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State of the art of advanced solar control devices for buildings

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ABSTRACT

This paper deals with the state of the art of advanced solar control devices for buildings, with the comparative evaluation of solar-control systems and with guidelines for the development of new solar control systems. It includes multifunctional systems with building integrated photovoltaic (BIPV) and/or building integrated solar thermal (BIST) energy conversion. In order to facilitate and to structure the understanding of solar control systems two multidimensional spaces are introduced: the design space and the evaluation space. The design space contains the design parameters which are to be selected by the designer when solar control devices are to be chosen for specific buildings or when new systems are to be developed, such us the color of the slat of a venetian blind or the fraction of holes (direct transmittance) of a fabric for a roller blind. The evaluation space contains the performance parameters or evaluation criteria, which indicate the design's ability to satisfy the functional and aesthetic requirements, such us passive solar gain control or visual comfort. All the design parameters and evaluation criteria are explained in detail in the paper. A chapter with examples of advanced solar control systems completes the overview of the state of the art of solar control systems.

1. Introduction

Solar-control systems can help to reduce the cooling energy consumption of buildings, to reduce the energy consumption of the artificial lighting system, to provide visual comfort, to ensure healthy natural lighting and to generate solar electricity and solar heat at the same time. All of these multifunctional aspects have to be assessed realistically and reliably when systems are chosen for specific buildings and when new systems are being developed. Well-designed solar-control systems are therefore important elements that help to achieve the CO_2 reduction goals worldwide and especially in the European Union as defined in the Energy Performance of Buildings Directive (Directive 2002/91/EC and the recast (2010/31/EC),EPBD). It is important to note, that solar-control systems should not be regarded purely as an unavoidable energy-saving measure. Well designed solar-control systems can also contribute positively to the architecture of the buildings and to the well-being of the users. This paper aims to contribute to achieving these goals with a description of the the state of the art of advanced solar control devices for buildings and with guidelines for the comparative evaluation and the development of new solar control systems.

2. Design space and evaluation space - the key to the understanding of solar control systems

The author of this paper has developed several solar control systems (Kuhn, 2016; Clauss and Kuhn, 2001; Baumann et al., 2002; Bläsi et al., 2002; Kuhn, 2006; Hermann and Kuhn, 2006; Kuhn and Hermann, 2007; Kuhn et al., 2007; Maurer et al., 2011; Nestle et al., 2013), theoretical evaluation methods (Kuhn et al., 2000; Kuhn, 2006; Kuhn, 2006; Kuhn, 2007; Kuhn and Herkel, 2011) and measurement procedures (Kuhn, 2014; Kuhn et al., 2016). This was the background for contributions to several standards (EN 14500, 2008; EN 14501, 2005; ISO/CD 19467, 2015; ISO TC160 and TC163, 2016). The author is convinced that the key to the understanding of solar control systems is to introduce two multidimensional spaces: the *design space* and the *evaluation*

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space. Fig. 1 provides an overview of the design space. The design space contains the *design parameters* which are to be selected/specified by the designer when solar control devices are to be chosen for specific buildings or when new systems are to be developed, such us the color of the slat of a venetian blind or the fraction of holes (direct transmittance) of a fabric for a roller blind. The choice of a set of design parameters is similar to the choice of a coordinate system with orthogonal (= linearly independent) coordinate directions in a vector space. It is important to find meaningful and independent design parameters, such as W (relevant for the necessary installation space) together with the dimensionless ratio W/D (relevant for the optical and visual properties) when a venetian blind with slat width W and slat distance D is to be specified. The parameter set $[W, D, W/D]$ would not be independent since changes of the parameter W would always change implicitly also the parameter W/D. The set of design parameters should not only be independent but also complete. The evaluation space contains the *performance parameters or evaluation criteria*, which indicate the design‘s ability to satisfy the functional and aesthetic requirements, such us passive solar gain control or visual comfort. Fig. 2 shows the aspects of the evaluation space which are related to energy and user comfort. The relative weight of the different evaluation criteria cannot be defined independent of the actual building context, such as small/large window or open plan/single office etc. A generally valid metric (like metrics in vector spaces) therefore does not exist in the evaluation space and the individual dimensions have to be evaluated separately. The best design (or the relative rating of different designs) therefore depends on the specific building and the preferences of the architect and the building owner. The author is nevertheless confident that the systematic overview and the structured procedure greatly helps to select solar control devices in building projects more objectively and to optimize newly developed systems. It is essential to clearly distinguish between evaluation criteria and design parameters in order to keep the overview.

