Renewable and Sustainable Energy Reviews 82 (2018) 205–214

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

First smart 8.64 kW BIPV in a building in Awali Town at Kingdom of Bahrain

Naser W. Alnaser

Department of Architecture and Interior Design, College of Engineering, University of Bahrain, P O Box 32038, Isa Town, Bahrain

ARTICLE INFO

Keywords:
BIPV
Solar electricity,payback
Bapco
Bahrain
Micro inverters

ABSTRACT

The performance of 18 months of 86.4 kW smart PV solar panels integrated in a building in Sadeem Building at Awali Town (middle of a desert area) in the kingdom of Bahrain is reported herein. The PV system covers an area of 59 m^2 (36 PV panels) and was installed on a roof titled by 25° and facing 225° (45° west of south). The panels are cleaned by sweet water every 2 months and it requires around 500 l of the water for the total panels installed on the roof each cycle (i.e. 14 l/Panel).

The records show that the annual generated solar electricity from this system (8.64 kW) in 2015 was 8879 kW h and the expected energy set by producer (Petra solar) was 11,990 kWh while it was expected to be 13,485.7 kWh (according to NREL PVWatt Calculator) and 14,137.0 kWh. These results indicate that the installation produced solar electricity less than the expected by 26.0%, 34.2% and 37.2%, respectively.

Surprisingly, the total solar electricity actually gained in 6 months (January to June) in 2015 was 4471 kWh, while the total solar electricity actually gained in 6 months (January to June) in 2016 was 5519 kWh.

The payback for this BIPV Sadeem Building will be 624 years, while if feed–in– tariff is set to purchase each 1 kWh solar electricity for 380 fils (about USD1) then the payback will be reasonable (about 5 years). This reaches to the conclusion that either the government sells the PV system with a highly subsidized rate or purchases each kWh of solar electricity at not less than USD1.

Assuming that each kWh results in emitting about 1 kg of CO_2, then this BIPV saves, annually, the emission of about 9 t of CO_2.

1. Introduction

Building Integrated Photovoltaic (BIPV) installed in semi-arid and desert lands are subjected to high dust deposition rate. The built up of dust layer on PV panels causes major energy-yield loss [1]. This means that BIPV requires more than 90% efficiency of light transmission for PV modules. The combinations of high relative humidity (RH), high surface temperature and long residence time of the dust on the optical surface lead to the degradation of the solar collectors over time. Recently [1], a water-free removal of dust technique enables maintaining power output efficiency greater than 90% compared to that of the panel under clean conditions with dust removal efficiency (DRE) which was more than 90% with test dust samples obtained from different arid zones and energy consumption for EDS operation is less than 0.03 Wh/m^2/cleaning cycle.

Large-scale solar plants which are generally located in semi-arid and desert lands suffer from two major environmental degradation factors: high ambient temperature and high concentration of atmospheric dust. These two parameters result in a considerable loss of energy yield in all PV systems and BIPV. Dust and other particulate accumulation on PV panels causes transmission loss in solar electricity yield. A brief review of the energy yield losses caused by dust deposition on solar collectors is available by Sayyah et al. [2]. The review includes some of the major studies reported on energy-yield losses on solar plants (including PV) and the laboratory-soiling studies in operation in several regions of the world. In addition, it also includes reports on degradation in the performance of solar plants based on the type of solar collectors, geographical location, local climate, and exposure period of the collectors absent any manual cleaning. Analysis of the advantages of cleaning processes that include natural, manual, automatic, and passive methods were included in this review.

The sensitivity of PV technologies to dust, temperature and relative humidity is investigated in an Arid Area environment (in State of Qatar) [3]. It was found that single-crystalline PVs have efficiencies as high as 85% compared to 70% for amorphous ones and dust accumulation degrades more critically the efficiency of amorphous and single-crystalline silicon PVs than the panel's temperature or relative humidity. Furthermore, amorphous PVs were found to be more affected by temperature and relative humidity than single-crystalline PVs although amorphous PVs were found to be more robust against dust settlement than single-crystalline PVs and hence are more suitable for implementation in desert climates like Qatar unless cleaning strategies are devised [3]. It was also estimated that 100 days of dust accumulation over single-crystalline PV panels caused the efficiency to decrease by around 10%. This limitation makes solar PV an unreliable source of power for unattended or remote devices and thus strongly suggests the challenge of cleaning the panel's surface regularly or injecting technical modifications specially the optimize production of the operating solar

http://dx.doi.org/10.1016/j.rser.2017.09.041
Received 28 August 2017; Accepted 14 September 2017
1364-0321/

PV plants in Qatar is from 11:00 a.m. to 02:00 p.m. [3]. Potential applications of self-cleaning solar panels in PV systems, particularly in arid and semi-arid regions, were reviewed previously, including the economic advantage in payback for the added cost [4].

