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A CASE STUDY ON DESIGN AND COST ANALYSIS OF A STANDALONE PV SYSTEM FOR A TWO STORIED RESIDENTIAL FLAT IN A TROPICAL REGION

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***Abstract*— The aim of this paper is to estimate the number of different components of a standalone solar PV home system for a two storied residential flat in a tropical region. Based on the assumed connected load, daily energy requirement is calculated and then, a solar PV home system is designed to meet the energy requirement. An economic analysis for installing the designed PV system is also done to estimate the total cost for such standalone system.**

***Keywords*— Standalone PV system, Load Estimation, PV Panels, Inverter, Battery.**

I. INTRODUCTION

The shifting of energy production from fossil fuel sources to renewable energy sources has accelerated significantly in the last decades. Due to the scarcity of primary sources like coal, oil, gas in the nature and their adverse effect on the environment, the importance of promotion of energy production is increasing rapidly. Although a good number of alternative energy sources exists now like solar, wind, biomass, tidal, wave energy etc., solar and wind energy source are playing the key roles to increase the electrical energy production from renewable energy sources [1]. In the tropical countries, the solar energy can be harnessed best due to their geographical location near to the equator. To increase the number of solar energy utilization, it is necessary to adopt solar PV panel system for more number of houses and institutions. Since more number of houses, institutions buildings depend on the solar cell system for electricity production, the dependency on the primary sources will reduce. In this paper, load estimation has been done for a two storied domestic building in a tropical region. Then, a solar PV system is designed for such a building based on the estimated load. Lastly, a cost analysis has been done to install such system.

II. STANDALONE SOLAR PV SYSTEM

A solar PV system which is not connected to any grid or interconnected system and meet the electricity demand in small scale, is known as standalone solar PV system [2-5]. Such system is usually installed in the remote areas where grid connection is not available and the geographical location is suitable for receiving sunlights for the solar panels. The main difference between this system and a grid connected PV system is that a standalone PV system could not exchange power with the grid [6]. Hence, the estimating of loads to which standalone PV system is going to supply electrical power is required to be done while designing such system.

A solar PV cell system takes sunlight as its input and after processing, it generates electrical energy at its output. Solar PV cells are semiconductors where free electrons are created due to the photoelectric effect when sunlight fells upon them. These free electrons are then driven towards a closed circuit and thus, current or electrical energy is produced and fed to the load. So, fundamentally a solar PV consists of solar cell, connecting wires and load. In practical, such system also involves battery, inverter and charge controller device [7-11]. The components of a solar PV system are shown as blocks in figure 1. A charge controller device controls the flow of charge from solar cell assembly to the loads. A battery is required as energy storage in the system so that electricity can be used in case of unavailability of the sunlight. An inverter is required to supply current to ac loads so that it can convert dc energy of battery to ac energy and thus, supply ac loads.

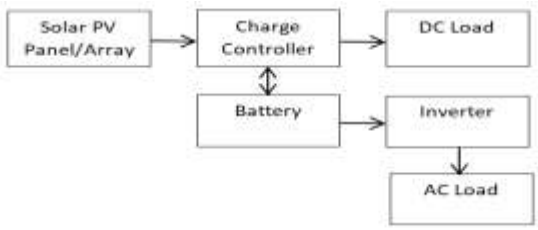

Fig. 1 Block Diagram of a Standalone Solar PV Home System

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III. CASE STUDY

In this paper, a two storied residential building with typical demand in a tropical region has been considered for the load estimation. The designed standalone solar PV system will supply all the loads of that building. To design the system, firstly the total connected load and required energy per day of that building will be estimated. Then, the number of PV panels, battery and inverter size will be calculated based on the load estimation. Lastly, cost estimation for the required components will be done.

A. Load Estimation

In the two storied building, it is assumed that the ground floor consists of a parking garage, one bed room, one kitchen and a washroom for caretaker of the building.

