BUILDING INTEGRATION OF SOLAR THERMAL SYSTEMS

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Abstract*:* *A solar thermal system (STS) is considered to be building integrated, if for a building component this is a prerequisite for the integrity of the building's functionality. If the building integrated STS (BISTS) is dismounted, dismounting includes or affects the adjacent building component which will have to be replaced partly or totally by a conventional building component. This applies mostly to the case of structurally bonded modules but applies as well to other cases, like in the case of replacing with BISTS one of the walls in a double wall facade. Generally, the benefits of building integration include: building envelope, thermal and optical performances, costs and aesthetics. The objective of this paper is to present some innovative designs that are used worldwide so far.*

Keywords*:* *solar thermal system, building integration, innovative designs.*

1. INTRODUCTION

All the forms of energy in the world are basically solar in origin. Oil, coal, natural gas and woods were originally produced by photosynthetic processes, followed by complex chemical reactions in which decaying vegetation was subjected to very high temperatures and pressures over a long period of time. Even the wind and tide energy have a solar origin since they are caused by differences in temperature in various regions of the earth. The greatest advantage of solar energy as compared with other forms of energy is that it is clean and can be supplied without any environmental pollution. Over the past century fossil fuels have provided most of our energy because these are much cheaper and more convenient than energy from alternative energy sources, and until recently environmental pollution has been of little concern [1,2].

In the time when the world is debating on climate change issues which is basically due to use of fossil fuel, the use of solar energy in various form is relevant. The existing buildings are responsible for use of large amount of energy for lighting, heating, cooling and use of various energy run equipments mostly powered by fossil energy. Today's intention should be to replace this fossil fuel by solar energy which is free and available in abundance [3]. But solar thermal technologies are not yet playing the important role they deserve in the reduction of buildings' fossil energy consumption and consequent greenhouse gas emissions, even though the increasing oil price has recently started to budge the market [4].

The major component of any solar system is the solar collector. This is a device which absorbs the incoming solar radiation, converts it into heat, and transfers this heat to a fluid (air, water, or oil) flowing through the collector. The solar energy thus collected is carried from the circulating fluid either directly to the hot water or space conditioning equipment, or to a thermal energy storage tank from which can be drawn for use at night and/or cloudy days [2]. STS are typically mounted on building roofs with no attempt to incorporate them into the building envelope, creating aesthetic challenges and space availability problems. This could create a number of problems due to the increased application of STS in buildings because of space availability problems (no enough roof space) and also more severe aesthetic problems if much more systems are installed using the current techniques.

By integrating solar collectors into building elements, both building materials and the time for installation work can be saved, making the collectors more cost-effective. It can also make these builings more attractive from design point of view. With this, the economical viability of integration is met and most importantly, they become architectural components.

Solar collectors should be developed to respond to the technical constraints, but should furthermore become an architectural element, conceived to be integrated into the building skin, possibly fulfilling more than one function, so as to ease designer's integration efforts and to reduce the overall cost [5].

This paper analyzes some novel designs of BISTS that are used worldwide so far and highlights design possibilities regarding the use of solar technologies into buildings with innovative approaches.

2. SOLAR THERMAL COLLECTORS

The main components of any solar system - solar energy collectors, are special kind of heat exchangers that transform solar radiation energy to internal energy of the transport medium [2].

There are two types of solar collectors: non-concentrating (stationary) and concentrating.

