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ScienceDirect

Energy Procedia 130 (2017) 114–121

Energy Procedia

www.elsevier.com/locate/procedia

SNEC 11th International Photovoltaic Power Generation Conference & Exhibition, SNEC 2017 Scientific Conference, 17-20 April 2017, Shanghai, China

Utilization of Constrained Urban Spaces for Distributed Energy Generation – Development of Solar Paved Pedestrian Walkway

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Abstract

Distributed energy generation is a challenge in urban areas. Conventional solar systems cannot be installed in cities (rooftop space is limited) and there is need for innovative, dual-purpose designs like BIPV, car-ports and solar walkways. Smart cities of the future would rely heavily on this philosophy. One such system design is presented in this paper that incorporates several novel concepts - solar panels on an elevated structure that generates electricity and provides shelter to pedestrians from the environment, takes care of module cleaning by an automated water management system and harvests rain water. The use of micro-inverters increases energy generation from the system and also reduces issues with shading and pedestrian safety. A pilot of the proposed design is being commissioned at a favourable location in India and analysis of the data obtained will form the basis of future development of solar system design for constrained urban spaces.

Peer-review under responsibility of the scientific committee of the SNEC 11th International Photovoltaic Power Generation Conference & Exhibition.

Keywords: Photovoltaic systems; footpaths; pathways; urban development

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Peer-review under responsibility of the scientific committee of the SNEC 11th International Photovoltaic Power Generation Conference & Exhibition.
10.1016/j.egypro.2017.09.406

1. Introduction

Generation of solar power in urban areas is a challenge keeping in mind the space constraints, aesthetics and technical issues related to distributed power generation. While rooftops are often ideal for deployment of solar systems, other concepts like BIPV and dual-purpose installations like paved walkways, car-ports, bus shelters etc. with solar panels embedded over the top or on the sides are gaining in popularity. Several countries, including India, have ratified COP 21[1] targets and are pushing ahead for more renewable energy generation. Cities utilize vast amounts of energy, but generate very little of it. About 75% of all power generated globally is consumed in cities [2], and most electricity consumed in urban areas is generated by power stations outside these cities [3]. Generating clean energy at the site of consumption could substantially contribute to the environmental, economic and social aspects of urban sustainability, and also reduce transmission losses. The last decade has seen tremendous decline in the cost of solar photovoltaic (PV) technology, owing to both technical advancement and favourable policies by governments [4,5]. It could be expected that smart cities of the future would generate a sizeable amount of the energy they consume.

With the launch of Smart City Missions [6] in multiple big cities across the globe, developers are now looking beyond the scope of rooftop and non-agricultural lands for installing solar panels. An example are solar paved walkways, which are multi-purpose installations that provide weather reinforcement to pedestrians and enable the generation of power at the same time. Since weather plays an important role in determining an individual's decision in traversing a certain walkable distance, these solar paved walkways increase the utility of walkways/sidewalks in general [7].

A novel design developed by Vikram Solar aims to utilize paved walkways in cities by installing PV modules on an elevated sheltered structure. The design includes automated cleaning techniques for the panels, recycles the water used for cleaning, and also incorporates rain water harvesting capability. Additionally, the sheltered walkway adds to the aesthetics of the smart city. The system is an amalgamation of several other techniques to ensure lesser consumption of space, reduced shading losses that occur in solar modules, and hence enabling a much higher energy yield from the system.

2. Design Philosophy

The aim of this project is to design a solar energy generation system that can be incorporated seamlessly in an urban setting, and can as well tackle the issue of water conservation and harvesting which is of paramount importance in urban society. The following points form part of the philosophy behind the proposed design:

Table 1. Problems of solar energy generation in cities & proposed solution.

Problem encountered	Proposed solution
Space constraint	Utilizing pedestrian walkways for solar power generation
Dust accumulation on modules	Automated cleaning system
Wastage of water	Recycling of cleaning water
Shading	Module level power electronics/micro-inverter
Hot spot heating	Micro-inverter
Effect of temperature	Backside of module has free access to air. Also, the cleaning system could be used for water cooling.
Rain water harvesting	Automated cleaning system can double up as rain water can be harvested
Safety for pedestrians	Micro-inverters eliminate the risk of high voltage DC carrying overhead wires

Solar paved walkways solve the problem of space constraint in smart cities in two ways. One, by placing solar module as the roof of the shaded pathways and thereby moving beyond the scope of rooftop of buildings. Two, a part of the system (for collection and recycle of water) is designed to be present under the ground.

A major problem with installing PV system in urban setting is partial shading at specific times of the day from nearby buildings, trees and other structures. This would lead to power degradation, hot spot heating and, ultimately, module failure. Bypass diodes are placed across groups of cells to prevent failure due to shading/mismatching. But they are still prone to power degradation during shaded condition. The use of conventional series connection in designing strings is at the root of this issue. Several researchers have tried to tackle this by employing module-level power electronics (MLPE). The most common of these is the use of micro-inverters [8, 9] that convert the DC output from a module to AC before transmitting it. Module and string level optimizers are also available that are capable of