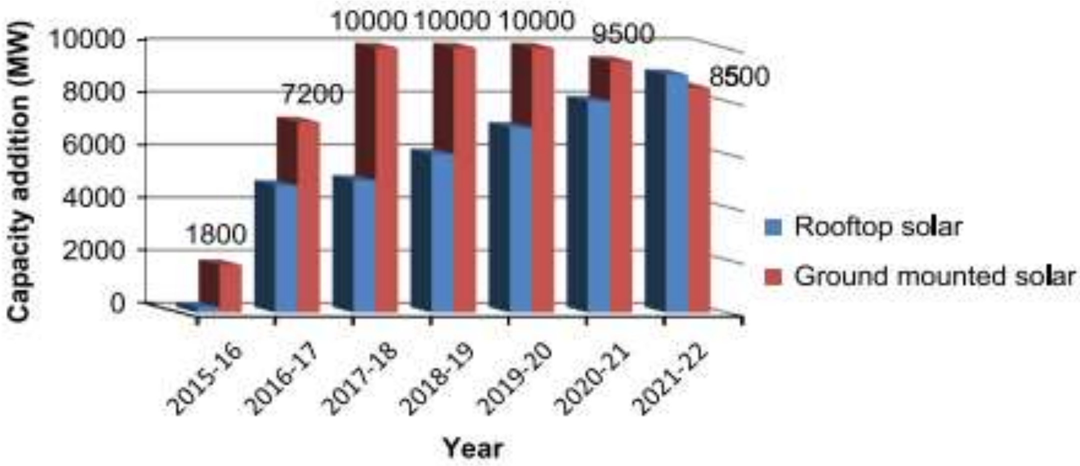

Figure 1: Solar energy capacity addition in India

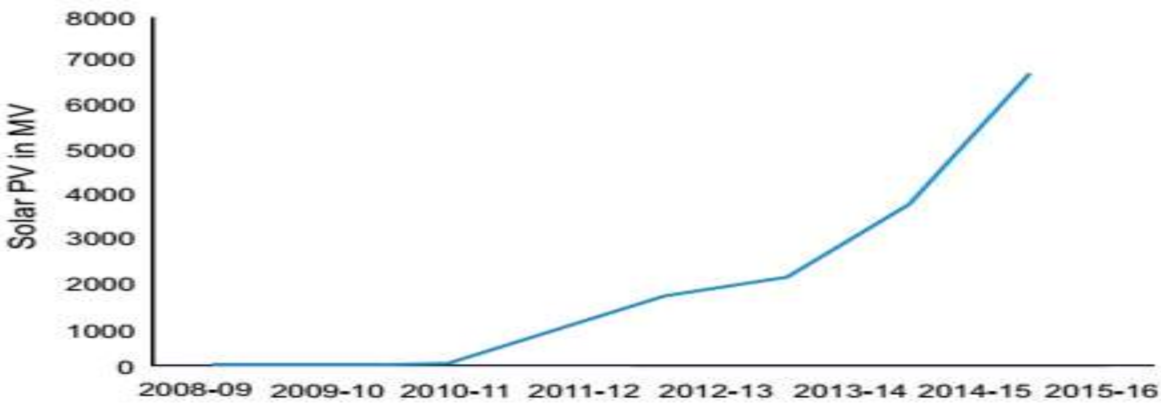

Figure 2: Solar energy growth in India [2]

Therefore, India has huge potential of solar radiation and this potential can be used effectively through RTPV system. In order to promote the solar energy, the Government of India (GOI) has come up with different incentives and schemes so that the customers as well as different companies feel interested to take up the RTPV project. Some important schemes i.e., Net Metering Policy, Fed in Tariff, Renewable Purchase Obligation (RPO) etc. are introduced for encouraging the use of solar energy. It is worth noting that GOI has set the aim to meet 40 GW roof top solar energy from total 100 GW. The year wise capacity addition of solar energy is represented in Fig.1 [2]. The huge growth in solar energy has been observed since last few years. The growth in solar energy in Indian market is displayed in Fig.2.