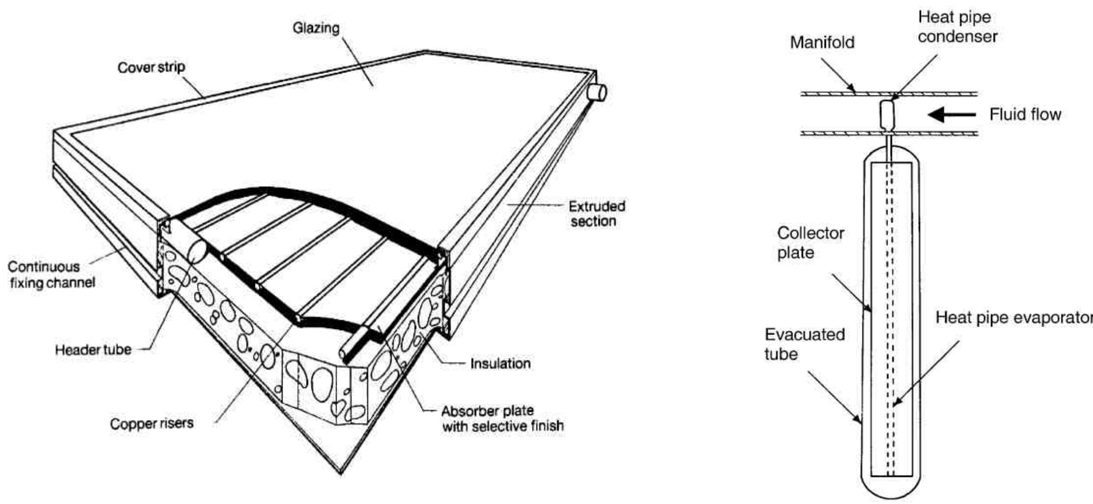
Table 1. *Solar energy collectors*

Motion	Collector type	Absorber type	Concentration ratio	Indicative temperature range (8C)
Stationary	Flat plate collector (FPC)	Flat	1	30–80
	Evacuated tube collector (ETC)	Flat	1	50–200
	Compound parabolic collector (CPC)	Tubular	1–5	60–240
Single-axis			5–15	60–300
	Linear Fresnel reflector (LFR)	Tubular	10–40	60–250
	Parabolic trough collector (PTC)	Tubular	15–45	60–300
	Cylindrical trough collector (CTC)	Tubular	10–50	60–300
Two-axes	Parabolic dish reflector (PDR)	Point	100–1000	100–500
	Heliostat field collector (HFC)	Point	100–1500	150–2000

The non-concentrating collectors are fixed in position and do not track the sun, and also they have the same area for intercepting and for absorbing solar radiation. The concentrating solar collectors usually have concave reflecting surfaces to intercept and focus the sun's beam radiation to a smaller receiving area, thereby increasing the radiation flux [2]. Solar energy collectors are basically distinguished by their motion, i.e. stationary, single axis tracking and two-axes tracking, and the operating temperature. A list of solar collectors, available in the market, is shown in Table 1 [6,2]. Concentration ratio is defined as the aperture area divided by the receiver/absorber area of the collector.

3. SOLAR COLLECTORS IN BISTS

Flat plate collector, Fig. 1a and Evacuated tube collector, Fig. 1b are commonly used in BISTS. Schematic diagrams of these collectors, respectively are shown at Fig. 1.



a) b)

Fig. 1. *a) Flat plate collector, b) Evacuated tube collector*

Typical flat-plate solar collectors are most common collectors used for domestic hot water and space heating. A flat-plat collector consists basically of an insulated metal box with a glass or plastic cover (the glazing) and a dark-colored absorber plate. Solar radiation is absorbed by the absorber plate and transferred to a fluid that circulates through the collector in tubes, Fig. 1a. The underside of the absorber plate and the side of casing are well insulated to reduce conduction losses. The liquid tubes can be welded to the absorbing plate, or they can be an integral part of the plate. The liquid tubes are connected at both ends by large diameter header tubes. The transparent cover is used to reduce convection losses from the absorber plate through the restraint of the stagnant air layer between the absorber plate and the glass. It also reduces radiation losses from the collector as the glass is transparent to the short wave radiation received by the sun but it is nearly opaque to long-wave thermal radiation emitted by the absorber plate [2].

Another category of collectors, which is also often used in BISTs, is the uncovered or unglazed solar collector. These are usually low-cost units which can offer cost-effective solar thermal energy in applications such as water preheating for domestic or industrial use, heating of swimming pools, space heating and air heating for industrial or agricultural applications [2]. These collectors heat the circulating fluid to a temperature less than that of the boiling point of water and are best suited to applications where the demand temperature is 30-70°C and/or for applications that require heat during the winter months [3,4].

Evacuated tube collector collectors can operate at higher temperatures than FPC, because the vacuum envelope reduces convection and conduction losses. Evacuated heat pipe solar collectors (tubes) operate differently than the other collectors available on the market. These solar collectors consist of a heat pipe inside a vacuum-sealed tube, Fig. 1b [2]. Evacuated-tubes collectors are composed of several individual glass tubes, each containing an absorber plate bonded to a heat pipe and suspended in a vacuum. The great insulation power of vacuum allows working at very high temperatures even in cold climates mainly due to low heat loss. These systems are suitable for domestic purpose for heating water and spaces and also for industrial applications where high working temperature is required. There flexibility to orient the inner absorbers independently from the module mounting angle is an advantageous feature of this type of collector [3].

4. NOVEL DESIGNS OF BISTS

It is very important task to respect the basic principles in building design [7].The need to produce and store thermal energy as close as possible near the consumption site, or in the building itself; makes the integration of this system even more relevant. Since the existing solar collectors were normally manufactured as pure technical elements, they have posed a challenge for architectural integration [3]. Most solar thermal integrations seen are of course with the use of specially manufactured modules.

