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Designing of Solar PV Energy System A Review

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Abstract
Energy demand is growing day by day, but depletion of fossil fuels and increasing pollution affect the environment and climate. Renewable energy resources are one of the best alternatives for clean and green energy. The development of such resources gives application to electrify the rural and remote areas. This study concentrates on solar energy which is a promising renewable energy source to fulfill the rural and remote areas energy demand. In India, solar energy is available 300 days for 7-8 hours; also it is a cost free fuel and requires low maintenance. This paper studies the various researches done to enhance the performance of solar energy extraction system.

Keywords: Renewable resources, solar PV energy system

1. Introduction
In today's scenario energy sources are depleting, which is the biggest problem for future. As energy demand and green house gas emission are increased, it gives rise to clean and green energy sources [1]. In India, the demand of electricity increasing continuously and the per capita energy consumption has reached 1075 kilowatt-hour (kWh) in 2015-16, followed by 1010 kilowatt-hour (kWh) in 2014-15, 957 kWh in 2013-14 and 914.41 kWh in 2012-13[2]. One fourth of the domestic consumers in the country still have no access to electricity, mainly in some states of East & North East less than 30% people with electricity access.

India's per capita electricity consumption is comparatively low among the world. In comparison, China has a per capita power consumption of 4000 kWh, with developed nations averaging 15,000 kWh per capita. For better development of country it is necessary to decrease un-electrification and should improve quality supply of electricity. For this purpose, solar energy can be used as it can be easily installed in rural and remote areas [3].

Solar energy is the promising source of clean and green energy generation [4]; in India it is available 300 days for 7-8 hours per day, also non-polluting and maintenance free. It becomes more successful especially when connected to grid [5]. It has attractive feature that its power output matches entirely with the peak load demand. It produces more power in sunny days [6]. Solar energy is increasingly taken as effective source of electrification, mainly for the areas where electric supply from power grid is not enough to fulfill consumer demand [7], also it give opportunity to build environmental friendly solar PV energy system [8]. It can be operate in two modes grid connected and stand alone, grid connected system has successful consumption of generated power as there is no storage losses but in case of standalone system batteries are required to store energy or it can be directly connected to load [9]. Solar PV energy system has many more advantages, although it's very costly to install but it is cheaper to maintain [10], [11].

Solar PV energy system works on the principle of conversion light energy into electrical energy by photovoltaic cell. PV arrays produces electricity when exposed to sunlight, in addition other components are also required to properly conduct, control, covert, distribute and store produced electrical energy by PV arrays. Depending on the functional and operational requirements, the main components required are DC-AC power inverter, battery storage, battery controller and electrical load.

For some loads, a maximum power point tracker (MPPT) known as DC-DC converter is used in between PV arrays and load to help better utilize the available array maximum power output. This paper includes solar PV energy system, modeling of solar PV energy system, hardware and software techniques to design required system.

2. Solar PV Energy System

Solar PV energy system is usually designed according to their functional and operational requirements, which also verify the connection of configured equipments to other power source and electrical loads [12]. The two main classification of this system are grid-connected and standalone system which are discussed below.

2.1. Stand-alone Solar PV Energy System

Stand-alone solar PV energy systems are designed to operate in autonomous mode other than electric utility grid, and are usually designed and sized to supply certain DC and AC electrical loads. The simplest form of this system is a direct-coupled system, where the DC output of a PV module or array is directly connected to a DC load and it is not contain any storage system, thus load can operates only during sunshine hours due to which it is only suitable for common applications such as ventilation fans, water pumps, and small circulation pumps for solar thermal water heating systems [12]. Now days in many stand-alone solar PV energy systems, batteries are used to store energy produced by the PV array during the day and to supply it to loads as needed, during the night and periods of cloudy weather.

2.2. Grid Connected Solar PV Energy System

Grid connected solar PV energy system are designed to share power with main grid to enhance the generation capacity and to decrease the power chopping and also maintain the efficiency of system [9]. These modules connected with MPPT & grid inverter which convert DC power to AC power to feed into the public utility grid. When system is connected to grid, initially the generated power supplies to the owner's load then access power is shared with public grid at a defined feed-in –tariffs [5].

3. Modeling of Solar PV energy System

Modeling of solar PV energy system includes PV module sizing, converter sizing, battery sizing and module circuit design. It also required geographical details such as solar radiation and temperature.

