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Optimal energy performance and comparison of open rack and roof mount mono c-Si photovoltaic Systems

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Abstract

Optimal energy performance of a 5 kWp mono crystalline silicon (mono c-Si) photovoltaic system is evaluated in this paper. This analysis is carried out for six different Indian cities. A photovoltaic system with similar electrical configuration and other loss parameters with two different installation methods is simulated. These installation methods includes open rack and roof mount array with fixed orientation and optimal tilt angle. The simulation is carried out using NREL software tool i.e. PV Watts with available solar radiation data resource and with appropriate plant specifications for each city separately. Results shows the comparative analysis of PV electricity yield of open rack and roof mount PV array on monthly and annual basis. Apart from the energy yield, performance factor i.e. capacity factor of simulated PV system for each location with two different installation methods also evaluated and compared.

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Keywords: PV electricity; mono c-Si PV modules; Optimal tilt angle; Open rack PV array; Roof mount PV array.

1. Introduction

Environmental issues that are concerned with the development of power and energy sector are the essential factors to be considered and focused in fast growing nations especially in developing counties like India [1].

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Development in power and energy sector relating to generation, transmission and distribution are mandatory for meeting the present day increased energy demand.

In order to have an efficient and reliable power generation, transmission and distribution sufficient measures are to be taken. At present, fossil fuels are being used in most of the power generating stations in India, which leads to low security, environmental and economic problems [1]. Apart from generation side, there are many problems like reliability, and power losses associated with the transmission and distribution (T & D) networks. Laying this T & D network is complicated in most of the places especially in hilly areas, more urbanized towns, and cities built without any proper planning and future scope for electricity. But to overcome the problems associated with present power and energy sector in meeting the load demands, distributed generation using renewable energy resources could be adopted [2, 3].

An alternate to fossil fuels are renewable energy resources which are more effective and opting them for power generation is an efficient way due to their ecofriendly nature [4]. These renewable energy resources can be installed in any location which avoids uncertainties in power supply and backup needs to meet high power load conditions during the normal working or maintenance periods. Among these renewable energy resources, solar energy has gained its importance and widely used for power generation in most of the tropical regions especially in countries like India [5]. Here, solar energy is opted as a study area to analyze its pre-feasibility and performance at different locations in India with respect to weather conditions of a location, load requirement, tilt angle, installation configuration, PV module and other electrical components used. Hence the selection of PV electricity generation has several constraints to capture energy from the environment, which varies from location to location. Hence this needs an extensive simulated studies for estimating the energy potential and performance of solar power plant [6, 7]. Now a days, NREL enables us to use advanced solar power plant design and modelling tools as an open source option for estimating the energy performance [8].

This paper is organized as follows: Section 1, describes the need for opting renewable energy sources mainly solar energy and the constraints to be considered for analyzing the prefeasibility. Section 2, gives the brief overview of the previous works related to present study area in analyzing the PV system performance. Section 3, describes the brief outline and components used in open rack and roof mount PV systems. Section 4, describes the optimal sizing of 5 kWp PV system considering the mono c-Si PV modules and two different installation methods (open rack and roof mount). Optimal tilt angle for two types of fixed installations is also analyzed using NREL tools. Section 5, describes the results and discussions related to the energy performance of mono c-Si PV system for five Indian cities. Finally the paper ends with conclusions summarized in Section 6.

2. Literature review

Manufacturer assigns power ratings to the modules they manufacture and it was calculated based on the standard testing conditions (STC), but this power rating will vary when PV modules where exposed to normal working conditions. Hence the performance of a PV system will vary from location to location and module to module. Apart from this PV system performance will also vary as per the installation adopted. This gives a scope for analyzing the performance of PV systems in a region with appropriate installation methods using simulation method.

A review on research activity involved in analyzing the pre-feasibility and performance of photovoltaic systems is studied. Benjamin Kroposki et al. investigated the performance of photovoltaics modules using six numerical equations for Golden in Colorado State, U.S.A and suggested realistic reporting conditions (RRC) method, which works efficiently in calculating monthly and annual energies of PV modules for actual solar radiation data [9]. A. J. Carr et al. presented the comparative performance of various PV modules over a temperature climates 16.5°C to 28°C and identified the performance of modules slightly deviating from its original rating [10]. R. P. Kenny et al. proposed an approach based on standard tests for energy output of a mono c-Si modules considering the solar radiation and the effect of ambient temperature. This approach showed a better accuracy when applied to mono c-Si in practical measurements of energy production [11]. A. Hunter Fanney et al. used computer simulation tools for predicting the energy production of various module under various environmental conditions. This simulation tools gave better scope in characterizing the module performance at outdoor conditions [12]. Christopher P. Cameron et al. used NREL simulation tools especially SAM, PV Watts., PV MOD for analyzing the performance of PV modules available in NREL data base and whose results were in permissible limits of measured performance done practically