

INTEGRATED PHOTOVOLTAIC SOLAR THERMAL PANEL

FIELD OF THE INVENTION

The present invention relates to an improvement in solar energy conversion using photovoltaic and solar thermal collection, and in particular to an apparatus in which solar energy is collected by an integrated photovoltaic solar thermal panel. This apparatus reduces the overall cost including production and installation cost.

BACKGROUND OF THE INVENTION

Conventionally, converting solar energy into electricity and solar heat collection are carried by two separate apparatus. Photovoltaic, or PV in short, is used to convert solar radiation into electricity. On the other hand, solar thermal collectors are used to harness solar radiation for heating up water or air. These two types of apparatus, namely PV and solar thermal collector, are usually installed independently, and therefore occupying larger area and involving double installation effort.

PV collects solar energy and converts it to electrical energy. PV panel and PV module are used interchangeably in the disclosure of this invention. The PV panel is heated up when exposed to the sun since only a small fraction of the solar radiation is converted to electricity by photovoltaic effect. When the PV panel is heated up, its temperature rises and the conversion efficiency declines. In other words, the conversion efficiency is inversely proportional to the photovoltaic panel temperature. This is commonly known as the negative temperature coefficient of a photovoltaic panel indicating how much a solar panel power output is reduced with the increase in temperature.

In order to maximize the output from the photovoltaic panel, it is important to reduce the increase in temperature during operation. Presently there is no active means of reducing the PV panel temperature by removing the heat away. Most of the present PV installation relies on natural air movement to dissipate heat. The bottom side of the PV panel is hotter than the front side and therefore the removable of heat from the bottom side is more effective. The backsheet which forms the bottom side of a PV panel besides having the role of support, isolation and protection, its heat dissipation factor needs to be considered too. Glass backsheet is effective in support, isolation and protection, it however does not

have good heat conductivity and therefore the heat absorbed by the solar cells are largely trapped within the laminated PV panel. Besides glass, multi-layered laminated polymers (such as TPT and TPE) are widely used as backsheets. Due to their smaller thickness than glass, they dissipate heat better.

The perimeter of the PV panel is usually enclosed by a frame of aluminum, steel or molded polymer. The most common one being aluminum profile. The frame serves the purpose of sealing the photovoltaic panel as well as providing mechanical support and protection. The frame also provides means for mounting to other structures in an installation. For the sake of clarity, the PV panel and laminated PV panel has to be differentiated. Hereinafter the PV panel is referred to laminated PV panel with frame and ready to be installed. The laminated PV panel is one without frame. A typical laminated PV panel is a treated multilayer structure with a top transparent cover of glass or clear polymer, followed by a layer of encapsulant such as EVA (Ethylene Vinyl Acetate), interconnection solar cells, another layer of encapsulant (usually EVA) and backsheet of glass or composite laminate. The laminated PV panel is an integral unit as the multilayer structure encasing the solar cells are adhered together by the encapsulants and protected by the front cover and backsheet. Electrical connections from the interconnected solar cells are brought outside of the laminated PV panel.

There are a number of different solar thermal collectors available commercially. They are broadly categorized into unglazed, glazed and evacuated tubes. The glazed solar thermal collectors are usually arranged within a glass cover with flat plate heat absorber and therefore commonly known as flat plate collector. Metal pipes of copper or aluminum or their alloy are attached to the flat plate heat absorber to transfer the heat to the circulating fluid. The fluid in the solar thermal collector can circulate with or without the aid of pumps or controls. When the fluid is circulating through the pipes without being aided by pumps, they are referred to as passive systems, in which a thermo-siphon principle is used. It relies on the natural convection where higher temperature fluid is lighter and rises above cooler fluid. The inlet of the fluid must come from the lower side of the passive flat plate solar thermal collector and exit on the higher end. In order for the thermo-siphon principle to take effect, the flat plate solar thermal collector has to be installed at an inclined angle with cold fluid inlet at the bottom side and heated fluid outlet on the top side.

The active solar thermal system uses pumps, sensors and controller to monitor the temperature of the fluid and activate the pumps accordingly to bring the heated fluid from

the flat plate solar thermal collector to a heat exchanger or buffer tank. An advantage of the active system is that the solar thermal collectors need not be installed at an inclined angle, however a disadvantage is that additional energy is required to drive the pumps.

There are many disadvantages when separate PV panel and solar thermal collector are purchased and installed as in the convention approach. Firstly, each of the systems requires its own installation procedure, and two systems may occupy a larger area than a single one.

