Effective Grid-Connected Solar Home-Based System for Smart Cities in India

Iram Akhtar, Sheeraz Kirmani and Majid Jamil

Abstract The reduction in fossil fuel reserves on a global base has initiated a serious exploration of renewable energy sources to satisfy the present energy demands. Among the different alternative energy sources, the solar energy is a clean and unlimited energy source; hence, it could play a vital role in the solar home-based system in a developing country like India. There is a requirement for a continuous supply of energy, which cannot be satisfied by the alone solar system because of regular variation of the solar irradiance. It has been found that installed capacity is extended 20 GW in February 2018 in India, and it will achieve around 100 GW in 2022. Hence, the grid-connected solar home-based system is now being used to fulfill the energy demand. In this paper, cost of 20 kW grid-connected solar home-based system in India is analyzed. This work presents the finest scheduling of grid-connected solar home-based system for efficient and economical operation of the system. The proposed system is best suitable for a rural area having the lowest price of energy as INR 3.15/kWh.

Keywords Solar home-based system · Grid · Cost · Energy · PVsyst V6.73

1 Introduction

The energy demand is changing day by day; hence, there is a need for a reliable energy source which fulfills the present energy scenario. The human depends on electricity and needs always accessible. The solar home-based system is a clean and reliable way to electrify the rural area. The grid-connected solar system has the advantage of real utilization of energy. When there is surplus power available, then it will be sold out to the utility. When the solar home-based system generates less energy in comparison with load demand, then this extra power can be taken from the grid. But it is a challenging task to connect the solar energy system to the grid.

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Hence, the proper control system is needed to perform this task. Different systems for integration of the solar system to the grid have been developed, but the main concern is stability and the power quality which degrades. Therefore, effective inverter size is chosen according to the power supply to the grid. If the high rating inverter is chosen, then cost would be increased, and when less rating inverter is chosen, then it affects the efficiency of the entire system. The price analysis for 8 kW solar photovoltaic plant is done and established a scheme based on the possible approximations completed for a selected area of 50 m^2. The solar panel efficiency is the main concern, and it is affected by the accuracy of the algorithm used for tracking of maximum power point [1] and the converter power conversion efficiency [2, 3]. Therefore, DC/DC converter efficiency is also important to concern. The frequency modulation switching can be used for controlling the DC/DC converters [4–7]. It has added to the decrease in electromagnetic interference by power spectrum diffusion [8, 9]. The solar system is becoming very famous to electrify the industries/colony because it is an economical solution and it also reduces the carbon footprints hence reduces the effect of global warming. The thermal power plants do not offer a better environment as the efficiency of coal-based power plant reduces, this would increase the fuel intake and carbon emission. So, there is a need for good matching between the renewable energy source and coal-based power plant accommodation [10]. On the other hand, the penetration of solar schemes rises, this is main to a problem of voltage difference and transient voltage variability with the case of less coupling with the grid. The significant penetration of solar units has an influence on the short-range voltage and transient stability of the proposed system, and it is not limited to the distribution network but also affects the entire system. The proposed work provides a design of a solar photovoltaic-based grid-connected system to electrify the different areas in India. This could improve the performance of the power system without impious the norms of system and restrictions and enable an effective contribution of solar power to the grid system. In this paper, solar home-based system design is presented in Sect. 2. The economic operation of the grid-connected solar home-based system is presented in Sect. 3. In Sect. 4, cost analysis of the proposed system is described. In Sect. 4, outcomes and discussion are presented. Finally, concluding declarations are presented in Sect. 5.

