Building and Environment 46 (2011) 2107–2113

Contents lists available at ScienceDirect

Building and Environment

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

Compromises between form and function in grid-connected, building-integrated photovoltaics (BIPV) at low-latitude sites

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ARTICLE INFO

Article history:
Received 29 January 2011
Received in revised form
13 April 2011
Accepted 18 April 2011

Keywords:
Grid-connected photovoltaics
Building-integrated photovoltaics (BIPV)
Thin-film PV
Performance of solar generators

ABSTRACT

The integration of photovoltaic (PV) modules on building façades and rooftops is an ideal application of solar electricity generators in the urban environment. Maximum annual performance of grid-connected PV is usually obtained with modules tilted at an angle equal to the site latitude, facing the equator. The performance of PV systems not tilted and oriented ideally can drop considerably, depending on site latitude. With grid parity – when the cost of solar electricity becomes competitive with conventional electricity – expected in many countries in the present decade, a more widespread application of PV on buildings is expected, and in this context the main goal of this paper is to demonstrate that good compromises between form and function are possible. In this work we compare the annual energy generation of a curved BIPV system installed as a car port rooftop, with an ideally-oriented and tilted, flat BIPV system installed as a building's rooftop cover at a low-latitude site (27°S). For the one-year period analysed, the curved-shape BIPV system annual yield was 12% lower than that of the reference BIPV system, and during the summer months (November to February), the curved BIPV installation presented a higher energy yield than the latitude-tilted generator. With these results we show that a good compromise can be reached between form and function in BIPV systems.

1. Introduction

The direct conversion of sunlight to electricity using solar photovoltaic (PV) devices is one of the most elegant and benign ways of generating electrical power. When PV modules are integrated to a building's skin, as part of the roof or as façade elements, the unique attribute of this power generating technology – the ability to generate energy where energy is consumed – is put to its most ideal application. When PV generators are constructed as part of a building's envelope, energy transmission infrastructure, and the associated costs and losses are also avoided, and final energy costs can be compared with end-consumer tariffs, instead of with energy costs at the generation plant busbar.

PV solar energy conversion in urban, grid-connected applications is expected to reach grid parity – become cost-competitive with conventional, utility grid supplied electricity – in many parts of the world in the present decade [1–3]. The impressive and ongoing cost and price reductions displayed by this technology in the last ten years were only possible because of the production volumes related to the consistent support of incentive programs, mainly in Germany and the rest of Europe [4–6]. With a more widespread use of this technology, enhancing the performance of BIPV installations will need to be addressed in more detail [7–14], and output power penalties due to sub optimal PV array tilt or orientation will become a more critical issue.

For grid-connected PV systems, annual performance optimisation is usually obtained when PV arrays are oriented towards the equator (facing south at sites in the northern hemisphere, and facing north at sites in the southern hemisphere), at tilt angles equal to the site latitude. At low-latitude sites, where the sun is always high in the sky, the integration of PV on vertical façades can lead to considerable performance losses in comparison with the ideal tilt and orientation. Burger and Rüther [15] have shown, however, that a vertical, north-oriented façade at a 27°S (Florianopolis) site in south Brazil still receives some 30% more solar irradiation over a year than a vertical, south-oriented façade at 48°N (Freiburg) site in Germany. There are a number of PV systems electrical design and engineering strategies, which try to assess and overcome the intricacies and consequences of the sub optimal position of PV arrays on buildings [16–23].

The electrical design and engineering, as well as the performance forecast of ground-mounted, ideally-tilted and -oriented PV systems is relatively straightforward to perform and assess. With

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doi:10.1016/j.buildenv.2011.04.024