Secondly, PV panels convert solar radiation energy to electricity, however, in collecting the solar energy, the PV panels are heated up, thereby reducing the efficiency of the PV panel, as these typically have negative power temperature coefficients.

Thirdly, typical conventional solar thermal collectors are heavy and expensive, as they are typically assembled together with a separate load bearing frame. Consequently, installation is difficult and may be expensive.

Reaction Injection Molding (RIM) is well known for molding a wide variety of parts, and especially large automobile parts such as bumpers and windscreens. For example, "Reaction Injection Molding in the Automotive Industry", Journal of Cell. Plastics, Vol. II, No. 2, 1975; Knipp: "Plastics for Automobile Safety Bumpers", Journal of Cell. Plastics, No. 2, 1973.

US4218543 discloses an invention of a process for the production of elastomeric moldings having a compact surface from polyurethane-polyurea elastomers.

US 4830038 and US5008062 disclose method of fabricating photovoltaic module by using reaction injection molding. These two interrelated patents focus on molding photovoltaic panels used for electricity generation only.

US2002148496 discloses solar modules having a transparent polyurethane front side and to a process for producing such modules. This invention is also directed to photovoltaic components for the direct generation of electric power from sunlight.

WO 96/02947 discloses a photovoltaic and thermal hybrid panel formed from layers of resin, which includes a photovoltaic panel and a fluid passage for removing heat from the hybrid panel by the flow of fluid through the fluid passage. This panel is comprised of separately molded layers of materials, including strengthening layers of glass reinforced

resin, a PV panel, and a hollow layer. However, in order for this hybrid panel to work, the various layers must have thermal coefficients which do not vary too much from each other, or else they will separate. Further, the additional layers of reinforced resin are heavy and add to the bulk of the hybrid panel.

JP 2001 068716 discloses a multilayered generation device which includes a PV panel, and a fluid conduit for removing heat from the device. This device is constructed of various layers including a PV panel, a piping structure, a wiring structure, and foamed aluminum layers for insulating the piping. However, the structure is required to be held together by a frame structure, as the aluminum foaming does not provide rigidity to the structure. Further, the multiple layers of loosely assembled materials may be complex and costly to assembly.

OBJECT OF THE INVENTION

An object of this invention is to provide a combined PV and thermal panel and method of manufacture therefore that at least partially overcomes the above disadvantages, or at least offer the public a useful choice.

This invention sets to at least partially overcome the above limitations and drawbacks by integrating both PV and solar thermal panels together to improve the overall effectiveness in harnessing solar energy. The invention also discloses the method to at least partially overcome the challenges in fabricating the integrated panel with dual purposes.

It is an object of the present invention to integrate both solar electricity generation and solar thermal collection into a single unit to optimize overall solar energy conversion.

Yet another object of the invention is the use of polymer to mold and encapsulate the integrated photovoltaic and solar thermal components into a single unit.

SUMMARY OF THE INVENTION

The present invention integrates both solar electricity generation and solar thermal collection into a single unit to optimize overall solar energy conversion. The integration of both solar electricity generation by photovoltaic and heat collection by solar thermal absorption reduces production cost and installation cost and thereby making renewable energy means more affordable.

The solar thermal absorption means transfers the heat gain by the photovoltaic elements to the circulating fluid, thereby reducing the photovoltaic elements temperature resulting in increased conversion efficiency. The photovoltaic panel serves the purpose of producing electricity as well as radiation heat absorption for the purpose of solar thermal collection. The photovoltaic panel further serves as glazing to the solar thermal collection to reduce convection and conduction loss from the top side.

The invention further uses polymers to mold and encapsulate the integrated photovoltaic and solar thermal components into a single unit by encapsulating them in a molded body. The molded body is preferred to be fabricated by Reaction Injection Molding using polyurethane formulation that can withstand outdoor applications. The molded body ensures that the integrated photovoltaic and solar thermal panel is durable, light weight, strong, sealed, isolated and yet cost effective. The molded body provides good thermal insulation to reduce heat loss from the solar thermal components to the surrounding. The invention further provides means for accommodating the thermal expansion between the different materials encapsulated within the molded body.

According to a further aspect, the invention may be said to broadly consist in an integrated photovoltaic solar thermal panel comprising

- a heat absorber assembly including a fluid inlet and a fluid outlet,
- a layer of elastomer wrapped around the heat absorber assembly, said heat absorber assembly being attached to the bottom side of
- a laminated photovoltaic panel, and
- a molded body encapsulating
 - the perimeter of the photovoltaic panel and
 - the complete heat absorber assembly and elastomer wrap; to
 - provide electrical connections from the laminated photovoltaic panel; and
 - the fluid inlet and outlet from the heat absorber assembly,

wherein the molded body is fabricated by a Reaction Injection Molding method.