BIPV systems were developed by the Solar and Day Lighting Laboratory and offer considerable advantages as compared to stand-alone PV installations as they can play a role as essential components of the building envelope. BIPV systems operate as distributed power generators using the solar radiation energy and have advantage of not requiring additional space [5]. This makes them appropriate for urban environments and they have been coupled by BIPV/Thermal (BIPV/T) systems which may use exterior air to extract useful heat from the PV panels, cooling them and thereby improving their electric performance [5]. BIPVs have the advantage of replacing traditional parts of the building envelope, e.g. the roofing. This integration limits the costs by serving dual purposes. BIPVs have a great advantage compared to non-integrated systems because there is neither need for allocation of land nor stand-alone PV systems. Currently, there are various categories of BIPVs which may be divided into photovoltaic foils, photovoltaic tiles, photovoltaic modules and solar cell glazings [6]. The evaluation of the different BIPV products involves, among others, properties such as solar cell efficiency, open circuit voltage, short circuit current, maximum effect and fill factor was studied [6].

The stand-alone photovoltaic (SAPV) system usually is tried and evaluated before deciding on BIPV. The performance of a 2.32 kWP stand-alone photovoltaic (SAPV) system in New Delhi (India) for four weather types in each month such as clear, hazy, partially cloudy/foggy and fully cloudy/foggy weather conditions was studied [7]. The daily power generated from the existing SAPV system was experimentally found in the range of 4–6 kWh/day depending on the prevailing sky conditions. These figures (maximum 10 kWh per day) are low compared with the expected (about 16 kWh); they operate ceiling fan, fluorescent tube-light, computer, submersible water pump, etc. [8].

Recently [9], the solar power converter has realized boost-type DC-DC conversion with maximum power point tracking (MPPT) with chip and less discrete components having been introduced for BIPV. It achieves high tracking and high conversion efficiencies, which outperforms current state-of-the-arts which enable a converter to be used in stand-alone systems and grid-connected systems if it is connected to a DC/AC inverter.

The topic of BIPV is becoming of interest to engineers, policy makers, economists and environmentalist. In this year (2016) about 50 papers have been published in respected journals and conference proceedings, about 60 in 2015 and about 70 in 2014. Among this year's publication is a review paper on BIPV [10], novel HP-BIPV/T system for use in residential buildings [11], renovation of apartment blocks with BIPV with evaluation of the energy and economy in temperate climate [12], cost-benefit analysis of integrating BIPV [13], the restriction BIPV integrated grid-connected [14], double skin facades (DSF) for BIPV [15], naturally-ventilated building integrated photovoltaic/thermal (BIPV/T) envelope [16], the current state of the art of BIPV and possible research pathways [17], material requirements, present status, and future prospects for building-integrated semitransparent photovoltaics (BISTPV) [18], the effect of Photovoltaic panels on the rooftop temperature [19], testing the operating cell temperature for BIPV modules [20] and finally the incentive policies for BIPV [21].

2. Component of the first 8.64 kW BIPV at Sadeem building at Awali, Bahrain

There are 36 panels on the roof, each having 240 Wp, so the total installed power is 8.64 kW. The panels' orientation are 225° from the north and have a tilt angle of 25° although the latitude of Bahrain is 26.13° N and latitude 50.8° E. The total area of PV panels on the roof is about 60 m^2 (Fig. 1).

These panels are cleaned by sweet water every 2 months and they require around 500 l of the water for the total panels installed on the roof for each cycle (i.e. 14 l/Panel). The cost of installation is US $43,000. The area of each PV panel is 1.63 m^2. Fig. 2 shows a schematic diagram of the installation of the system at Sadeem Building in Bapco at Awali town.

The installed PV panels each has a micro inverter (Fig. 3) with many

Fig. 1. The First 8.64 kW BIPV at Sadeem building in Bapco at Awali, kingdom of Bahrain.

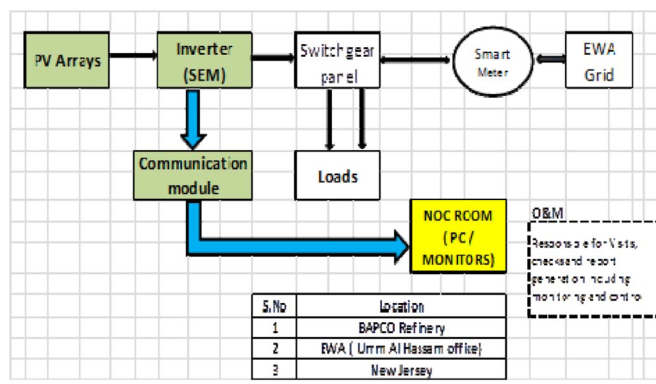

Fig. 2. A schematic diagram of the installation of the system at Sadeem Building in Bapco at Awali town, Kingdom of Bahrain.

Fig. 3. Smart Energy Module (SEM), which is provided with micro inverter integrated with each PV panel installed on the roof of Sadeem Building at Bapco, Awali Town, Kingdom of Bahrain.