2 Grid-Connected Solar Home-Based System

The grid-connected solar home-based system comprises a solar charge controller, electric meter, inverter, and PV modules as presented in Fig. 1. To get the cost of 8 kW solar-based home system in India, there is a need to measure solar radiation over a different period of time. We defined the value from January to December for Delhi site. The input and output of solar radiation are very important to install any solar project. So, we can know about the efficiency of any plant by knowing how much solar irradiance is used for electricity generation. The selected area for the

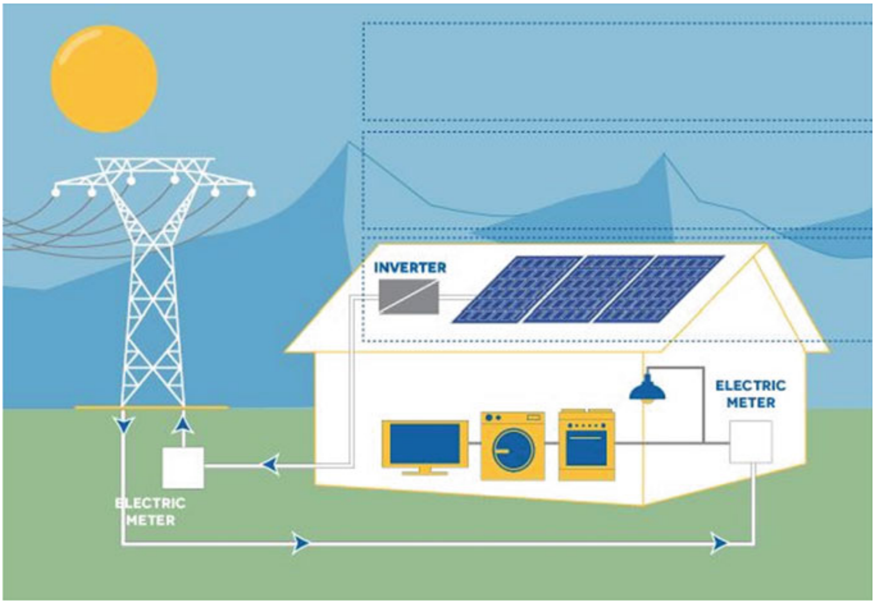

Fig. 1 Grid-connected solar home-based system

expected plant capacity is chosen as 50 m^2. The 8 KW solar system is linked to the grid via an inverter. The power consumption demand is determined by the connected loads. The 8 KW solar home-based system is considered for electrification of rural area.

The total solar panels energy needed = 8 kWh/day.

The quantity of solar panels needed can be known by considering complete power necessary and the solar panel watt rating.

$$\begin{aligned}\text{The number of solar panels required} &= 8000/270\\ &= 29.62.\end{aligned}$$

Real requirement = 30 modules.

Therefore, 30 solar modules of 270 W rating are desirable for this grid-connected solar system.

Table 1 shows the solar model specifications. Whereas, the inverter size depends on the appliances' rating so for safety concerns two inverters are taken with 5000 W capacity every one. Table 2 displays the inverter description. Intelligent control is used to control the inverter output, and it should be constant for reliable operation.

The geographical site is very significant and it is essential to collect data from different hubs and Delhi rural area is chosen for this work. In this site, the latitude is 28.58° N and longitude is 77.20° E.

Table 1 Solar model specifications

Parameter	Specifications
The voltage at maximum power (V)	31.01
Current at maximum power (A)	7.93
Module voltage (V)	24
Cell numbers	60
Short-circuit current (A)	8.50
Open-circuit voltage(V)	36.86

Table 2 Inverter description

Parameter	Specifications
Maximum solar array voltage (V)	105
Maximum efficiency (%)	93
Surge power (kVA)	10
Rated power (kVA)	5
Output voltage (V)	230

3 Economical Operation of Grid-Connected Solar System

Economical operation is essential for the effective and reliable operation of the system. When the solar system generates power which is more than the required load, then this power is sold to the utility. Whereas when the solar system in some environmental conditions generates less power than load, then this power is got from the grid.

The economical operation for the grid-connected solar system is defined as below.

Step 1—Observe the solar system output power.
Step 2—Observe the home load.
Step 3—Calculate the extra power by

$$P_{\text{extra}} = P_{\text{solar}} - P_{\text{load}}$$

Step 4—Calculate the grid power by

$$P_{\text{grid}} = k * P_{\text{extra}}$$

where for lossless system k is equal to 1.
Step 5—Check if, $P_{\text{load}} > P_{\text{solar}}$, then extra power is got from the grid otherwise power is sold out to utility.