There must exist some level of flexibility in all the system characteristics affecting the building appearance. These include collector material and surface texture, absorber colour, shape and size of the modules and type of jointing. The other equally important aspect of integration is that they should become multifunctional construction elements, facade cladding being the most relevant added function for glazed and unglazed flat plate collectors. With this the need for conventional cladding materials are replaced and cost can be economized. The use of dummy elements also becomes relevant on the non-exposed surface of the facade or roof according to the design [3,4]. Overall, the integration must result in public acceptance, thermal performance, aesthetics and cost effectiveness.

4.1 Facade Integration of STC systems

The application of solar energy technology to buildings often depends on its ability to be integrated into common building structures, such as facade elements.

Facade integrated collectors become popular mainly due to the fact that they are visible and in turn enhance the overall look of the building. The other advantage of facade-integrated collectors is the uniform irradiation of sunlight over the year, which is due to their vertical installation. This is very beneficial as a lot of irradiation can be used even in winter, when the highest heat demand occurs for space heating. Further, arguments for installing solar thermal collectors on the facade are that there is often not enough space on the roof or no suitable oriented roof area is available [3].

Several main functions of facade-integrated collectors are: they function as energy generators for heating water, they improve the building's thermal insulation, and they act as a weather skin for the façade through the glazing and are at the same time a structural element of the facade [3].

Facade integrations are still very rare as they are, in fact, much more delicate than their roof counterpart because of the higher visibility of the collectors. As the facade is the public face of the architecture, the collectors cannot simply be used as added technical elements. Their architectural integration need to be satisfactory and the design controlled (4).

In new buildings, solar wall collectors are usually completely integrated in the facade as part of the total construction and design principle. When solar collector elements are built into the facade, they must satisfy the same building codes as the building does.

Typical example is the integration of STC in the office building of AKS DOMA Solartechnik, Fig. 2a. Large area of glazed flat-plate solar collectors is integrated in to the south facade of the building [3].

a) b)

Fig. 2. *a) Facade integration of glazed flat-plate collector, office building of AKS DOMA Solartedhnik b) Facade integration of unglazed flat-plate collector, CeRN, Switzerland*

Another example of good integration of STC system is the south facade of the Centre d'exploitation des Routes Nationales (CeRN) in Switzerland, Fig. 2b. The south facing facade integrated with non-glazed Energie Solaire metal collectors covering 40% of the building's heating demand and hot water [3,4].

a) b)

Fig. 3. *Facade integration of evacuated tube collectors a) as balcony railings, Sunny Woods multi-family housing in Zurich, Switzerland, b) as fence in the driveway of the house, family house in Cyprus.*

The tubular vacuum collectors as balcony railings, which makes the conventional railing unnecessary, have a nice degree of transparency giving interesting shadings on the floors. Most important is that these tubes make solar energy visible, Fig 3a [3,4]. Interesting example of similar kind of integration is shown at Fig. 3b. In fact, the tubular vacuum collectors are used as fence in the driveway of the house.

4.2 Roof Integration of STC systems

Fig. 4a represents the house in Aarhus, Demark, which claims to be one of the first active houses in the world. Flat solar thermal collectors are well integrated into the lower part of the roof, and they cover 50-60% of the yearly hot water heating demand and to supplement for room heating. PV system is integrated into the higher part of the roof, and these perfectly integrated and combined systems: PV and STC, are in perfect harmony with the overall expression of the roof [3].

The large continuous roof area of multi-family house in Hamburg is integrated glazed flat-plate solar collectors, Fig. 4b. This integration has a positive architectural effect and thereby an influence on the building's architecture. The solar thermal collector system is a combined system, contributing to both domestic hot water preparation and space heating.

a) b)

Fig. 4. *Examples of Integration on Pitched roof*

Very successful integrations are the roofs with unglazed solar collector systems presented in Fig. 5. In both examples, the collectors occupy the whole roof area and have the double function of solar absorbers and upper layer of the covering system [3,4].

Fig. 5. *Examples of Integration on flat roof*

6. CONCLUSION

STC is very important active system to produce green and clean energy using sunlight and can be developed as fundamental part of the building envelop with added aesthetics to the building.

When this system is considered very early in the design, it can perform very well both technically and aesthetically. The overall reduction in construction cost resulting from the multifunctional use of this system is another important feature of integration. However, with the availability of STC systems that can be well integrated into the building envelop, it becomes equally important to develop systems into a more integrable form similar to other building elements. Designers and manufacturers have shared an important task in the process of implementing a successful integration.

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