Preferably, the heat absorber assembly comprises of at least one pipe with optimised contact with the bottom side of the laminated photovoltaic panel for collection and transfer of heat therefrom.

Preferably, the heat absorber comprises a plurality of pipes arranged largely in parallel, and connected by manifolds on both ends for fluid inlet and outlet;

Preferably, the pipe(s) are arranged in a meander form with multiple bends with one inlet and one outlet to allow fluid to flow through.

Preferably, the pipe(s) have an extended surface to contact with the bottom side of the photovoltaic pane.

Preferably, the pipe(s) have an extended surface in the form of welded fins to contact with the bottom side of the photovoltaic panel.

Preferably, the laminated photovoltaic panel has a transparent top cover and a laminated composite polymer backsheet on the bottom side.

Preferably, the moulded body encapsulates the perimeter of the laminated photovoltaic panel exposing the transparent top cover and encapsulates the heat absorber assembly to form the underside of the integrated photovoltaic solar thermal panel.

Preferably, the molded body is polyurethane polymer.

According to a further aspect, the invention may be said to broadly consist in an integrated photovoltaic solar thermal panel comprising

- a laminated photovoltaic panel having a bottom side;
- a heat absorber assembly attached to the bottom side of the laminated photovoltaic panel;
- a single molded body encapsulating at least part of the perimeter of the laminated photovoltaic panel and substantially the whole of the heat absorber assembly.

Preferably, the molded body encapsulating the laminated PV panel and the heat absorber assembly is formed in a reaction injection molding (RIM) process.

Preferably, the integrated photovoltaic solar thermal panel includes a layer of elastomer surrounding the heat absorber assembly, the layer of elastomer being encapsulated by the molded body.

According to a further aspect, the invention may be said to broadly consist in a method of manufacturing a photovoltaic solar thermal panel comprising the steps of

providing a laminated photovoltaic panel
providing a heat exchanger assembly; and
molding the heat exchanger assembly and the laminated photovoltaic panel together in a molding process to as to form a molded body which substantially encapsulates the heat exchanger assembly and at least part of the perimeter of the laminated photovoltaic panel.

Preferably, the method further includes the steps of surrounding the heat exchanger assembly with a layer of elastomer sheeting before carrying out the molding step.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a top perspective view of the integrated photovoltaic solar thermal panel.

Figure 2 shows a top perspective exploded view of the integrated photovoltaic solar thermal panel.

Figure 3 shows a top perspective view of one embodiment of a heat absorber assembly with parallel pipes and manifolds 24.

Figure 4 shows a top perspective view of an alternative embodiment of a heat absorber assembly with meander pipe.

Figure 5 shows a cross sectional view of a typical laminated photovoltaic panel.

Figure 6 shows a cross sectional view of the integrated photovoltaic solar thermal panel.

Figure 7 shows a top view of multiple units of the invention forming an array with separate electrical and solar thermal connections.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The preferred embodiment describes an apparatus and the method of fabricating the integrated photovoltaic solar thermal panel 1.

The integrated photovoltaic solar thermal panel 1 comprises laminated photovoltaic panel 10, heat absorber assembly 25, polymeric molded body 30 and layer of elastomer sheet 31 between the heat absorber assembly 25 and molded body 30. The photovoltaic solar thermal panel 1 has two types of connections to the outside world namely an electrical connection and a fluid connection.

The electrical connection 22 refers to the output from the photovoltaic cells from the laminated photovoltaic panel 10. The fluid connections have at least one inlet 20 and one outlet 21 for fluid to be circulated through the heat absorber assembly 25.

A typical laminated photovoltaic panel 10, as shown in figure 5, typically consists of a piece of glass 13, an encapsulant 14, solar cells 12, electrical connection 15, another encapsulant 14 and a backsheet 11.

In a conventional flat plate solar hot water unit, glazing made of large panels of glass is used to reduce heat loss from the absorber to the ambient. The glazing glass is heavy and adds cost to the conventional flat plate solar hot water unit. The present embodiment of the invention uses the laminated PV panel 10 as the glazing for reducing heat loss especially conduction and convection. The laminated PV panel 10 is also the solar radiation thermal collector as only a small amount of the total radiation energy is converted into electricity while majority of the rest is converted to heat. A very small amount is reflected back to the surroundings.

