Development of glazed and unglazed PVT collectors and first results of their application in different projects

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Abstract

After a short introduction on glazed and unglazed PVT collectors, we report on two projects with different applications of uncovered PVT collectors: (1) regeneration of ground bore-hole storages coupled to heat pumps for space heating and domestic hot water and (2) pre-heating of domestic hot water in multi family houses.

Keywords: PVT collectors, regeneration of ground bore-hole storages, BTES, pre-heating of domestic hot water

1. Introduction

The combination of different renewable energy technologies is the big task for the future. The aim is to supply our buildings to a large extent with renewable heat and electricity. With respect to the solar technologies (solar thermal and PV) it is true that the individual technologies are well developed. PV converts solar radiation into electricity; a very valuable, high exergy-form of end-energy. But its energy efficiency is only about 12 to 17% and thus rather low. On the other hand, solar thermal collectors and systems for domestic hot water and room heating convert solar radiation into heat with a high efficiency: 80% collector efficiency for temperatures near to ambient temperature and 60-50% collector efficiency under operating conditions, 50-30% of yearly system efficiency. But low temperature heat is produced and the exergy-efficiency of solar thermal systems is rather low (about 5% only for domestic hot water systems). But if the technologies are combined in a PVT-collector the energetic efficiency is high (about 70%) and at the same time the exergetic efficiency is increased also to more than about 20%. Under these basic considerations PVT technology offers very promising perspectives. But it is important to develop PVT-collectors from the very basic principles and as a new solar energy converting device and not to look at the task as...
simply gluing together a ready-made PV-panel and a standard fin-and-tube heat transfer sheet from a thermal collector. It is very important that the heat resistance between the solar cell (in which the heat is produced) and the heat transfer fluid is as low as possible in order to achieve a high thermal performance and at the same time a good cooling effect of the cells (leading to higher electricity production) as well.

In this paper we report on two projects in which uncovered PVT collectors from our partner Mayer Burger AG are used in applications with favorable operating conditions for PVT collectors: (1) regeneration of bore hole thermal energy storages (BTES) and (2) pre-heating of DHW in multi-family houses.

2. Regeneration of bore hole thermal energy storages

There are some first systems installed in projects in Switzerland using unglazed PVT collectors in combination with heat pumps and bore-hole thermal energy-storages ("BTES"). The heat from the PVT collectors is used for the regeneration of heat in the ground heat-storages during summer time to compensate for the heat extracted from the BTES by the heat pump during winter time.

A very simplified system set-up is shown in figure 1a for the case of the project "Bern Oberfeld". This project does not only concern a single house (as in the sketch) but a whole settlement with three buildings which have 4 storeys and contain in total 100 apartments, see figure 1b. The buildings have a low heating energy consumption and are built with respect to the Swiss energy label "Minergie-P-Eco". There will be 1280 m² of uncovered PVT collectors installed in the final stage of the project (800 PVT collectors). The first phase of the system with an area of 625 m² and a total of 380 PVT collectors was installed in spring and summer 2014.

Figure 1: (a) Simplified sketch of system with uncovered PVT collectors for regeneration of BTES which are delivering heat to heat pumps for DHW and space heating; (b) Architectural model of the new settlement "Bern Oberfeld" on which the system is installed.

Figure 2: (a) Uncovered PVT collectors installed on the roof of the newly built settlement "Bern Oberfeld". b) The heat from the PVT collector field is stored in a BTES with 15 ground bore holes.
This system will be monitored by the Institute for Solar Technology SPF with respect to the thermal and electrical gain of the PVT collector field and the thermal energy stored in the BTES consisting of a field of 15 ground bore holes. The monitoring system has just been installed and taken into operation. First results will be reported in due time.

3. Pre-heating of DHW with uncovered PVT collectors in multi-family houses

Another interesting and promising application of unglazed PVT collectors is solar pre-heating of domestic hot water (especially in larger multi-family residential buildings). In order to investigate such systems we installed a scaled testing system at our institute and operated it for a full year. Figure 3 shows the system installed and its components. It was already described in [1] as follows: The six PVT collectors [2] are connected in parallel and installed on a test-roof of our institute SPF in Rapperswil at an angle of 45° with South-orientation. Two PV-modules [3] with the identical module construction as used in the PVT-collectors are installed to the left for comparison reasons.

![Figure 3: The left picture shows the field of two PV-modules and the field of 6 PVT-collectors. The PVT collector field has an aperture area of 6*1.656 m * 0.991 m = 9.85 m². It is connected to a 500 l solar thermal storage tank. Each of the PV and PVT devices is electrically connected to its own inverter.](image)

Each single module and PVT-collector is connected to its own inverter. The PVT collector field is connected to a solar water storage tank of 500 liters volume using an immersed heat exchanger. Every day 600 liters are drawn from the storage tank. The draw profile was generated based on the simulation of the draw pattern in multi-family-houses, using the software DHW-calc and is shown in figure 4. The draws are taken hourly with a rate of about 450 l/h.
4. Measured results from one complete year of operation

The system has been operated over a full year from May 2013 to April 2014. Figure 5 shows the monthly solar radiation measured in the plane of the PVT collectors, the electrical gain (measured on the DC side) and the solar heat output of the uncovered PVT collector field.

This results in the following evaluation for the complete year: The global irradiation in the collector plane at our location for the measurement year was 1356 kWh/m². The thermal gain of the uncovered PVT-collectors was 258 kWh/m². The electrical output of the PVT collectors was 168 kWh/m² whereas the PV modules had an output of 162 kWh/m². In terms of yearly efficiencies based on the measured global radiation it means 19% for the thermal performance of the PVT collectors, 12.4% for the electrical performance of the PVT collectors (DC), and 11.9% for the performance of the PV modules (DC).
It should be stressed here explicitly that these values are of course very much depending on the dimensioning of the system with respect to collector size, storage volume and hot water demand. In our case, the yearly solar fraction for the measured year was 22%. The monthly solar fraction reached its highest value of "only" 53% in July 2013. Higher solar fractions will result in lower thermal and electrical performance of the PVT collectors as also described in [1].

Concerning measured PV module temperatures and PVT collector temperatures, figure 6 gives an example for a day without clouds during summer time (2-August-2013). During noon time the PV modules were about 22 K warmer than the PVT collectors. The temperatures were measured with PT100 sensors attached to the rear side of the module and the collector respectively, directly behind a solar cell in the middle of the module. At that point in time the PVT collectors had a power output (DC) which was 17% higher than the power output of the PV modules. But summed up over this whole day, the relative difference in electrical gain was 8.7%.

![Figure 6: Measured temperatures and electrical output (DC) of PV module and PVT collector on a cloudless day during summer time.](image)

The additional electrical gain of the PVT collectors compared to electrical gain of the PV modules was +4.1% when evaluated for the complete measured year and the operating conditions we had due to the dimensioning of the system as a DHW pre-heating system with a low solar fraction. A more detailed evaluation of the measured data with respect to the measured temperature differences and other aspects is given in [4].

5. Conclusions

Uncovered PVT collectors are already used successfully in applications with favorable operating conditions. Two examples are given here: (1) regeneration of bore hole thermal energy storages (BTES) and (2) pre-heating of DHW in multi-family houses. In the first case we just started with a monitoring project which is briefly described. In the second case it is shown by an experimental investigation and measurements for a complete year that uncovered PVT collectors in DHW pre-heating systems reach a yearly thermal output of about 270 kWh m\(^{-2}\) and at the same time produce about 4 % more electricity compared to PV modules. The results enabled us to validate simulation programs for the dimension and planning of DHW pre-heating systems on large multi family houses.
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References