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RESEARCH ARTICLE

The Adaptive Solar Facade: From concept to prototypes

Zoltan Nagy*, Bratislav Svetozarevic, Prageeth Jayathissa, Moritz Begle, Johannes Hofer, Gearoid Lydon, Anja Willmann, Arno Schlueter

Architecture and Building Systems, ETH Zürich, John-von-Neumann-Weg 9, 8093 Zürich, Switzerland

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Abstract
The Adaptive Solar Facade (ASF) is a modular, highly integrated dynamic building facade.The energetic behavior as well as the architectural expression of the facade can be controlled with high spatio-temporal resolution through individually addressable modules. We present the general design process, the current mechanical design, and simulation results on photovoltaic power production and building energy consumption. We introduce the controller concept and show results on solar tracking as well as user interaction. Lastly, we present our current and planned prototypes.

1. Introduction

Over a third of the anthropogenic greenhouse gas (GHG) emissions stem from the operation of buildings (heating, cooling and electricity), due to their fossil fuel based operation (Lucon and Ürge-Vorsatz, 2014). Therefore, the existing building stock offers a great potential for CO_2 mitigation. In fact, the EU aims for all newly constructed buildings to have close to zero net energy consumption by 2020 (EU, 2010). To achieve this, incorporating renewable energy generation, such as photovoltaic (PV) systems, into buildings has been recognized as a viable path. Building integrated photovoltaic (BIPV) systems are typically rooftop installations owing to the relatively heavy weight structure of traditional silicon-based PV modules (Frontini et al., 2015). In addition to this bulkiness, while alternatives are slowly emerging, traditional PV modules still suffer from the monotonic blue color, which makes individual building integration challenging. Novel developments, such as organic solar cells, offer lightweightness and color variations and have been successfully applied in large scale buildings as, e.g., windows. However, the significantly low efficiency does not make them yet a viable approach for efficient solar power generation (Barraud, 2013).

*Corresponding author.
E-mail address: nagyz@ethz.ch (Z. Nagy).

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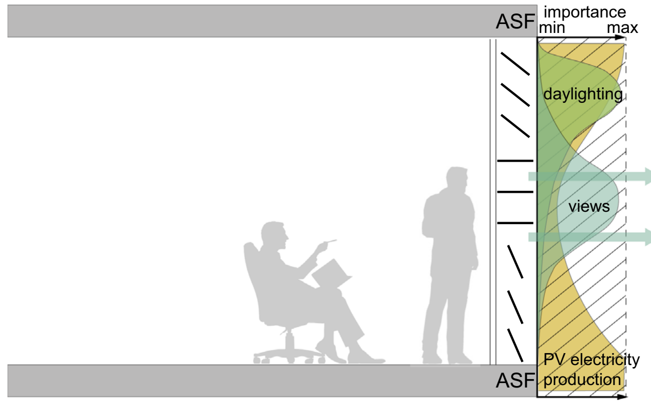

Fig. 1 The facade acts as mediator between the interior and the exterior environment and fulfills various functions. Modified from Jakica and Zanelli (2014).

Fig. 2 Modules on a building facade, mounted in frames on a cable net structure within the shading layer of the facade.

On the other hand, thin-film PV modules, such as Cu(In, Ga)Se_2 (CIGS), offer the advantage of flexible, curved, shapes and a lightweight structure when compared to the traditional modules, which come at the price of lower energy conversion efficiencies. However, recent research results have demonstrated that thin-film PV modules can also attain efficiencies similar to the traditional modules (Reinhard et al., 2013). In addition, from an economical perspective, the price per watt-peak of both systems have become comparable. Therefore, thin-film PV systems have become a powerful technology for BIPV (Kaelin et al., 2004; Chen et al., 2014).

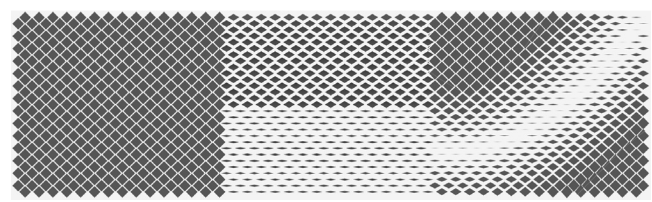

Fig. 3 Abstract representation of possible emergent module patterns of the ASF.

The lightweight structure of thin-film modules allows it to consider their integration into the building envelope. Although such facade PV systems receive less irradiation than rooftop and ground installations, they offer lower diurnal and seasonal variations, and can therefore substantially contribute to local electricity generation.Integrating BIPV with conventional building components, such as shading systems, can further lower costs and environmental impacts (Perez et al., 2012).

From an architectural perspective, the building envelope, or facade, is in essence the public face of a building, and has therefore a large impact on the perception of the building. From an energetic perspective, the envelope acts as a buffer or mediator between the interior and the exterior environment (see Fig. 1). The envelope can mitigate solar insolation, thereby offering reductions in heating/cooling loads, and improve distribution of daylight. Therefore, integrating PV modules into a dynamic shading system offers the possibility to fine tune the different functions, generate electricity, and balance energetic performance with architectural expression.

In this paper, we present our current progress on the Adaptive Solar Facade (ASF), a modular highly integrated dynamic building facade.The energetic behavior as well as the architectural expression of the facade can be controlled with high spatio-temporal resolution through individually addressable modules. The novelty of the ASF, compared to other dynamic facade systems,lies in the complexity of the integration of the individual functions, resulting in multidimensional functionalities.