Chapter 3 discusses the list of requirements for solar control systems within the context of the evaluation space. Chapter 4 discusses design options for advanced solar control systems within the context of the design parameter space.

3. Requirements for solar-control systems - the evaluation space

Transparent components are essential to the design and performance of a building. They influence its indoor comfort and energy budget in many diverse ways: daylight illuminates indoor rooms throughout the year, solar energy can be used to heat buildings passively, excessive solar gains can cause glare and overheating, transparent areas allow visual contact with the exterior and the transparent areas are also important for the architectural appearance of a building. The following sub-sections are providing an overview on the different criteria which are relevant for the evaluation of solar-control systems with respect to energetic aspects and user comfort including health issues. The criteria are summarized in Fig. 2.

3.1. Criteria for passive solar gain control

Passive solar gains, transmitted through the facade, are determined primarily by:

- the size of the glazed areas,
- the orientation of the glazed areas with respect to the sun,
- external obstructions by surrounding buildings and trees,
- the insulation properties of the facade system (U-value),
- the solar heat gain coefficient g of the complex fenestration system/facade system,
- the operation of the facade system.

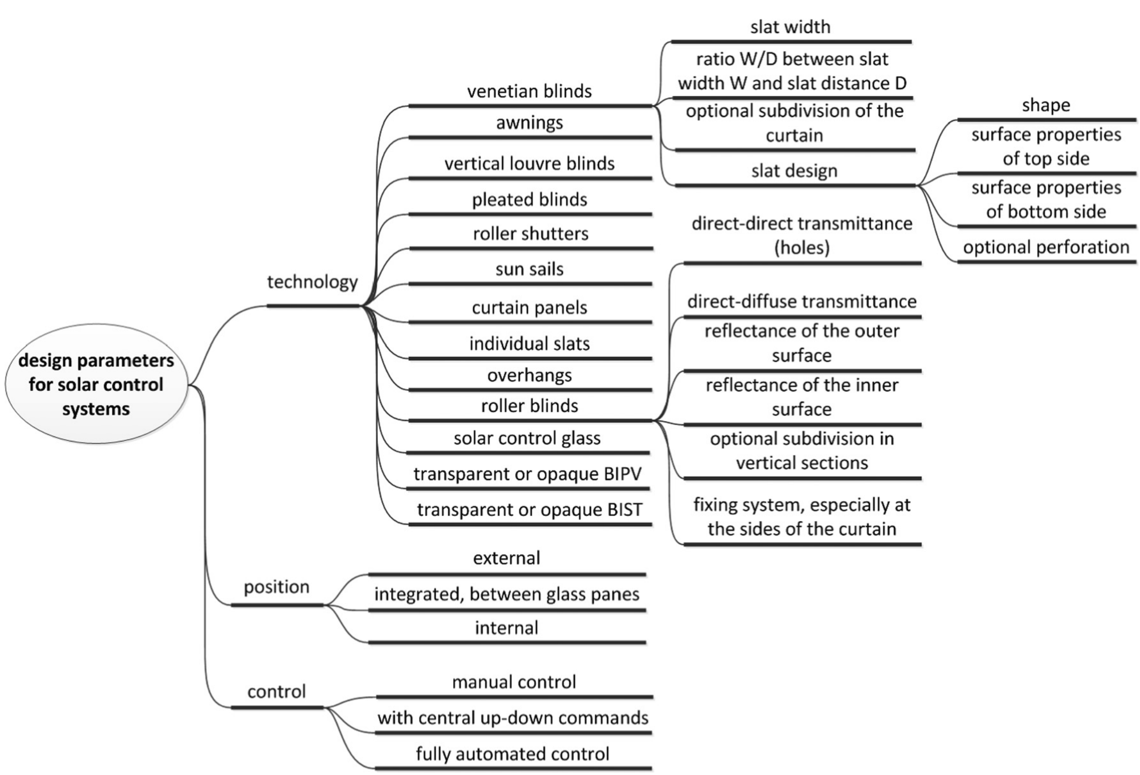

Fig. 1. Design parameters for solar-control systems.

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