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Technical note

Maximizing the performance of an energy generating façade in terms of energy saving strategies

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A B S T R A C T

In the context of façade planning, it is essential to integrate energy saving with energy generation given that there are significant correlations between these two factors at many levels. In this study, we present a method for determining the optimum façade criteria that can considerably enhance building performance. This method can be implemented by architects in the early planning phase of a project via the use of a solar energy optimization tool. In this research study, we address basic issues of energy balance, user comfort and the impact of the chosen criteria on the formal quality of the building. Single and multi-criteria optimizations are carried out using sensitivity analysis, and the potential of this approach is demonstrated using a multistory office building as a case study. The generated optima can then be used to decide how different architectural configurations can affect façade performance.

1. Introduction

Building integrated photovoltaic cells [BIPV] are becoming an important part of modern low- and high-rise buildings. At lower latitudes, such as in the subtropics, vertical surfaces receive less irradiation than horizontal surfaces. Thus, the energy yield of façade-integrated photovoltaic cells [FIPV] is less than that of roof integrated photovoltaic cells [RIPV]. The energy demand of a room is typically much higher than the energy output that can be generated by its façade. That is, typical single office rooms usually have a negative energy balance despite technological advances in photovoltaic cells and the high solar exposure of such rooms. This effect can be seen more clearly in multistory buildings with roof and façade integrated PVs. Fig. 1 shows the simulation results for a multistory building for which the façade attributes and FIPV are not optimized to investigate the effect of increasing the number of floors on the final energy balance (i.e., how demand affects output). For simplicity, a generic office space model is used for the four façades and is detailed in Fig. 2 and Table 1. This model is used for the analysis in this study.

The vertical axis in Fig. 1 represents the end energy balance (electricity) per square meter of the simulated building, and the horizontal axis represents the varying number of floors. The energy balance in this example is the sum of the electricity output from the BIPV and the energy demand for cooling, lighting and electric appliances. The energy balance of the building per square meter clearly decreases exponentially as the number of floors increases. It has become critically important to develop net zero or nearly zero energy buildings; however, the simulation results show that it is very difficult for multistory, and thus high-rise buildings, to be energy autarchic. The end gained value of the optimization method and the tool used in this study is to lift the curve shown in Fig. 1 and to increase the energetic potential of the building by maximizing the efficiency of its envelope, while taking visual comfort and day lighting into consideration.

The cooling energy demand of a room is usually affected by both the external load, i.e., from global irradiation, and heat emissions from equipment, humans and lights. The electric demand from lighting is another factor that correlates with the availability of daylight and therefore, the external loads. The physical parameters of windows and shading devices are determining factors because these objects reduce the cooling load and impact the lighting demand, which correspond to thermal and visual comfort, respectively. It is important not to neglect the esthetic effect of the transparent façades that are currently in favor, which is difficult to evaluate quantitatively. In addition, high cooling loads are

