Energy for Sustainable Development 47 (2018) 17–22

Contents lists available at ScienceDirect

Energy for Sustainable Development

Operational Testing of Rooftop SA-SPV System in Coastal Tropical climate of India

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ARTICLE INFO

Article history:
Received 1 August 2018
Revised 14 August 2018
Accepted 17 August 2018
Available online xxxx

Keywords:
Stand-alone SPV system
Reference yield
Array yield
Final yield
Performance ratio
Load ratio

ABSTRACT

In the present work, we report results of operational testing of a rooftop stand-alone solar photovoltaic (SA-SPV) system of capacity 6.75 kW_p over a period of one year. The performance is measured in terms of daily energy yield from SPV array, daily energy output from the battery energy storage (BES) and the inverter. The system's gross annual energy yield is 6069.68 kWh, and corresponding daily average energy yield is 16.58 kWh/day. The annual average reference yield, array yield and final yield of the system are 5.47 h/d, 2.44 h/d and 2.38 h/d, respectively. The annual performance ratio (PR) and capacity utilization factor (CUF) of the system are computed as 43.58% and 10.24%, respectively. The PR of the SA-SPV system is compared with other SA-SPV systems located in different climatic regions.

Introduction

In the present work, we have carried out operational testing of 6.75 kW_p rooftop SA-SPV system, installed for street-lighting loads on the campus of our Institute, over a period of one year. Using the actual measured data, the performance of the system is analyzed as per IEA guidelines (IEA (International Energy agency), 2014). The present work is the first attempt to investigate performance of SA-SPV system in coastal tropical state of Goa, India. The performance of the system is measured in term of PR and is compared with SA-SPV systems located in other regions. The results will be useful for future expansion of SPV system capacity in the state.

Description of climate in Goa and the site of SA-SPV System

Goa is the smallest state in India covering 3702 km^2 area lying between latitudes 14°53′54″ N and 15°40′00″ N, and longitudes 73°40′33″ E and 74°20′13″ E. Goa features tropical climate which is hot and humid for most of the year. The climate of Goa is divided into three seasons: Southwest monsoon period (June – September); post monsoon period (October – January) and fair weather period (February – May). There are no extremes in temperature and no clear demarcations from one season to the other except for the monsoon. The monsoon is the main feature of the climate of Goa. The wettest month is July with an average of 99.5 cm of rain. The annual average rainfall in Goa is approximately 23.44 cm. Also, Goa receives abundant solar energy for minimum 300 days in a year. The maximum hours of sunshine per day is as high as 9 to 10 h during summer month and the minimum sunshine hours per day is 3 to 5 h during the monsoon months. During the two months preceding the onset of the monsoon the humidity increases dramatically, and normally clear skies become hazy and then cloudy.

The SA-SPV system is mounted on roof of a small building housing a Power Control Centre (PCC), located on the campus of our Institute. The PCC is one of the four power distribution centres on campus, servicing different electrical loads, including single phase load due to street lights. The specifications of the location of rooftop SA-SPV system is shown in Table 1.

The weather monitoring system installed near the SA-SPV system, (Make: Dynalab Weathertech Pvt. Ltd.), is used to measure Global Horizontal Irradiance (GHI), atmospheric temperature, relative humidity and wind speed over an interval of every 5 min throughout the year from January, 1st to December 31st, 2016. Meteorological data at the site measured using Dynalab Weathertech at the site during year 2016 is shown in Table 2.

Description of Rooftop SA-SPV System

The SA-SPV system is mounted on roof of a small building for power control centre (PCC) in local distribution grid on campus of our institute. The system was installed and commissioned in December 2015. The total capacity of rooftop SA-SPV system is 6.75 kW_p, which consists of two

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https://doi.org/10.1016/j.esd.2018.08.005
0973-0826/

Table 1
Specifications of the site of the rooftop SA-SPV system.

Site	State, country	Latitude at the site	Longitude at the site	Inclination of the panel	Region
BITS Pilani, K.K. Birla Goa Campus	Goa, India	+15.39° N	+73.78° E	21°	Western Ghats, coastal region

Table 2
Meteorological data at the site.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Daily solar radiation (GHI) (kWh/m^2/day)	5.21	5.92	6.40	6.56	5.94	4.87	4.7	4.7	5.0	5.34	5.15	5.08
Clearness index	0.639	0.657	0.648	0.621	0.554	0.456	0.441	0.445	0.495	0.580	0.619	0.646

Table 3
Specifications of rooftop SA-SPV system.