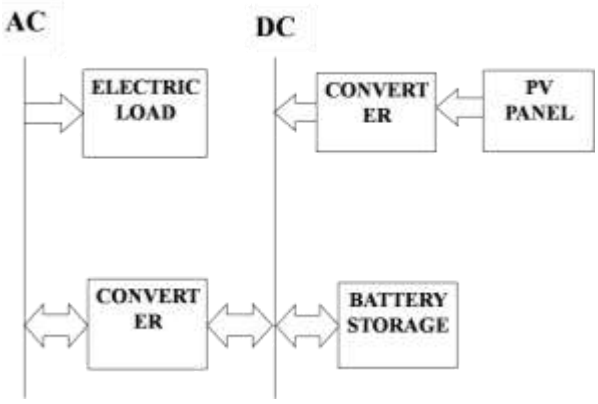

Fig. 1 Solar PV Energy System

3.1. Solar PV Module Sizing

Modeling of solar PV energy system requires PV module which sized according to panel generation factor, energy required by load, watt peak rating and number of PV module [8].

3.1.1. Panel generation factor

Panel Generation Factor is a key element in designing a solar PV energy system which gives for every watt peak rating (W_p) capacity in the panel to get an average of Wh/day and it is different in each site location.

$$f_{pg} = \frac{G(t)}{G_{STC}} \quad \ldots\ldots (1)$$

Where,

f_{pg} = Panel generation factor

$G(t)$ = Solar radiation in kW/m^2

G_{STC} = Solar radiation under standard test condition in W/m^2

3.1.2. Energy required from PV modules

Energy required from PV modules will be daily energy demand of load and compensation for the system losses which is generally taken as 30%, therefore the total energy required will be

$$E_{pv} = E_d * f_{pv} \quad \ldots\ldots (2)$$

Where,

f_{pv} = System losses compensation factor
E_{pv} = Energy required from PV panel in kWh
E_d = Energy demand in kWh

3.1.3. Watt Peak rating for PV modules

Total Watt peak rating for PV modules is calculated to identify system sizing which depends on the energy required from modules and panel generation factor

$$W_p = E_{pv} * f_{pg} \quad \ldots\ldots (3)$$

Where,
W_p = Total watt peak rating in kW
E_{pv} = Energy required from PV panel in kWh
f_{pg} = Panel generation factor

3.1.4. PV modules

The total number of modules required is depend on the peak rating of the module

$$N_{pv} = \frac{W_p}{P_{pv\_r}} \quad \ldots\ldots (4)$$

Where,
W_p = Total watt peak rating in kW
N_{pv} = Total number of modules in the solar field
P_{pv_r} = Peak rated power output in kW

3.2. Battery sizing

For solar PV energy system the batteries are common storage medium to operate appliances in night and cloudy days, also it should be large enough to store sufficient energy. Battery capacity can be defined as state of charge and is given by:

$$\text{SOC} = \frac{[E_{d\_r} * \text{DOA}]}{[V_{\text{b\_n}} * (1-DOD) * \eta_b]} \quad \ldots\ldots (5)$$

Where,
SOC = State of charge of battery in Ah
DOA = Day of autonomy
DOD = Depth of discharge of battery
E_{d_r} = Energy required in Wh
$V_{\text{b\_n}}$ = Nominal battery voltage in V
η_b = Battery efficiency

Number of Batteries required:

The total number of batteries requirement is depends on the capacity of each battery.

$$N_b = \frac{SOC}{SOC_1} \quad \ldots\ldots (6)$$

Where,
SOC = State of charge of battery in Ah
SOC_1 = State of charge of single battery in Ah
N_b = Number of batteries required

3.3. Inverter rating

Size of the inverter is depends upon the peak load requirement and it should be large enough to handle the total amount of watts peak requirement. Practically inverter size should be 25%-30% bigger than total watts requirement.

$$W_{i\_size} = P_{p\_1} * f_{pv} \quad \ldots\ldots (7)$$

$$N_i = \frac{W_{i\_size}}{P_{i\_r}} \quad \ldots\ldots (8)$$

Where,
W_{i_size} = Inverter size in kW
P_{p_1} = Peak load requirement in kW
P_{i_r} = Rated power of an inverter kW
f_{pv} = System losses compensation factor
N_i = Number of inverters

3.4. Module circuit

It means the number of modules to be connected in series to form an array. They are connected in series and parallel depending upon the solar PV arrays to generate DC power directly from the sun's intercepted solar power.

$$N_{ms} = \frac{V_{moi}}{V_{oc\_pv}} \quad \ldots\ldots (9)$$

$$V_{mii} = V_{mm} * N_{ms} \quad \ldots\ldots (10)$$

$$N_a = \frac{N_{pv}}{N_{ms}} \quad \ldots\ldots (11)$$

Where,
V_{moi} = Maximum open circuit voltage of inverter
V_{oc_pv} = Open circuit voltage of each PV module
V_{mii} = Maximum voltage input to the inverter
V_{mm} = Maximum voltage from a module
N_{ms} = Number of modules in series in an array
N_{pv} = Total number of modules in the solar field
N_a = Total number of Arrays in the solar field