Heat absorber assembly 25 consists of at least one heat collection pipe 23 preferably with extended heat absorbing fin 26 (shown in figure 6) to enable incident radiation to be transferred as heat to a fluid passing within the pipe. In one embodiment as shown in figure 3, the pipes are arranged largely in parallel connected by manifolds on both ends for fluid inlet 20 and outlet 21. In a second embodiment, as shown in figure 4, the pipes are arranged in a meander form with multiple bends with one inlet 20 and one outlet 21 on each end to allow fluid to flow through.

The heat collection pipe 23 and the heat absorbing fin 26 are made of copper or aluminum with excellent heat conducting properties. . The fluid circulating in the heat collection pipe 23 carries the heat away from the heat absorber assembly 25. The fluid for heat collection can either be water or other liquid. When water is used as the thermal fluid, it is added with antifreeze agent such as ethylene glycol to prevent freezing in the winter. The heat absorbing fin 26 is attached to the backsheet 11 of the laminated PV panel 10 to absorb the heat away from the laminated PV panel 10. In the case where heat absorbing fin 26 is not in use, the heat collection pipe 23 can also be attached directly to the backsheet 11 of the laminated PV panel 10 with a reduced effect of heat transfer due to the reduction of contact area.

The body 30 is one integral element formed by molding or casting in which Reaction Injection Molding (RIM) method is preferred to form a structurally strong, weather resistant and good thermal insulation polyurethane molded body 30 that encapsulates the laminated PV panel 10 with the tightly coupled heat absorber assembly 25. The surface finishing of the RIM process can be controlled to achieve water resistance and the desired aesthetic appeal. The size of the present invention varies between 0.5 sq m to 2 sq m with typical size of about 1.2 to 1.5 sq. m. This means that RIM is a highly cost effective process with which to carry out the molding process to form the molded body 30.

The RIM molded body 30 forms the frame of the laminated PV panel 10 that enhances its resistant to moisture and water. The molded body 30 also provides thermal and electrical insulation to the laminated PV panel 10 and the heat absorber assembly 25. Mounting holes and brackets can be easily incorporated into the molded body 30 to facilitate installation. With suitable selection of polyurethane formulation, the molded body 30 is sufficiently elastic to cater for the differences in thermal expansion between the different materials encapsulated within. For example, the top cover of the laminated PV panel 10 is usually glass with lower thermal expansion. For rather small size integrated photovoltaic solar thermal panel 1, the relative change in size due to temperature change can be accommodated by the elasticity of the molded body 30, thereby reducing mechanical stress and deformation. Commercially polyurethane formulations are available to produce light weight, durable and strong molded body 30 for extended periods of outdoor use.

In the case of large panels with linear dimension of more than 0.5m, the change in dimensions due to thermal expansion of different materials can be significant. In such a case, the molded body 30 may not be able to accommodate such differences in expansion.

The largest difference in thermal expansion will typically be expected to be between the polyurethane molded body 30 and the heat absorber assembly 25 (typically composed of copper, copper alloy, aluminum or aluminum alloy). The use of a rigid heat absorber assembly 25 assists in adding structural rigidity to the photovoltaic solar thermal panel 1. The typical coefficient of thermal expansion of copper and brass pipes is in the range of 0.017 to 0.019 mm per m per degree C. The typical coefficient of thermal expansion of commercially available polyurethane is about 0.1mm per m per degree C. With a 50 degree C temperature change, a 1m length pipe and the enclosed polyurethane molded body 30 can experience dimension difference of more than 3mm.

This expansion difference has to be accommodated. The polyurethane molded body 30 alone may not be able to accommodate this difference. A layer of elastomer sheet material 31 that wraps around the pipes 23 of the heat absorber assembly 25 is used to absorb the relative change in dimension with respect to the molded body 30. The layer of elastomer material sheet material 31 is preferably precut into size and shape sufficiently covering the heat absorber assembly 25. A wide range of elastomeric precut sheet such as rubber, silicone, EPDM, foamed PU, or fibrous matt can be used for the layer of elastomer sheet 31, to serve the purpose of accommodating the thermal expansion. The most cost effective and light weight elastomer precut sheet is fibrous rockwool matt of thickness in the range of 5 to 10mm. The fibrous rockwool matt has sufficient density that will not be overly penetrated by the reaction injection polyurethane during RIM process. The fibrous rockwool matt is also a good thermal insulator. After the RIM process, the precut layer of elastomer sheet 31 forms a wrapping around the heat absorber assembly 25 serving as a cushion with respect to the molded body 30.

The electrical connections 22 from the laminated PV panel 10 are extended by wires (as shown in figure 7) to the exterior of the molded body 30 for ease of electrical interconnection. The fluid inlet 20 and outlet 21 connections can be extended outside the molded body 30 by flexible pipe 45 for ease of plumbing installation.