P_{extra} is the extra power, P_{solar} is the solar powers, P_{load} is the load power and P_{grid} is the grid power.

By using these steps, economical operation can be achieved. The electric meter is used to calculate the units taken from the grid or sold out to the grid.

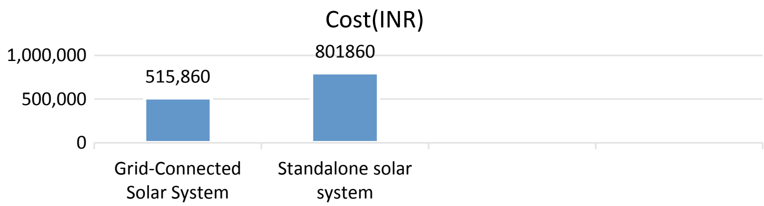

Fig. 2 Cost of the grid-connected solar system and standalone solar system

4 Cost Analysis of Proposed System

Cost of solar panels can be calculated by using the price of a single module. We use the Vikram 270 W Solar Panel Polycrystalline with the cost of 8960 INR. We use 30 modules, and hence, the total cost for the complete panel is equal to 268,800 INR. Whereas the cost of 2 Flin Energy Lite Solar Hybrid Inverter—5 kVA/ 5000 W is equal to 71,000 INR. The system costs (fires, switches, fuses, O&M, etc.) are equal to 128,000 INR approx. The Su-Kam MPPT Solar Charge Controller cost is equal to 48,060 INR. Hence, the total expected grid-connected solar system cost is 515,860 INR.

On the other hand, if the grid-connected system is not used, then an extra battery and battery charge controller is needed. The cost of Exide battery and battery charge controller is 286,000 INR. Hence, the total expected standalone solar system cost is 801,860 INR as shown in Fig. 2. Therefore, we can say that grid-connected solar home-based system gives the saving of 286,000 INR. If solar energy is not accessible, then the system automatically shifts on the main grid and load is supplied by the grid.

5 Results and Discussions

The planned 8 kW grid-connected solar scheme has a peak load of about 8 kW, and therefore, the cost of energy by this system would be 3.15 INR per unit. The expected grid-connected solar system cost is 515,860 INR, and this system is mounted for 25 years. Thus, cost/year would be 20,634.40 INR. The proposed system would provide approximately 20 units per day. The overall bill for these units, when purchased from the grid, is 36,000 INR. By subtracting yearly units' price for the proposed system, we will get the actual saving per year.

$$\begin{aligned}\text{The total saving} &= 36{,}000 - 20{,}634.40 \\ &= 15{,}366\,\text{INR/year}\end{aligned}$$

The performance of 8 kW grid-connected solar system is assessed using PVsyst software. The monthly energy production and maximum global radiation are

Table 3 Different parameters by PVsyst software

Months	GlobHor (kWh/m^2)	Coll. plane (kWh/m^2)	System output (kWH/day)	System output (kWH)
January	3.81	5.70	38.35	1189
February	4.89	6.59	44.31	1241
March	6.07	7.17	48.21	1494
April	6.83	7.04	47.35	1421
May	7.16	6.61	44.46	1378
June	6.55	5.79	38.96	1169
July	5.37	4.86	32.69	1013
August	5.16	4.96	33.32	1033
September	5.69	6.21	41.77	1253
October	5.31	6.76	45.48	1410
November	4.28	6.27	42.14	1264
December	3.71	5.87	39.45	1223
Year	5.41	6.15	41.34	15,088

calculated, and it varies due to the temperature effect on the solar panel. Table 3 shows the different parameters throughout the year plus the effect of shading. The GlobHor is 3.81 for January and 4.28 for November, and this variation displays that this factor also changes throughout the year. The Coll. plane is 5.70 for January and 6.27 for November. This factor does not alteration fast, and this may be about less vary all over the year.