4. Various Techniques to design PV System

For performance analysis of Solar PV energy system, it can be designed by various ways, it may be physical model using PV panels or can be designed by using any software modules such as HOMER, PVsyst, SolarMAT, SolarGIS, MATLAB simulation etc. many researches had been done in past. Some are discussed as follows: -

4.1. Software model of PV System

Various softwares like HOMER, PVsyst, SolarGIS and SolarMat has been used to design a solar PV energy system and also evaluate the performance of various solar PV energy systems. Author evaluated the technical performance of 110KWp roof top grid connected solar PV energy system in MANIT hostel at the location 10 Km North in Bhopal, India. Also four types of PV modules had been simulated to verify the performance ratio and energy yield. The inclined fixed modules configuration at angle of 25 in any system had major problem of tracking the sun according to PV modules. This problem is overcome by using SolarGIS PV planar software. The author considered two configuration i.e. two axis tracking configuration and horizontal surface with annual degradation rate as (1%-0.5%) and fixed module angle of 23 to maximize the irradiance received by PV modules. At last the author concluded that the module receive 123% more solar radiance in a two axis tracking configuration and as much as 92.1% solar radiance in horizontal surface. The Performance Ratios of PV system varies from 70%-88%, but only two PV modules i.e. amorphous-silicon (a-Si) module and Cadmium telluride (Cd-te) module has PRs above than 75% and energy yield of all PV system ranges from 2.67 kWh/kWp to 3.36 kWh/kWp. It is also observed that simulated PV system has satisfactory performance in tropical weather conditions [5]. Analysis of the performance of a 2KW stand alone PV system in Dhaka, Bangladesh is done by using PVsyst, HOMER and SolarMAT and compared results of them. In case of PVsyst there is discrepancy with practical data to a small level. And result shows by SolarMAT have a great similarity with practical data. The graphs and diagram obtained by PVsyst is highly instructive whether SolarMAT provides a quite straight forward result and contains only basic functionality. For a detailed design and economical analysis of a stand-alone or grid tie system PVsyst is a good choice. HOMER would be preferable for hybrid solar system design, optimization and sensitivity analysis. But SolarMAT as a freeware tool can be a reliable choice for simple design. However SolarMAT will be more developed to meet the increasing demand of computer based design and analysis of solar system. There are a lot of scopes to make it better in future. Like economical analysis can be added with it. Adding geographical database for other countries, analysis of hybrid PV system along with stand-alone solar PV energy system and more user friendly GUI will make SolarMAT more effective [6]. Author estimated a design of a 336 kW_p Solar PV plant in the area 4816m^2 for girl's hostel of MNIT University in Jaipur city and examines its financial feasibility with parameters connected and real time market prices. It is required to analyze all the parameters carefully before installing solar PV energy system in any area as current market scenario with low cost of renewable technology would affect the feasibility of financial parameters. The cost of the land required for project installation is also a considerable factor [8]. Evaluation of the performance included seasonal variation of solar PV energy system and technical performance of 10 MW PV grid connected power plant installed in Ramagundam, India, evaluated results then compared with simulated results generated by PVSyst and SolarGIS softwares [9]. Performance and cost factors are evaluated by using PVSyst of 1kw stand alone solar PV energy system designed for small homes in rural areas sited in India. Here the author found that the generated energy is not properly consumed or stored, as the huge amount of generated energy is used by consumers but the balance amount had been waste due to full condition of batteries or due to low demand period [10]. Study analyzes the sizing of various components connected in standalone solar PV energy system which is used to supply power to small and remote installation. Sizing is achieved by using two softwares i.e. PVsyst and Homer [11]. MATLAB simulink model is used to investigate partial shading on mismatch losses in long strings of 18 PV cells in series and three short strings of 6 PV cells each in parallel, based on investigation found that connection should be minimized in order to increase energy yield solar PV energy system which are lies to partial shading condition [13].

4.2. Hardware model of PV System

Based on the load requirement and output voltage requirement, PV modules are connected in series and parallel combination to form an array and then connected to various hardware components to form solar PV energy system, which further used for various applications like water heater, ventilations,

heating purpose etc. A project of rooftop grid connected solar PV system of 1KW discussed in Puducherry, India; it shows two configurations either with battery backup or without battery backup. It analyzed the two ownership option with meter arrangement followed by gross and net metering system. Author considered the estimated cost of power injected to grid @ $5.50 Rs/Unit$, assuming that consumers would pay for their consumption charges as per the existing tariffs /slab rates. Although estimated installation cost should be 1.95 lakh with battery backup and 1.67 lakhs without battery [4]. An extensive survey related to solar PV energy system done in north, eastern and north-eastern part of India. There comparative analysis presents for four prevalent solar lightning technologies, namely Solar home system, solar charging system, solar AC mini grid and solar DC micro grid, study focused on technical, financial and environmental issues in rural household electrification [7]. The result of the survey gives the main issue lack of technical assistance regarding maintenance required for PV panel due to which number of solar PV energy systems are either not working efficiently or not in working condition.

