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Energetic contribution potential of building-integrated photovoltaics on airports in warm climates

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Abstract

Especially in warm climates, a considerable fraction of the electricity demand in commercial buildings is due to the intensive use of air-conditioning systems. Airport buildings in sunny and warm regions present a perfect match between energy demand and solar resource availability. Airport buildings are also typically large and horizontal, isolated and free of shading, and have a great potential for the integration of solar photovoltaic (PV) systems. In this work, we assess the potential impact in energy demand reduction at the Florianopolis International Airport in Brazil (27°S, 48°W) with the use of building-integrated photovoltaic (BIPV) systems. We analyse the building's hourly energy consumption and solar irradiation data, to assess the match between energy demand and potential generation, and we estimate the PV power necessary to supply both the total amount and fractions of the annual energy demand. Our results show that the integration of PV systems on airport buildings in warm climates can supply the entire electric power consumption of an airport complex, in line with the general concept of a zero-energy building (ZEB).

Keywords: Grid-connected photovoltaics; Building-integrated photovoltaics (BIPV); Value of photovoltaic (PV) electricity; Zero-energy buildings (ZEB)

1. Introduction

Over the last three decades world energy demands have shown a consistently growing trend, with primary energy growing by 89.5% and CO_2 emissions by 79% in the 1973–2006 period (IEA, 2008). It is forecasted that this trend will continue, with emerging economies energy use growing at an average annual rate of 3.2%, and developed countries growing at a rate of 1.1% (IEA, 2008; Pérez-Lombard et al., 2008). At these rates, by 2020 emerging economies energy use will exceed that of developed nations (Pérez-Lombard et al., 2008).

Buildings are responsible for a considerable share of energy consumption, and will play a growing role in the energy demands of emerging economies in the next decades. The concept of zero-energy buildings (ZEBs), or net zero-energy buildings is a general term applied to a building with a net energy consumption of zero over a typical year under normal operation and use. Buildings are typically responsible for 40% of the total primary energy consumption in the US, the European Union and also in developing countries like Brazil (Baden et al., 2006; Geller, 2002). ZEBs are gaining in importance and popularity, mostly in the developed world. In developing countries the ZEB concept is starting to attract interest, mostly as a public relations or marketing strategy of companies that

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can profit from the image of environmental responsibility and forward-thinking behaviour.

In countries like Brazil, office buildings in urban areas often present considerably high air-conditioning loads, with electricity demands that can hardly be generated on site with renewable energy generating systems. The typical prestige building is a tall, glass envelope, with a electricity demand curve that is usually in good synchronicity with the solar irradiation profile, but which often lacks the necessary (and conveniently oriented and tilted) areas to accommodate enough active solar generator systems that could produce enough power on site. Airport buildings in particular, especially in warm and sunny climates, present even higher energy demands due to air-conditioning units. These loads usually present a very good match with the local solar radiation resource availability, both on a seasonal and daily basis, and there is also a good correlation between ambient temperatures and energy demands. Airport buildings are typically large and horizontal, free of shading and ideal for the integration of solar photovoltaic generators. Building-integrated photovoltaics (BIPV) use the building envelope to incorporate solar cells that convert sunlight directly into electricity, and we argue that they are not only the ultimate showcase for this clean, renewable and benign energy generation technology, but represent a perfect application of on-site energy production as well. Furthermore, on-site BIPV generation avoids the need of voltage step-up and step-down typical of centralised generation and transmission and distribution (T&D) systems, as well as all the associated hardware and losses. The building's electrical installation itself can be used as the interface between the PV generator and the public distribution grid. With near-future prospects of cost reduction to levels where it might compete with conventional grid electricity prices (van der Zwaan and Rabl, 2003), a more widespread use of BIPV generators can be expected, triggered by national incentive programs carried out in many countries (BMU, 2001; Erge et al., 2001; Kurokawa and Ikki, 2001; Schoen, 2001; Castro et al., 2005).

Energy demands in buildings can be either reduced by the implementation of energy efficiency strategies, or met by on-site generation. Hamza (2008) presented a study on the use of double versus single skin façades in hot arid areas, pointing out that the single skin configuration in warm climates is a major contributor towards influencing the cooling loads of office buildings. Façade configurations are predicted to be responsible for up to 45% of the building's cooling loads (Hamza, 2008). Double skin façades are an architectural concept composed of two façade layers separated by a cavity. Transparent glazing is often used on the exterior leaf to maintain a distinct transparent appearance to buildings. Yun and Steemers (2009) have recently demonstrated the effectiveness and implications of applying PV to façades, and Infield et al. (2004) have analysed the thermal performance of PV façades. Charron and Athienitis (2006) have optimised the performance of double façades with integrated PV and motorized blinds. We have recently shown that BIPV systems in residential buildings in Brazil can assist in reducing their energy demands (Ordenes et al., 2007), and have also demonstrated that in a typical office building over 50% of the energy demands can be supplied by solar energy (Marinoski et al., 2004). Another recent study carried out in less sunny Tokyo-Japan, concluded that with the use of semi-transparent, BIPV modules, energy consumption was reduced by 54% (Miyazaki et al., 2005). In this work, we analyse the particular characteristics of airport buildings; due to the distinct characteristics of the building envelope in airport constructions, BIPV systems can represent an interesting alternative to assist in meeting their energy demands. Because airport grounds often present large open areas used as sound buffer zones, there is considerable potential for airport complexes to accommodate PV installations that could generate more power than necessary to run the airport, exporting excess energy to the grid, and assisting daytime peaking utility distribution feeders in urban areas (Jardim et al., 2008; Rüther et al., 2008). Furthermore, BIPV can be also used as a Distributed Generation (DG) strategy, adding capacity and power quality to the distribution grid and shaving demand peaks. Caamaño-Martín et al., 2008 have recently performed an extensive revision of the state-of-the-art of the mutual impacts between PV-DG and electricity networks, with a main focus on power quality and safety. They have raised the technical issues, indicating potential problems and solutions, and showed that PV systems offer good options to improve grid supply quality and provide grid services.

2. Methodology

The energetic contribution potential of BIPV on the Florianopolis International Airport in Florianopolis-SC, Brazil (27°S, 48°W) was calculated analysing the electricity demands of the whole airport complex, and the local solar radiation resource availability. In order to correlate solar irradiation with PV generation, performance data of a 2 kWp BIPV system operating since 1997 at Universidade Federal de Santa Catarina in Florianopolis (Rüther, 1998; Rüther and Dacoregio, 2000; Rüther et al., 2004, 2006) were used for the corresponding period. This fully monitored installation uses thin film amorphous silicon (a-Si) PV modules, which have demonstrated superior performance in warm climates (Rüther, 1999; Rüther et al., 2003, 2008).

Global horizontal solar radiation levels in Brazil range from 1500 up to 2200 $kWh/m^2/year$ (Pereira et al., 2006), with small seasonal variations especially at low latitude locations, where abundant sunshine and warm weather lead to the extensive use of air-conditioning systems in urban buildings. Florianopolis is a state capital in the south of the country, with a climate that can be described as moist maritime, with warm winters and hot summers. Despite showing one of the lowest solar irradiation levels in Brazil, Florianopolis is still a very sunny place, and