DEVELOPMENT OF A HIGH PERFORMANCE FACADE ELEMENT

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ABSTRACT

This paper presents an overview of the R&D activities for the *Bâti-Tech* project that concerns integration of solar thermal collectors into an existing, commercialised multifunctional facade element. The study involves both monitoring and test bench measurements along with dynamic simulations of the facade element integrated in a building. The existing facade concept includes thermal and acoustic insulation and PV production. The overall objective of the project is to modify the current facade element and integrate a solar thermal collecting function for building heating purposes. This project, funded by the Canton of Vaud, was launched at the end of 2013 within the framework of its "*100 millions pour les énergies renouvelables et l'efficacité énergétique*" programme. Research has indicated that the PV performance of the investigated facade is greatly affected by shading of the near surrounding. Measured stagnation temperatures of the PV panel of the facade element have also shown a limited potential for using heat from these modules for heating applications unless combined with a heat pump. Simulations have further suggested that the use of flat plate systems as a collecting device integrated in the building envelope could be interesting for space heating and domestic hot water preparation. The study is now focusing on the modification and integration of a solar thermal collector into the existing facade concept.

Keywords: multifunctional facades, building integration, active solar components

INTRODUCTION

In Switzerland, space and domestic water heating are estimated to account for more than 40% of the total energy consumption in buildings [1]. They, therefore, represent an important opportunity to enhance buildings energy and environmental performance. Improved building envelopes and equipment along with exploiting renewable energies are key to minimising heat consumption and achieve higher energy efficiency and low greenhouse gases emission.

Today, the use of renewable energy in the building sector is dominated by solar installations for space and water heating and photovoltaic systems, mainly on the roof. In order to comply with current energy efficiency policies and legislation, for example [2], facades must also be considered as multifunctional energy conversion elements. The idea of changing the building envelope primary role so that it additionally becomes an active solar element is a good opportunity to optimise building energy efficiency. Thus, this project deals with the development of a multifunctional high energy performance facade element for new and refurbished buildings. This paper summarises the project different steps, describes the facade element concept and presents the main findings in the optimisation process of the facade system under investigation.

PROJECT DESCRIPTION

The overall objective of the project is to improve the functions of an existing, commercialised facade element. The facade element to optimise is a prefabricated layer module, fully integrating thermal and acoustic insulation along with photovoltaic panels for electricity generation. The investigated system is commercialised in Switzerland under the name of *Face*

InTec© and in association with Alpic InTec AG [3] a number of buildings have already been implemented with this technology [4]. Figure 1 shows a schematic representation of the *Face InTec*© system.

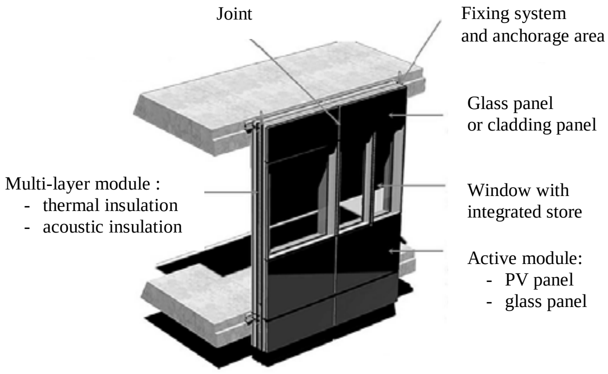

Figure 1: Schematic representation of the Face InTec© facade element

This project is concerned with the extension of facade element functions to include heat generation while keeping its aesthetics and modularity.

This will be achieved through a programme of work with the following sub-objectives:

- To monitor the energy performance of a pilot building installation and estimate heat recovery from the PV panel
- To study the system on a test bench, set up to characterise the facade element
- To develop a numerical model to simulate the behaviour of the facade element and predict the potential for heat recovery from different types of solar collectors. In addition, to simulate the annual performance of a building made of these elements over a wide range of conditions

Monitoring campaign

A monitoring campaign on a pilot building installation is underway allowing the evaluation of the electricity production of the *Face Intec*© elements. This helps verifying how well the PV installation is performing by comparing the actual PV production with expected targets. These latter were computed with the simulation software PVsyst [5].