The solar irradiance changes with time as shown in Fig. 3, and this proves that the solar system does not give same output at all time because the cloudy

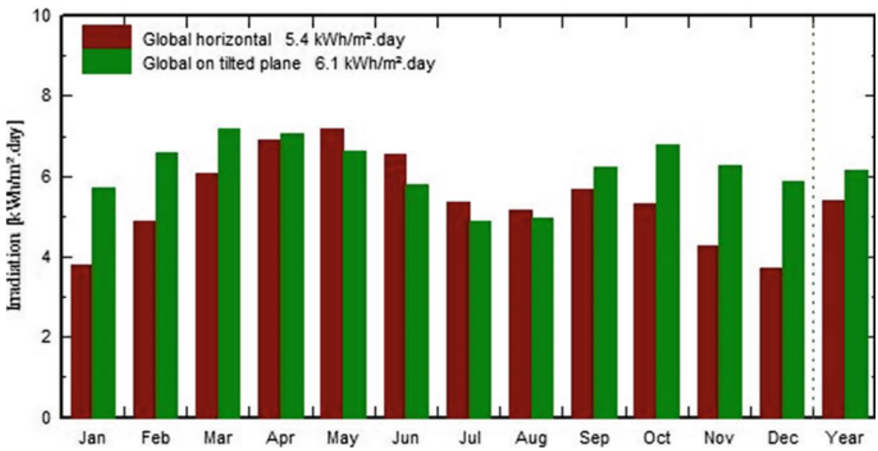

Fig. 3 Solar irradiation variation throughout the year

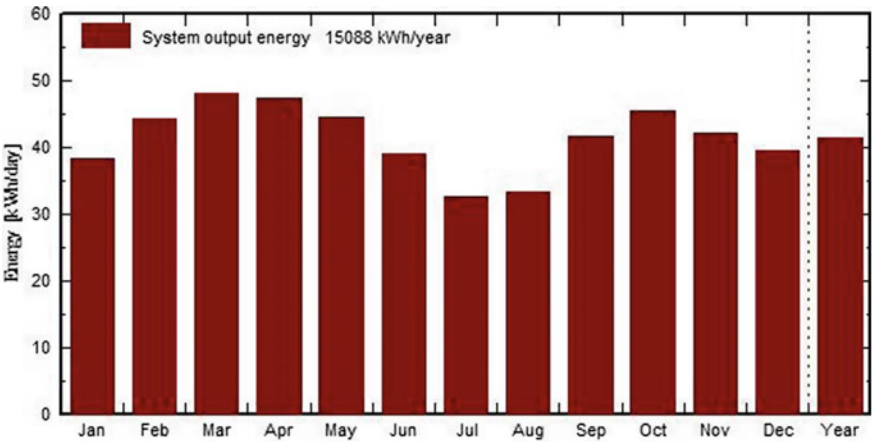

Fig. 4 Output energy distribution during the year

atmosphere varies the irradiance so it is hard to attain the same irradiance throughout the year. Hence, there is a necessity for MPPT manager. MPPT manager provides constant output regardless of the solar irradiance changes.

Output energy distribution is shown in Fig. 4. The output energy varies throughout the year because of the solar irradiance changes with climate conditions. The graph is generated by PVsyst software based on longitudinal and latitude information of the place.

The maximum power of solar modules be determined by the output voltage and current, and it depends on the solar irradiance. Uncertainty solar irradiance is high than maximum power which would be attained easily without using MPPT controller, but due to the restriction of the solar scheme, the irradiance is not constant all the time; hence, MPPT controller is an essential component of any solar-based system.

*1 USD is equal to 68.82 INR as on July 5, 2018.

6 Conclusion

This work presents the economical scheduling and costs analysis of the grid-connected solar home-based system for efficient and reliable operation in the rural area in India. Relating to the grid-connected solar system and standalone solar system that has been used for solar power generation, the outcomes show that the proposed grid-connected solar system is best suitable for the residential purpose in the rural area based on overall cost. The cost/year of the proposed system would be 20,634.40 INR. The overall bill for the same units, when purchased from the grid, is

36,000 INR. Hence, this system gives the total saving 15,366 INR/year. Besides, the performance of 8 kW grid-connected solar system is assessed using PVsyst software.

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