3. Techno Economic Analysis

It is essential to find out the required technical parameters for installation of the RTPV system. In this section, the methodology for finding out the general technical parameters of the RTPV system is described. We cover both the technical as well as economic aspect. The technical parameters associated with RTPV system are number of PV panels, number of batteries, size of the inverter, size of the charge controller etc. All these parameters are evaluated one by one in this section. The methodology presented in this work is based on the concept described in [3].At first, we must know the total energy consumption of the system for which the design parameters are to be evaluated.

3.1. PV Module Sizing

The total energy consumption can be computed using following expression

$$E_d = \sum_{k=1}^{N} \frac{(G_k P_k n_k)}{1000} \text{ KWH} \quad (1)$$

Here k represents the category of load (fan, lights etc.). The G_k represents the number of hours/day equipment type-k is used, P_k denotes the rated power of k-th device, n_k represents the number of $k-th$ type equipment. Therefore, the total required PV generation can be computed as

$$P_{PV}^{total} = \frac{E_d}{(H_d * D)} \text{ KW} \quad (2)$$

Here, H_d represents the number of hours the solar radiation received, D represents the de-rating factor. We consider the value of H_d 7 hours (in West Bengal). Further, we assume 80% derating factor. Now, the required number of PV panels can be computed as follows

$$N_{panel} = P_{PV}^{total} / P_{panel} \quad (3)$$

Here P_{panel} denotes the capacity of each PV module.

3.2. Battery Sizing

Now, the number of batteries $N_{battery}$ can be calculated by

$$N_{battery} = (E_d * n_{day})/(V_{battery} * I_h * DOD) \quad (4)$$

Here, $n_{day}$and $V_{battery}$ represent the days for which the backup power required, and the battery voltage rating respectively. Moreover, I_h denotes the ampere-hour of the battery and the depth of discharge of the battery is denoted by DOD.

3.3. Inverter Sizing

Now, we have to find the size of the inverter which basically depends on the peak load . Further, the peak load is can be obtained from the diversity factor (DF) and connected system load. The DF is defined as follows

$$DF = \frac{Maximum\ demand}{Total\ connected\ load} \quad (5)$$

Therefore, the size of the inverter can be expressed as

$$P_{inv} = \frac{\sum_{i=1}^{N} \mathrm{P_i n_i}}{\mathrm{DF}} \quad (6)$$

3.4. Economic Aspect

In this section the economic aspect of RTPV system is described. The aim of this section is to measure the profit and quantity the economic benefit of the RTPV system.

Let Q_{grid} and Q_{pv}^{with} represent the cost of grid power, and cost of RTPV system taking subsidy into account. Now, assume the lifetime of RTPV system is Y years, and per unit energy charge imposed by utility is Q_{unit}. Now, the total cost of the power taken from the grid may be expressed as

$$Q_{grid} = 365 * E_d * Q_{unit} * Y \tag{7}$$

Considering four main components such as battery, inverter, PV panel and controller, the total cost of the RTPV system without subsidy ($Q_{pv}^{w/o}$) may be expressed as

$$Q_{pv}^{w/o} = (Q_{panel} + Q_{battery} + Q_{inv} + C_{ctrl}) \tag{8}$$

Where $Q_{battery}$ and Q_{panel} represent the total cost of battery and total cost of PV panels respectively.

$$Q_{battery} = N_{battery} * cost\ per\ battery \tag{9}$$

$$Q_{panel} = N_{panel} * cost\ per\ PV\ panel \tag{10}$$

It is interesting to note that the Government is promoting the RTPV system by providing subsidy so that the utilities and customers are encouraged. The different organizations, Government bodies [4] and Ministries [5] are associated with the promotion of solar energy in India. It is worth noting that 30% subsidy can be availed from National Clean Energy Fund (NCEF). The subsidy is disbursed in the following way:

- On completion of the installation and commissioning of the RTPV system, 20% subsidy is provided
- As soon as the operation of the project starts, another 5% subsidy is disbursed
- On completion of the two years successful operation, the rest 5 % subsidy is allocated

Considering government subsidy ($Q_{subsidy}$) the total cost of the RTPV system Q_{pv}^{with} can be written as

$$Q_{pv}^{with} = \left(1 - Q_{subsidy}\right) * (Q_{pv}^{w/o}) \tag{11}$$

Where $C_{bat} = N_{bat} * cost\ per\ battery$ and $C_{panel} = N_p * cost\ per\ PV\ panel.$