The building is a two storey office situated in Lausanne with an envelope totally implemented with *Face Intec*© elements, see Figure 2.

Figure 2: Northwest and southwest facades of the pilot building

Some of these incorporate PV panels, apart from the northeast facade for which no PV panels were integrated. The building longitudinal axis runs from northeast to the southwest. The PV installation is made of 402 micromorph modules[1] for a nominal rating of 46.2 kWp. The output is then fed to ten inverters[2]. Electricity production and module temperatures are recorded continuously since 2011 at 5 minutes intervals using a solar data logger with PC control.

Figure 3 shows a comparison between the annual PV output power per inverter (and orientation) and the corresponding simulated values for outdoor conditions based on the closest meteorological station to the building (Pully, CH).

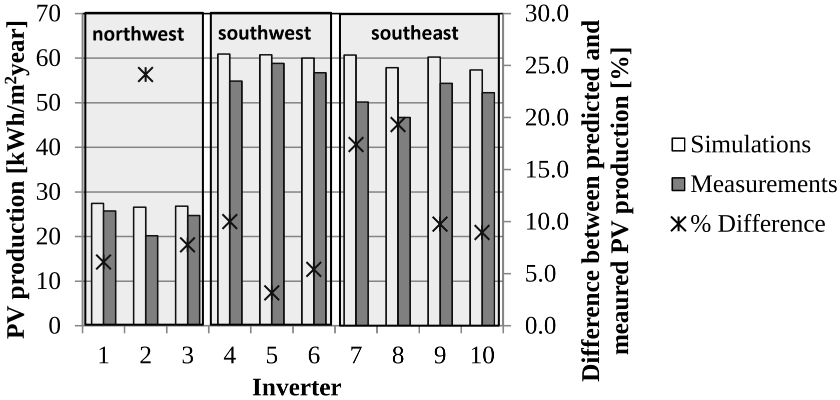

Figure 3: Comparison of predicted and measured PV production of the pilot building facade

As expected, the northwest facade presents lower electricity production in comparison with the other two facades mainly because of less exposure to the sun. Southwest and southeast facades present a similar PV production with values slightly higher for the southwest side probably due to slightly better insolation conditions.

It can also be seen that predictions are systematically higher than measurements with differences up to 24%. These are probably due to energy losses associated with module and inverter efficiency, shades, cabling, mismatch and soiling. However, a detailed analysis of the PV panels associated with these large differences have shown that due to their location, shading effects by the near surrounding and consequent mismatch losses are quite important. These effects have not been included in the simulation and result in great discrepancies, particularly for inverters 2, 7 and 8. This analysis considered direct shading using information based on both on-site observation and shadow projection on a sun-path diagram.

In order to estimate the potential for heat recovery of the *Face Intec©* facade, one PV module in the southwest facade has been fitted with two Pt1000 sensor to continuously monitor the rear-side temperature. The results revealed stagnation temperatures ranging from -8°C to 74°C on an annual basis. However, in winter the potential for applications such as space heating and domestic hot water (DHW) preparation (20°C and higher) is only about 15%. For temperature levels below 20°C, the use of a heat pump for heating purposes becomes necessary.

Test bench

A test bench comprising two independent support structures for studying the active module of *Face Intec©* is operational and equipped with different sort of sensors for monitoring purposes, see Figure 4. It allows to measure module temperatures, weather data and electricity

[1] Pramac Luce MCPH P7 115Wc
[2] Powador 6002, KACO new energy

production of the PV module. Situated in Yverdon-les-Bains, this facility offers the possibility to make comparisons between different modules under the same climate conditions. Modules undergoing testing are a PV micromorph panel, a simple glass panel and a solar thermal collector. This test bench is used not only to characterise the behaviour of the different modules but also to allow direct comparisons of performance between module types.