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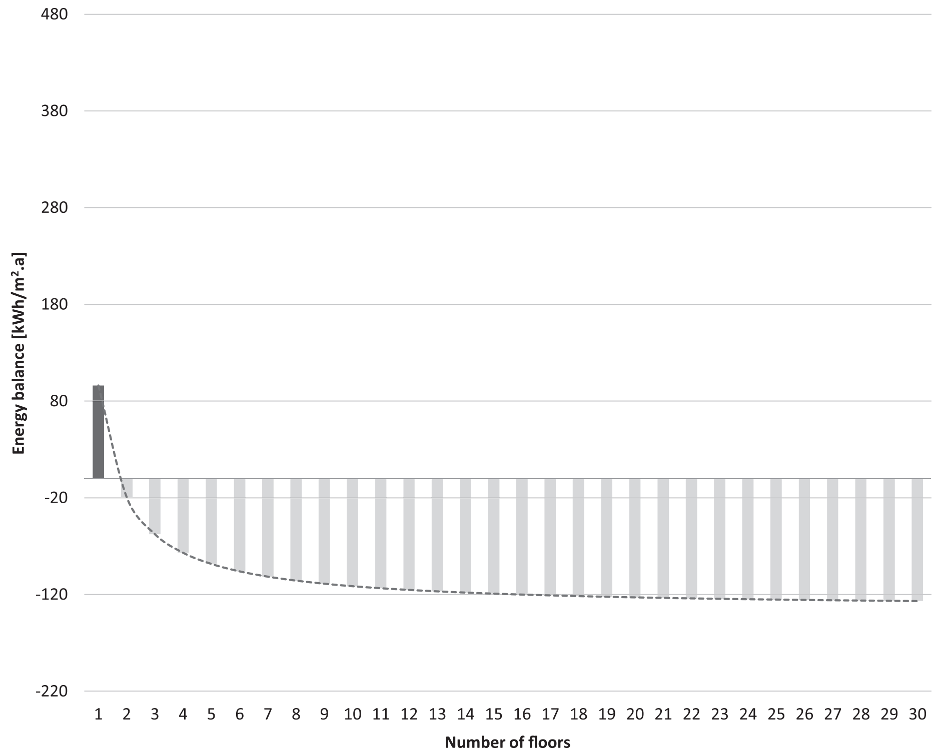

Fig. 1. Decreasing energy balance with the increasing number of floors in a building with façade and roof integrated BIPV; Location: Jeddah, SA.

concurrent with high irradiation levels in office buildings; thus, an energy generating façade cannot meet the total energy demand of the room behind it, especially while maintaining the visual comfort of the users within a recommended range.

The aforementioned issues can be investigated using different types of currently available conventional software. It is essential to clearly distinguish between simulation and optimization. In a simulation, a user inputs a set of criteria to the computer software. The impact or results are generated as output. Within the scope of this study, optimization is considered to be the reverse of this simulation process. The criteria in this case are the generated output, whereas the specific results or the desired range of results are the input. Simulation and validation are performed via an optimization process that is used to determine the local optima. Fig. 3 provides an overview of the differences between the two processes.

Simulation software are currently becoming an essential component of the design process. Limitations have been identified for many tools that are used to analyze computational performance [1,2]. These programs are mainly used within a trial and error approach, where the planner inputs the parameters for a concept and then performs a simulation to evaluate the concept. This repetitive process can be regarded as an analog approach that is time consuming and does not guarantee the best possible set of parameters. Thus, these tools do not provide solutions but are instead being used to evaluate decisions that have already been made [3].

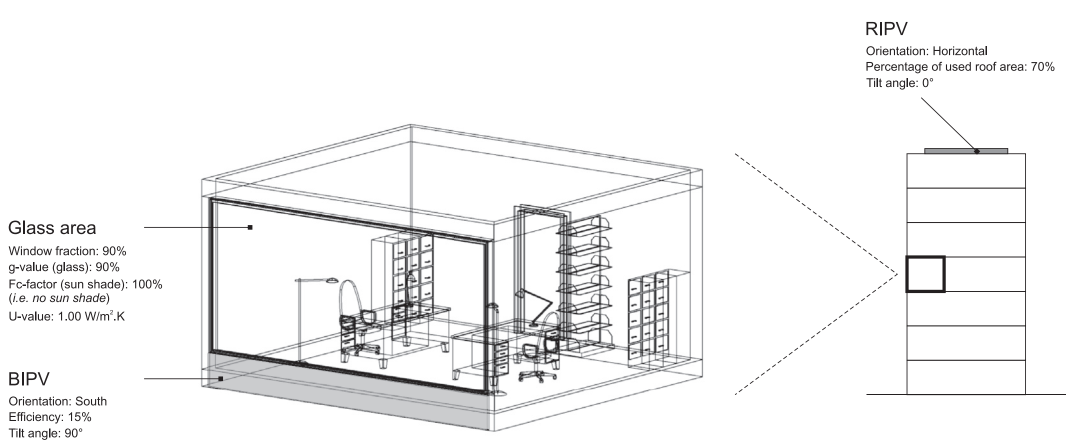

Fig. 2. Generic simulation model.