TABLE I

TOTAL ESTIMATED LOAD OF THE BUILDING

Floor Number	**Room**	**Appliances**	**Power (Watt) rating**
Ground Floor	1 garage	1 LED Bulb	10
	1 Kitchen	1 LED Bulb	10
	1 bed room	1 LED tube light + 1 ceiling fan	16+75=91
	1 washroom	1 LED Bulb	10
First Floor	1 kitchen	1 LED Bulb+1 ceiling fan	10+75=91
	3 washroom	3 LED tube light+ 3 ceiling fan	30
	1 living room	1 LED tube light+ 1 ceiling fan + 1 LED TV	16+75+60 =151
	3 bed room	3 LED tube light+ 3 ceiling fan	273
	2 veranda	2 LED light	20
	1 dining room	1 LED tube light+ 1 ceiling fan+ 1 Refrigerator+ 1 water purifier	16+75+400+80= 571
	Other appliance	1 Wi-Fi router+ 5 mobile phone charger+ 3 laptop charger + 1 water pump	5+50+150 +500 = 705
Second floor	1 store room	1 LED Bulb	10
Total connected load			1962

The first floor is the floor where flat owner lives and it consists of four bed rooms, one living room, one dining room, one kitchen, three washrooms and two verandas. The third floor is used as the roof place and contains one store room. The assumed load in different rooms and their power rating are shown in Table I. The total connected load for the building is found as 1962W. Some appliances like air conditioning system, micro oven, and iron are not considered due to their high power rating since it contributes to the increased number of connected loads and maximum inverter size ranges up to 2000 VA usually.

To consider the watt-hour energy required per day, it is assumed that in ground floor, the LED bulb in garage operates for half hour/day, in kitchen six hours/day, in washroom one hour/day, in bedroom the tube light six hours/day and ceiling fan twenty hours /day.

So, the total energy requirement from ground floor = $(10\times 0.5+10\times 6+16\times 6+75\times 20+10\times 1)$ = 1.67 KWh.

In case of first floor, in kitchen, the LED bulb operates 10 hours/day, ceiling fan 8 hours/day; in three washrooms, the LED bulb 3 hours/day; in two verandas, LED bulbs half hour/day; in living room, the tube light six hours/day and ceiling fan twenty hours /day, one TV for 5hours/day; in three bed rooms, the tube light six hours/day and ceiling fan twenty hours /day; in dining room, the tube light six hours/day and ceiling fan twenty hours /day, one refrigerator 24hours/day, one water purifier 24 hours/day; other appliances like internet router 24 hours/day, five mobile phone charger 2 hours/day each, three laptop pc 5 hours/day each, one water pump 3 hours/day and the LED bulb in top floor (roof) half hour/day.

Thus, the total energy requirement from first and second floor $=(10\times 10+75\times 8+3\times 10\times 3+5\times 16+75\times 5+300+3\times 6\times 16+3\times 75\times 12+2\times 0.5\times 10+6\times 40+6\times 75+400\times 24+80\times 24+5\times 24+5\times 2\times 10+3\times 50\times 5+500\times 3+0.5\times 10)\ KWh=12.618\ KWh$

So, the total energy requirement for the whole building = $(1.67KWh+12.618\ KWh)$ = 14.288 KWh.

B. PV system components estimation

The main components of a PV system are solar panel, battery and inverter. To find out the number of PV panels required, peak power rating of solar panel, operating factor and combined efficiency are to be known. The peak power rating of a solar panel is the maximum power output that a solar panel can supply under standard test conditions [12]. The operating factor indicates that the actual power output is always less than the rated power and its value ranges from 0.6 to 0.8 [13]. The combined efficiency is the product of battery efficiency and inverter efficiency. If a 300 Wp (watt peak) solar panel is chosen for the designed system, then the actual output power of the panel = peak power rating of a panel $\times$ operating factor.

Considering 0.75 operating factor in this case, the actual output power of panel = 300 $\times 0.75 = 225W$. Considering, battery efficiency as 0.9 and inverter efficiency as 0.9, the combined efficiency will be = 0.9 $\times 0.9 = 0.81$. Thus, the ultimate power available for end use = the actual output power of the panel $\times$ combined efficiency = 225 $\times$ 0.81= 182.25 W.

Now, considering solar panel gets sunlight 8hours/day on average, energy produced by one 300 Wp solar panel per day = The available end power from panel $\times$8 hours/day = 182.25 $\times$ 8 = 1458 Wh.

Number of solar panels required to satisfy the estimated daily load = (total watt-hour rating daily load / Daily energy produced by a panel) = (14288 Wh / 1458Wh) = 9.8 $\approx$ 10.