System	Manufacturer and name	Specifications
PV panel	Waaree Pvt. Limited	Rated power (P_R) = 250 W_p, open circuit voltage (V_{OC}) = 43 V, short circuit current (I_{SC}) = 7.75 A, efficiency of panel (η_p) = 15.4%, area of the panel (A_p) = 16.643 m^2
MPPT charge controller	Schneider make - Schneider Conext MPPT 60150	Battery operating voltage = 0 to 80 V, nominal battery volatge = 48 V, max. charge current = 60 A, max. output power = 3500 W, efficiency = 98%
Inverter	Schneider make - Schneider Electric model XW+ 7048 E	Output power = 4500 W, frequency = 50/60 Hz, output voltage = 230 V, input DC voltage range = 40 to 64 V
Battery	Exide – 6SGL 40	Nominal volatge = 2 V, capacity = 800 Ah, type = C10, 1.75 V/cell, max. discharge current = 240 A
Control and monitoring unit	Schneider make - Xantrex XW System Schneider make - Conext™ ComBox	System setting operator - connected to MPPT charge controller and inverter Data logging facility – micro SD card or online monitoring – connected to Xantrex XW System
Pyranometer	Dynalab Weathertech Pvt. Limited	Spectral range = 0.3 to 3 μm, sensitivity = 4 mV/kW/m^2, time constant <22 s, output = Watts/m^2

arrays of SPV panels, namely, Array-1 (3 kW_p) located in front, and Array-2 (3.75 kW_p) located behind Array-1. The two arrays are connected to two MPPT charge controllers, which extract maximum power available and deliver to battery bank. The battery bank consists of twenty-four gel type batteries. The DC energy stored in the battery bank is converted to AC energy using an inverter to provide power to street lighting loads (3 kW) on campus upto maximum 11 h during night time. Fig. 1 explains the schematic layout of rooftop SA-SPV system installed in the campus.

The Array-1 and Array-2 are installed at height of 3 m above ground (Fig. 2). The other sub-systems: viz., MPPT charge controllers, inverter, DC junction box, control and monitoring unit and data logger (Fig. 3) and battery bank are placed inside the room beneath the arrays. The specifications of rooftop SA-SPV system are listed in Table 3. The arrays are installed at fixed inclination at inclined angle of 21° facing south. The arrays are positioned such that mutual shadowing of panels is eliminated.

Operation of rooftop SA-SPV system

The rooftop SA-SPV system is installed for the purpose of streetlighting on campus, for a period maximum upto 11 h during night time. The balance of system consists of battery bank, control and monitoring unit for selecting operational modes of the inverter to operate as stand-alone mode or grid-interactive mode. In the present work, the operational testing of the system is carried out in stand-alone mode for a period of one year from January to December 2016. The energy generated from both SPV arrays is fed to MPPT charge controllers to harvest maximum current which can be fed to the battery bank.

The system is provided with automatic timer which controls turning ON of streetlights during night time. During operational testing, the automatic timer is set to turn ON the inverter at 7 P.M. and turn OFF the inverter at 6 A.M. The MPPT charge controller cuts off charging current to battery bank when maximum voltage cut-off level is attained i.e.

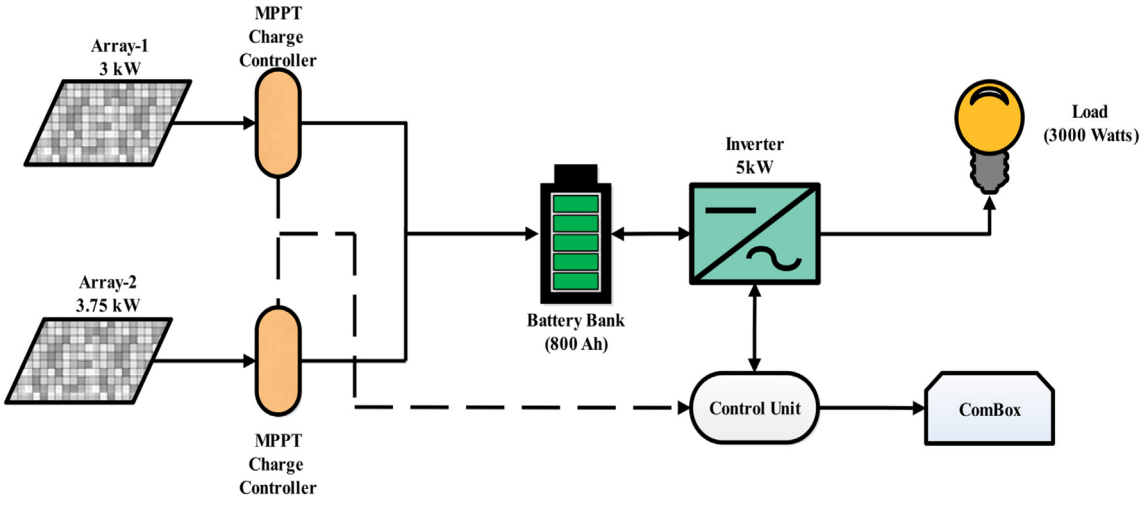

Fig. 1. Schematic layout of rooftop SA-SPV system installed at PCC on the campus.