Figure 4: Test bench of the Face Intec© active module

Validation of results obtained on the test bench with measurements on the pilot installation was performed under near clear sky conditions. Figure 5 compares the temperature values obtained on an autumn day.

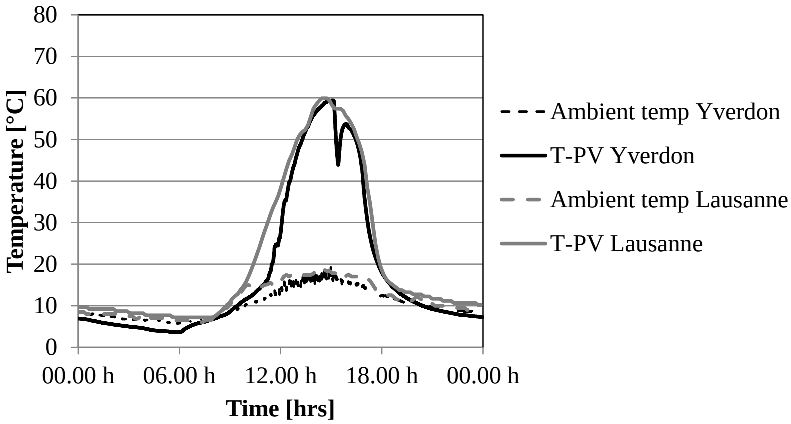

Figure 5: Comparison of test bench and pilot building PV module temperature

The daily temperature profiles of the PV module for the two locations follow the same trends with discrepancies more pronounced in the morning as some clouds partly covered Yverdon-les-Bains, reducing momentarily the solar irradiance. Another decrease of solar irradiance occurred in the afternoon at Yverdon-les-Bains due to a near surrounding object partly overcasting the tested module. The testing campaign of the different modules is ongoing and the results recorded using a Labview [6] acquisition system. This facility will allow the experimental characterisation of the performance and efficiency of the integrated heat recovery system under different climate and configuration conditions. These tests will benefit the development and design of a future solar thermal integrated *Face Intec*© element.

Simulation of the system

A dynamic model has been developed to characterise the performance of the facade active module on its own and when integrated in the building envelope. For these simulations the software TRNSYS 17 [7] was employed. The numerical model considers:

- Reference building: pilot office building at Lausanne with a heating area of 3650 m^2.

- Building space heat demand estimated with a single node model: thermal losses through the envelope and by ventilation as well as heat gains through windows and from people and equipment are accounted for.
- Building DHW demand: according to standard SIA 380/1 [8].
- Three different types of solar thermal collectors: flat plate; selective unglazed; non-selective unglazed.
- Two different Swiss climates: typical midland climate (Lausanne) and typical mountain climate (St-Cergue).

In order to assess the potential of generating heat from building integrated solar thermal devices, an analysis of the monthly average of global available solar irradiation on a south oriented surface for two slopes was performed. The resultant profiles are plotted in Figure 6 for the two surface inclinations of 30° (optimum tilt angle) and 90° (vertical facade) for the climate of Lausanne. Similar trends were observed for the mountain climate.

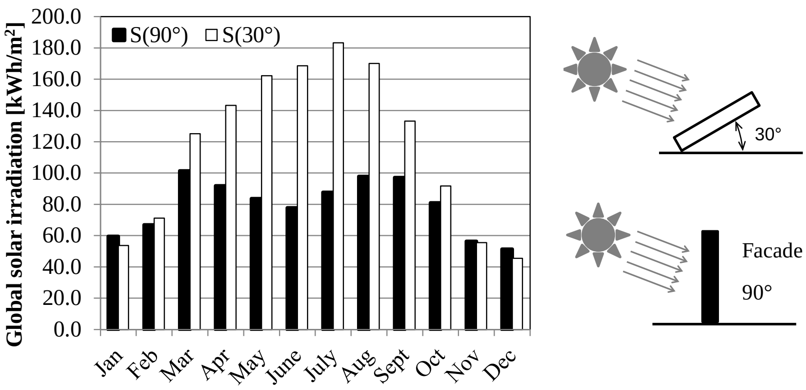

Figure 6: Average monthly distribution of the global solar irradiation on a south oriented surface for two slopes (Lausanne)

