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Optimizing buildings energy performance through photovoltaic panel integration within a mobile shading system

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Abstract

The paper aims at evaluating the energy performance of an office building that integrates photovoltaic panels in a mobile shading system with horizontal elements, based on simulations, while also defining the optimum performance parameters: shading degree, orientation and inclination angle. The impact analysis of the energy performance of an office building model conveys a perspective on the benefits of integrating this type of dynamic (adaptable) envelope, taking into consideration the general context of energy conservation and the limitations imposed to conventional energy use. The combined envelope system optimizes the energy performance by allowing winter solar gains, reducing overheating in summer and transforming the solar energy in electricity. The simulations are made by using an average size office building model located in the city of Iasi, Romania. The 3D model was designed in Archicad, while the thermodynamic simulations are performed in PHPP, Design Builder and SolarPro programs. The results show significant improvement of energy performance by choosing a shading system with horizontal elements using the optimum inclination angle for the shading device and the minimum inclination for the photovoltaic panels. Combined with the shading system which reduces the cooling energy demand, the entire system provides a substantial decrease in heating and cooling energy demand.

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Keywords: energy efficiency; renewable energy; photovoltaic panels; mobile shading system; sustainability.

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1. Introduction

The envelope, that significantly influences the building energy performance, must respond to the changes of the internal and external conditions.

The paper concerns the evaluation of the energy performance of an office building where photovoltaic panels are integrated in a mobile shading system with horizontal elements, based on simulations, while also defining the optimum performance parameters: shading degree, orientation and inclination angle. Therefore, the energy production of the photovoltaic panels is analysed, as a wide-spread non-conventional technology used for renewable energy production.

The impact analysis of the energy performance of a model office building conveys a perspective on the benefits of integrating this type of dynamic envelope, taking into consideration the general context of energy saving and the limitations in using the conventional energy. The heating and cooling energy demand and the energy collected from renewable sources were determined by using the thermodynamic simulation programmes PHPP (Passive House Planning Package) and Design Builder with EnergyPlus, the 3D modelling programme Archicad and the performance evaluation of photovoltaic panels programme SolarPro, based on the utilisation scenario conceived for this type of envelope system. The decrease in energy demand is analysed in order to put into evidence the positive impact of the system.

2. Theoretical background

The renewable energy sources result from natural processes with replacement cycles that occur in periods of time equal or lower than the consumption periods. Some of these sources, like solar, wind, geothermal energy, or biomass can be used to supply energy for buildings. Out of these, photovoltaic panels are among the most wide-spread technologies, directly transforming the solar radiation into electricity due to the photoelectric effect over a semiconductor diode. Silicon-based solar cells dominate the market due to the generous silicon resources and low environmental impact. They are connected in series and grouped into solar modules, which in turn form solar matrices.

Advantages:

- low maintenance;
- over 25 years life span;
- building integration of photovoltaic panels leads to lower total costs and the system can also perform a secondary function: the shadowing.

Disadvantages:

- the fluctuations in sunlight and energy demand, that leads to the need for using batteries;
- the present high cost, which will decrease with the evolution of this technology.

Efficiency depends on:

- module quality;
- cell temperature (the efficiency decreasing as the temperature rises to a rate of -0.5%/^{o} C);
- efficiency of alternating current conversion to inverter current;
- dust or snow that can decrease solar radiation at panel surface level;
- elements that can shade the panels;
- losses due to different system components.

To achieve a high performance of photovoltaic panels, the following aspects should be taken into consideration:

- south orientation to fully benefit of solar radiation;
- angle of inclination:
  - the optimal angle if the panels are fixed: α = latitude * 0.76 + 3.1 ^{o} (if the latitude is within the range 25-50^{o});