5. Conclusion

This papers discuses about the increasing use of renewable resources and concentrated on solar energy to electrify the remote and rural areas. It includes modeling of solar PV energy system in two modes; i.e. in stand-alone and grid connected mode. In case of stand-alone system energy storage system is must to maintain reliability of system, however in case of grid connected system it can provide frequent supply to load. Also study various techniques which are helpful for development of solar PV energy system. Various softwares like Homer, PVSyst, SolarMat and SolarGIS had been used to analyze performance of solar PV energy system and also used to design solar PV energy system.

References

1. N.B. Desai, S. Bandyopadhyay, J.K. Nayak, R. Banerjee, S.B. Kedare, **"Simulation of 1MWe Solar Thermal Power Plant"**, *2013 ISES Solar World Congress, Energy Procedia 57*, pp. 507 – 516, 2014.
2. Rakesh Dubbudu, **"Report shows on India's per capita electricity consumption lowest among BRICS nation"**, May 10, 2016.
3. Utpal Bhaskar, **"Report shows on India's per capita electricity consumption touches 1010 kWh"**, July 20, 2015.
4. Ramakrishna Kappagantua, S. Arul Daniel, M. Venkatesh, **"Analysis of Rooftop Solar PV System Implementation Barrier in Puducherry Smart Grid Pilot Project"**, *Smart Grid Technologies, Procedia Technology 21*, pp. 490 – 497, August – 2015.
5. Akash Kumar Shukla, K. Sudhakar, Prashant Baredar, **"Simulation and performance analysis of 110kwp at manit hostel Bhopal, India"**, *Energy Reports 2*, pp. 82–88, 2016.
6. Md. Sifat Morshed, Shoaib Mohammad Ankon, Md. Tanzil Hoque Chowdhury, Md. Anikur Rahman, **"Designing of a 2kw stand alone PV system in Bangladesh using pvsyst, homer solarmat"**, *IEEE Transaction*, 2015.
7. Rishi Raj Borah, Debajit Palit, Sadhan Mahapatra, **"Comparative analysis of solar photovoltaic lighting systems in India"**, *ICAER 2013, Energy Procedia 54*, pp. 680 – 689, 2014.
8. Rahul Khatri, **"Design assessment of solar PV plant for girls hostel (GARGI) of MNIT Jaipur"**, *Energy Reports 2*, pp. 89–98, 2016.
9. B. Shiva Kumar, K. Sudhakar, **"Performance evaluation of 10 MW grid connected solar photovoltaic power plant in India"**, *Energy Reports 1*, pp. 184–192, 2015.
10. Shahzad Ahsan, Kashif Javed, Ankur Singh Rana, Mohammad Zeeshan, **"Reports shows on Design and cost analysis of 1kW Photovoltaic system based on actual performance in Indian scenario"**, June 11, 2016.
11. C. O. Osueke, E. M. Obiora, **"Design of a solar power system for optimal output"**, *International Journal of advanced engineering science and technologies*, vol. 11, issue no. 1, pp. 232 – 237, 2011.
12. Henerica Tazvinga, Tawanda Hove, **"Photovoltaic/ diesel/ battery hybrid power supply system, generator component sizing and energy performance analysis"**.
13. Anssi M¨aki, Seppo Valkealahti, **"Power Losses in Long String and Parallel-Connected Short Strings**

of Series-Connected Silicon-Based Photovoltaic Modules Due to Partial Shading Conditions", *IEEE Transaction on Energy Conversion*, vol. 27, no. 1, pp. 173-183, March 2012.

14. Yu Ru, Jan Kleissl, Sonia Martinez, **"Exact sizing of battery capacity for photovoltaic systems"**, *European Journal of Control*, pp. 1-14, 2013.
15. Payal Suhane, Saroj Rangnekar, Arvind Mittal, **"Optimal Configuration of Wind/ Solar/ Diesel/ Battery Hybrid Energy System for Electrification of Rural Area"**, *IOSR Journal of Electrical and Electronics Engineering*, vol. 10, Issue 3, pp. 23-31, May – Jun. 2015.
16. Payal Suhane, Saroj Rangnekar, Arvind Mittal, **"Optimal Sizing of Hybrid Energy System using Ant Colony Optimization"**, *International Journal of Renewable Energy Research*, vol.4, no.3, 2014.

