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Design and Performance Prediction of an Energy+ Building in Dubai

Giovanni Brumana , Giuseppe Franchini*, Antonio Perdichizzi

*Departement of Engineering and Applied Science, University of Bergamo, Viale Marconi 5, Dalmine 24144 (BG), Italy

Abstract

The result of the joint efforts of University of Bergamo and Mohammed Bin Rashid Space Centre (a Dubai Government institute) is the first Energy+ building in Dubai, virtually off-the-grid and PassivHaus certified. The present work deals with the computer models developed to predict the energy performance and to guide the design choices of the two floor office building unveiled to the public in November 2016. Trnsys software has been used to revise and validate the architectural ideas and the energy design.

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Keywords: Energy+ Building, Trnsys model, Dynamic simulation, Solar cooling

1. Introduction

The severity of environmental problems is forcing the construction sector in hot climate regions to introduce new paradigms in the design and erection of energy-efficient buildings. The growing interest in the development of passive buildings for hot climates [1] is inextricably linked to the climatic conditions of the site as well enlightened by Schnieders et al. [2]. A critical issue is often due to the difficulty of obtaining data in particular areas of the world [3]. This process involves new energy systems and a new shell design [4], including efficient shading devices to reduce energy consumption [5]. The development of sustainable solutions goes through the construction of more and more efficient buildings, such as Nearly Zero Energy Buildings [6] and Zero Energy Buildings [7]. Fundamental is the development of simulation tools for assessing the building energy performance [8] [9], especially when they are

* Corresponding author. Tel.:+39 035 2052078; fax:+39 035 2052077.
E-mail address: giuseppe.franchini@unibg.it

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coupled with experimental measures [10]. The difficulty of performing reliable predictions of the thermal behavior and the energy consumption of buildings is well illustrated in [11] by Song et al.

Besides the development of well-insulated thermal envelopes according to the Passive House standards, an important step for improving the building sustainability is the use of high-efficiency cooling technologies coupled with renewable energy sources. Several types of solar cooling systems are available (Nanda et Panigrahi [12]): among these, the option based on compression chiller driven by a PV field assisted by a battery pack is highlighted. A remarkable comparison between this solution and absorption chiller driven by solar collectors was done by Lazzarin [13]. The results show that the performance is today comparable but the PV has a greater adaptability. In this contest, the study of Viera et al. [14] evaluates the performance of a residential building equipped with photovoltaic modules and batteries. The growth of the self-production energy and battery capacity leads to the development of the buildings called off-the-grid or stand-alone [15] [16]. These buildings do not require connection to the grids, can supply the own energy needs and jointly maintain high standards of comfort. The management of the self-produced energy is another topical point, as illustrated by Chekired et al. in [17], especially when the overproduction is exported to the network [18] [19]. The importance of the consumption of electrical equipment in buildings is well illustrated by Widen in [20]. Moreover, Hoxha and Jusselme in [21] show the relevance of using efficient lights and appliances adapted to new low-impact buildings. Furthermore, the analysis of occupancy reveals its relevant impact on the energy performance as well documented by Blight and Coley [22].

In the energy-efficient buildings a primary interest is the comfort perception: predictive techniques for quantifying and qualifying the indoor comfort are included in several building models [23] [24]. Frequently the goal of a high level of comfort perception is achieved through radiant floor cooling systems [25].

Starting from previous researches on solar cooling systems for buildings in hot climates [26], the present paper deals with the modeling and the design of the first Energy+ Building in Dubai, virtually off-the-grid. The developed computer models aimed to predict the energy performance and the thermal comfort, and was used to dictate the design choices for the building construction.

Nomenclature

$G_{-value,w}$	windows solar factor (%/100)	U_{roof}	roof U-value (W/m^2/K)
HX	Heat Exchanger	$U_{-value,w}$	windows U-value (W/m^2/K)
PV	Photovoltaic	U_{wall}	wall U-value (W/m^2/K)

2. Building Design

Geometry and orientation of the two floor building aim to reduce as much as possible the primary energy consumption taking into account the irradiation on the walls during the day and across the seasons. The surface to volume ratio is minimized. A small patio shrinks the radiation on the glazed elements and keeps shaded the office areas. This solution allows for avoiding window shields even in daylight hours. The diffuse light naturally illuminates the 550 m^2 floor surface and – at the same time – the solar gains are minimized.

A timber trimmed structure is designed to support the photovoltaic field, to promote the ventilation on PV modules and to shade the flat roof. The outline elements of the windows are protruding to limit direct radiation.

A lightweight load bearing structure made by wood supports timber walls and roof. The walls are designed to reduce as much as possible the building cooling load. The balance between mass and insulation improves the energy performance: the insulation thickness is designed to minimize thermal transmittance and the phase shift is controlled by adding mass layers. Walls are painted with a special reflective paint to curtail the absorption of solar radiation on the outer layer. Similarly, the roof is treated with a reflective film and infrared reflector films are inserted inside the walls. Windows are specific for warm climates with very low U and G values to limit the solar gains.

The building envelope is designed according to the Passive House standard and the energy plants are selected to reach the level of Energy+ Building. Power supply is ensured by the rooftop PV field. A battery pack is available to store electricity during light hours and to supply electricity after sunset.