In the case of the vertical facade, it can be seen that the available solar irradiation is rather constant throughout the year, limiting summer overproduction when heating requirements are lowest (DWH only). Also, due to the high slope, solar irradiation is more important during spring and autumn. In addition, because during winter the sun is low in the sky, winter months receive an amount of irradiation comparable to that of the optimal case when energy needs are at the highest. The results indicate that vertical facades could provide a good alternative to more conventional solar thermal systems as they are able to better match the solar energy offer to the building heating demand.

Based on these profiles, the potential amount of heat that can be delivered from a solar thermal collector to the building heating system has been determined. Three different types of solar collectors able to be integrated in a façade without compromising the aesthetics were considered, see above. Variation of the inlet temperature to the collector was simulated for values between 15°C to 80°C in order to assess the effect on the heat recovery during winter months. Because results exhibit similar trends, only predictions for December are presented here. Figure 7 shows the predicted amount of heat recovered in December for the location of Lausanne for three types of solar thermal collectors placed on a south oriented vertical facade

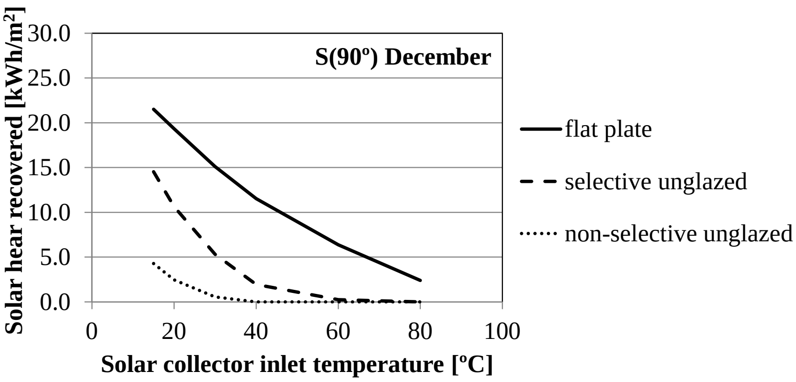

Figure 7: Predicted amount of solar heat recovered for three types of solar thermal collectors mounted on southern vertical facade

It can be seen that heat recovered by the non-selective unglazed collector is quite small when compared with that from the other two collectors. The selective unglazed collector could be an interesting option for heating purposes if combined with a heat pump to reach higher temperature levels. Finally, the flat plate presents the best solution with a predicted heat recovery at low to moderate temperature levels. Unlike unglazed collectors, their ability to collect solar energy is less dependent on the outside temperature. In all cases heat recovered decreases with increasing collector inlet temperature. The small amounts of heat recovered by the non-selective unglazed collectors suggest further that if combine with a PV module, resulting in the so-called photovoltaic thermal hybrid solar collector (PV/T), would not be appropriate for heating applications.

CONCLUSION

This paper presents the ongoing R&D activities for the *Bâti-Tech* project that deals with the integration of solar thermal collectors into an existing, commercialised multifunctional facade element. The investigation involves monitoring, test bench measurements and dynamic simulations of the facade element integrated in a building envelope. Monitoring of a pilot building facade has shown that PV performance is greatly affected by shading of the near surrounding. In addition, the potential for heat recovery from the rear-side of a PV panel is found to be small for heating applications unless combined with a heat pump. Conversely, simulations have shown promising results regarding the use of flat plate collectors integrated in the facade to better capture the available solar energy for heating applications. Based on these results, research is now focusing on the physical modification of the current facade element to include a solar thermal collecting device.

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