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A PVT collector concept with variable film insulation and low-emissivity coating

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Abstract

Hybrid photovoltaic-thermal (PVT) collectors co-generate solar electricity and heat in a single component with an optimum utilization of space. Spectrally selective but transparent low-emissivity (low-e) coatings are a proven method to reduce thermal losses. However, overheating and stagnation are critical issues for these collectors due to material degradation, thermal stress, and low electrical efficiency.
This paper presents a PVT collector concept with variable film insulation as overheating protection. An inflatable glass-film cushion regulates thermal losses. Performance and stagnation tests were carried out with a prototype. During normal operation the collector achieves a high thermal efficiency. In periods of standstill, the deflated cushion has a high heat dissipation rate by deactivating the low-e coating. Stagnation temperatures are thus limited to 95 °C. To conclude, the PVT collector combines the advantages of glazed and unglazed PVT collectors which are a high thermal efficiency and low stagnation temperatures.

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Keywords: hybrid photovoltaic-thermal (PVT) collector; spectrally selective coating; switchable insulation; overheating protection; thermal management

1. Introduction

Hybrid photovoltaic/thermal (PVT) collectors convert solar energy into both electricity and heat in one component. Typical photovoltaic (PV) modules have an efficiency of 10 – 20 %. The major part of the solar spectrum remains unused and is transformed into heat. PVT collectors use the excess heat by coupling the solar cells

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thermally to a fluid. Thus, they have the potential to make optimum use of the solar resource with the maximum utilization of available space.

PVT collectors can be categorized according to their design (unglazed, glazed, and concentrating) [1]. Each design has its specific temperature levels and accordingly suitable applications. Unglazed PVT collectors are optimized towards electrical performance but deliver heat at low temperature levels. Glazed PVT collectors reach higher temperature levels because of reduced thermal losses due to a transparent cover. Low-emissivity (low-e) coatings are a proven measure to further decrease radiative losses. Analogous to spectrally selective solar thermal absorbers low-e coatings feature low emissivity in the infrared spectrum but a high transmittance in the solar spectrum. At Fraunhofer ISE, a novel low-e coating was developed which is specifically optimized for the application in PVT collectors. With this coating radiative losses are reduced by 80 %, so that a thermal efficiency similar to state-of-the-art solar thermal, flat plate collectors is achieved [2]. Hence, glazed PVT collectors with low-e coatings are a suitable technology for conventional solar thermal applications such as hot water preparation or space heating [3]. However, overheating is an issue exacerbated by low-e coatings. Stagnation temperatures can exceed 150 °C. Materials employed in PV modules, especially EVA, are not designed to withstand these temperatures. Moreover, high stagnations temperatures increase thermal stress and the occurrence of brittle cell connectors [4].

Fortuin [5] describes two approaches for high-temperature PVT collectors: temperature resistant materials [6] or overheating protection. A switchable insulation limits temperatures in both the collector and the hydraulic system by actively increasing heat losses. Additionally, the switchable insulation enables a flexible, more efficient operation. By adjusting instantaneous efficiencies the generation priority can be switched between electricity and heat-driven operation.

The collector concept presented in this paper uses a fluoropolymer film to achieve a variable insulation. Fluoropolymer films such as ETFE, FEP, or PTFE are used in architectural façade applications, in solar thermal collectors as convection barrier, and in greenhouses. Different inflatable glass-film-combinations for flexible greenhouse systems were investigated in [7]. A variable film insulation for solar thermal collectors is used as overheating protection in [8] and to achieve variable heat dissipation rates by adjusting convective losses in [9]. In the presented PVT collector concept the film is sealed hermetically at the edges to the low-e glass. A small air pressure stabilizes the cushion and ensures low thermal losses. Deflating the cushion increases heat losses and thus reduces collector temperatures during stagnation.

2. Collector concept and construction

The basis for the collector concept forms a flat plate, glazed, liquid-type PVT collector design. A fluoropolymer film replaces the external glass cover as used in conventional flat plate collectors. Inflating and deflating the glass-film cushion regulates the heat losses and enables an effective switchable insulation (Fig. 1). The requirements for the collector are a high efficiency during operation combined with low stagnation temperatures comparable to unglazed PVT collectors to avoid damage and increase electrical efficiency. The overheating protection needs to be fail-safe ensuring that even during power outages and failure of the hydraulic system critical temperatures are avoided.

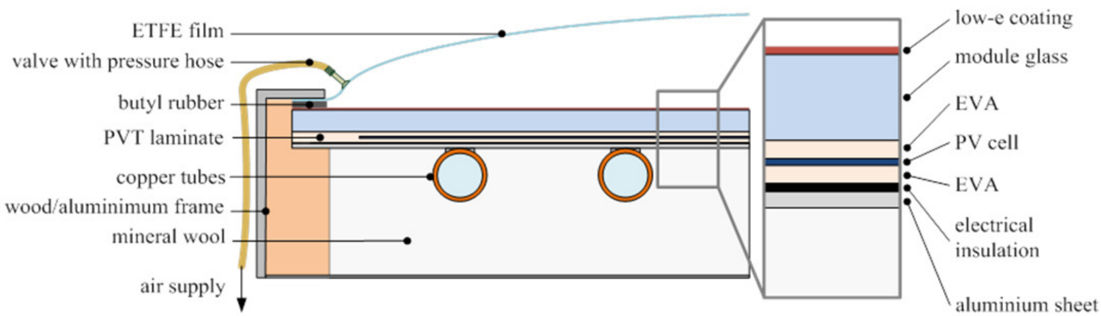

Fig.1. Schematic drawing of the collector concept with inflated ETFE cushion.