To calculate the required number of batteries, total ampere hour rating is required. Total amp-hour required = Total watt-hour rating/ (inverter efficiency $\times$ Depth of discharge $\times$battery voltage). Depth of discharge of a battery indicates the useful amount of charge of that battery. Considering the battery voltage as 48V, amp-hour rating as 310 Ah and depth of discharge as 0.8, total amp-hour required = 14288/ (0.9$\times$0.8$\times$ 48) = 413.43 Ah. Thus, the number of batteries required = (total ampere hour required / battery rating under use) = (413.43/310) = 1.33$\approx$ 2.

Inverter size depends on total connected load. As the total connected load is 1962W in this case, a 2000VA rated inverter can be chosen. So, the required PV system components are 10 solar panels (300Wp), 2 batteries (48V, 310Ah) and 1 inverter (2000VA).

C. Cost Analysis

Considering, the cost for a monocrystalline 300 Wp solar panel is 60$ [14]; 48V, 310Ah $LiFePO_4$ battery is 100$ [15]; 2000W inverter is 320$ [8], the total cost for ten panels, two batteries and two inverters= 60$ $\times$10+ 100$$\times$2+320$ $\times$1= 1120$. If additional cost of wirings and supporting structures are 6% of total cost, then it will be = 1120$ $\times$ 6% $\approx$ 67$. So, the final cost can be calculated as (1120$+67$) or, 1187$.

IV. CONCLUSION

In this paper, the components required for a solar PV system has been estimated for a two storied residential flat in a tropical region. For the assumed 1962W connected load, the main required components are 10 solar panels of 300 Wp, 2 batteries of 48V, 310Ah and 1 inverter of 2000VA. The total estimated cost for installing the designed system is 1187$. So, such standalone system can be installed conveniently for two storied residential flat for the assumed load types.

V. REFERENCE

[1] Ahmed T. (2015). The prospect of renewables of Bangladesh: A study to achieve the policy goal, In 3rd International Conference on Green Energy and Technology (ICGET), pp. 1-6. IEEE.

[2] Ali W., Farooq H., Rehman A.U., Awais Q., Jamil M., and Noman A. (2018). Design considerations of stand-alone solar photovoltaic systems. In International Conference on Computing, Electronic and Electrical Engineering (ICE Cube), pp. 1-6. IEEE.

[3] Kolhe, M., Kolhe, S., & Joshi, J. C. (2002). Economic viability of stand-alone solar photovoltaic system in comparison with diesel-powered system for India. Energy economics, 24(2), 155-165.

[4] Huang, B. J., Hsu, P. C., Wu, M. S., & Ho, P. Y. (2010). System dynamic model and charging control of lead-acid battery for stand-alone solar PV system. Solar Energy, 84(5), 822-830.

[5] Kolhe, M. (2009). Techno-economic optimum sizing of a stand-alone solar photovoltaic system. IEEE transactions on energy conversion, 24(2), 511-519.

[6] Shukla, Kumar A., Sudhakar K. and Baredar P. (2016). Design, simulation and economic analysis of standalone roof top solar PV system in India.Solar Energy 136 437-449.

[7] Kumar, N. M., Subathra, M. P., & Moses, J. E. (2018, February). On-grid solar photovoltaic system: components, design considerations, and case study. In 2018 4th International Conference on Electrical Energy Systems (ICEES) (pp. 616-619). IEEE.

[8] Mohanty, P., Muneer, T., & Kolhe, M. (Eds.). (2016). Solar photovoltaic system applications: a guidebook for off-grid electrification. Springer International Publishing.

[9] Baharwani, V., Meena, N., Dubey, A., Brighu, U., & Mathur, J. (2014). Life cycle analysis of solar PV system: A review. International Journal of Environmental Research and Development, 4(2), 183-190.

[10] Alsafasfeh, Q., Saraereh, O. A., Khan, I., & Kim, S. (2019). LS-solar-PV system impact on line protection. Electronics, 8(2), 226.

[11] Amelia A. R., Irwan Y. M., Leow W. Z., Irwanto M., Safwati I., and Zhafarina M. (2016). Investigation of the effect temperature on photovoltaic (PV) panel output performance.Int. J. Adv. Sci. Eng. Inf. Technol 6, no. 5 682-688.

[12] Solanki C. S.(2008), Renewable energy technologies: A practical guide for beginners. PHI Learning Pvt. Ltd..

[13] https://www.alibaba.com/showroom/300wp-solar-panel.html

[14] https://www.alibaba.com/showroom/48v-solar-system-battery.html

[15] https://www.aliexpress.com/popular/solar-inverter-2000w-20a.html