Now, the overall profit that can be achieved through RTPV system is

$$Profit = Q_{grid} - Q_{pv}^{with} \tag{12}$$

The others benefits of RTPV system includes independency on grid power. Nowadays, frequent power cut is observed in the rural areas due to peak deficit. In this context, the RTPV system will be very fruitful for reliable supply of electricity. In order to find the economic benefit, the simple payback period is to be calculated. The simple payback period can be expressed as

$$Pay\ back\ period = \frac{Q_{pv}^{with}}{365(E_d Q_{unit})} \tag{13}$$

3.5. Environmental Aspect

Environmental impact is one of the major concern considering the future generation. In this context, the considerable emission reduction can be achieved through RTPV system. However, a proper baseline is required in this regard to quantify the amount of emission reduction. The standard emission data is provided by Central Electricity Authority (CEA). In this context, the emission factor for thermal generating units is 0.82 Tons of CO_2 per MWh of energy according to the CEA guideline [6]. Based on this concept, we can calculate the reduction of CO_2 emission for 25 years period as follows

$$Emission\ reduction = 0.82(E_d)365 * \frac{25}{1000}\ \text{t/MWh} \tag{14}$$

4. Typical Case Study

A typical composite house building is chosen for case study purpose. The load distribution of the house building is demonstrated in Table 1. We have considered the cost of battery Rs. 14500 per battery [7] and the cost of inverter Rs. 38000 [8]. The cost of the 330 watt PV module is assumed to be Rs. 9199 per module [9]. The techno economic evaluation of the case study is illustrated in Table 2.

Table 1
Load distribution of a typical building

Load type	Quantity	Total capacity(KW)	Hours	Energy consumed (KWh)
Tube 40 W	10	0.4	10	4
Fan 40 W	20	0.8	4	3.2
Water pump 746 W	1	0.746	2	1.492
Fridge 1 KW	1	1	5	5
Total				13.692

Table 2
Techno economic evaluation of a typical house building

Total consumed energy/day in KWh	13.692
PV module rating in KW	13.692/(7*0.8)=2.445
Required number of PV modules considering 330 W/ per module	2.445*1000/330≈8
Cost of each PV module in Rs.	9199
Total cost of PV module in Rs.(C1)	8*9199=73592
Total number of batteries required (each battery 12 V, 220 A-h) considering one day backup	13.692*1*1000/(12*220*0.5)≈12
Total cost associated with batteries (C2)	12*14500=174000
The cost of 2.5 KVA inverter (C3)	38000

Total cost of installation i.e., (C1+ C2 + C3)	285592
Government subsidy in %	40%
Total cost of installation considering subsidy	199914.4
Total bill is to be paid for 25 years considering Rs. 6 / unit (if solar power not used)	624697.5
Total profit (Rs.)	624697.5-199914.4=424783.1
Total amount of CO2 emission reduction (25 years)	13.692*0.82*365*25/1000 = 102.4504 Tons
Payback period in years	8.00448

5. Conclusion

In this study, the techno economic feasibility analysis of RTPV system is nicely presented. The different technical aspects like number of PV panels, number of batteries, inverter size etc. are highlighted. Moreover, the economic aspect of installing RTPV system is also outlined. A typical case study of house building considering total energy consumption of 13.692 KWh is also conducted to check the financial benefit of the monetary investment on the RTPV project. It has been observed that the simple payback period is around 8 years and 102.45 ton reduction of CO_2 emission can be achieved. Therefore, the presented work will be helpful to the customers, utilities, designer etc. for successful implementation of the RTPV project. Furthermore, the Government is promoting the RTPV project by providing the subsidies to the capital investment. Additionally, the land availability issue is a major concern due to which the traditional PV projects (PV panels mounted on land) are losing the attraction of the investors due to complication arises during land acquisition. In this context, this is the high time to avail the subsidies by implementing the RTPV project. Thus, the dependency on the conventional grid power can be avoided and the sustainable future can be ensured. It is worth noting that few aspects such as partial shading, weather variability, environmental hazards etc. have the impact on performance of RTPV. Although, some government policies are introduced for promoting the solar energy, 100% proper implementation could not be possible due to regulatory obstacles. Therefore, it is urgent need for the government to introduce flexible policies or schemes so that they can be adopted at large scale easily.

6. References

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