The integrated photovoltaic solar thermal panel 1 can be used alone or as an interconnected array of a plurality of similar panels 1 as shown in figure 7. These units are supported by mounting structures 41, held in place by mounting clips 42. Fluid is brought to the array by inlet pipe 43, and distributed to various photovoltaic solar thermal panels 1 via flexible pipe 45 and fluid inlet 20. After absorbing the heat from the laminated PV panel 10, the fluid flows out through the fluid outlet 21, flexible pipe 45 and

subsequently the outlet pipe 44. Whether the photovoltaic solar thermal panel 1 is used singly or plurality, the electrical connections are independent from the fluid connections and therefore allows for greater flexibility to achieve higher efficiency.

The orientation of the integrated photovoltaic solar thermal panel 1 is such that it is to maximize solar gain where most solar radiation is received. The photovoltaic solar thermal panel 1 is not limited to roof installation, and can be mounted on a solar tracker (not shown) to track the sun for maximizing energy output of both electricity and heat collection.

A typical mold used by the RIM process has a bottom mold, known as cavity, and a top mold also known as core. In order to facilitate the assembly and molding process, the top cover of the laminated photovoltaic panel 10 is faced downward exposing its backsheet 11 for ease of attachment of the heat absorber assembly 25.

Assembly of the photovoltaic cell to form a laminated photovoltaic panel 10 is a well established process and hence will not be described in this specification. The laminated photovoltaic panel 10 together with the attached heat absorber assembly 25 is placed inside the bottom mold. The heat absorber assembly 25 is held in place on the laminated photovoltaic panel 10 by applying elastic adhesive at certain locations but not too much to cause poor thermal conduction. All accessories such as electrical wiring 22 are pre-assembled and placed in the bottom mold. A layer of elastomer sheet 31 cut to the size and shape is then placed onto the heat absorber assembly 25. The layer of elastomer sheet 31 is held in place with respect to the heat absorber assembly 25 by double sided tape or adhesive. The layer of elastomer sheet 31 is wrapped around the heat pipes 23 of the heat absorber assembly 25 before closing the top mold (not shown). The two components of the RIM polyurethane process are then well mixed and injected into the bottom mold when the top mold is securely closed. The RIM process is an established industrial process and will not be further elaborated in this invention.

It will be appreciated that the invention disclosed in this specification allows manufacture of a hybrid photovoltaic and thermal solar radiation collecting photovoltaic solar thermal panel 1 that is weather resistant, does not require further structural strengthening, resistant to thermal stresses and differential thermal expansion, and modular. Further, the method by which the photovoltaic solar thermal panel 1 is made is simple, effective, and does not

require multiple layering steps, or the careful matching of materials for differential temperature expansion.

CLAIMS:

1. An integrated photovoltaic solar thermal panel comprises of
 - a heat absorber assembly including a fluid inlet and a fluid outlet,
 - a layer of elastomer wrapped around the heat absorber assembly, said heat absorber assembly being attached to the bottom side of
 - a laminated photovoltaic panel, and
 - a molded body encapsulating
 - the perimeter of the photovoltaic panel and
 - the complete heat absorber assembly and elastomer wrap; to
 - provide electrical connections from the laminated photovoltaic panel; and
 - the fluid inlet and outlet from the heat absorber assembly,

wherein the molded body is fabricated by a Reaction Injection Molding method.
2. The integrated photovoltaic solar thermal panel as claimed in claim 1, wherein the heat absorber assembly comprises of at least one pipe with optimised contact with the bottom side of the laminated photovoltaic panel for collection and transfer of heat therefrom.
3. The integrated photovoltaic solar thermal panel as claimed in claim 2, wherein the heat absorber comprises a plurality of pipes arranged largely in parallel, and connected by manifolds on both ends for fluid inlet and outlet.
4. The integrated photovoltaic solar thermal panel as claimed in claim 2, wherein the pipe(s) are arranged in a meander form with multiple bends with one inlet and one outlet to allow fluid to flow through.
5. The integrated photovoltaic solar thermal panel as claimed in claim 2, wherein the pipe(s) have an extended surface to contact with the bottom side of the photovoltaic panel.
6. The integrated photovoltaic solar thermal panel as claimed in claim 2, wherein the pipe(s) have an extended surface in the form of welded fins to contact with the bottom side of the photovoltaic panel.
7. The integrated photovoltaic solar thermal panel as claimed in claim 1, wherein the laminated photovoltaic panel has a transparent top cover and a laminated composite polymer backsheet on the bottom side.

8. The integrated photovoltaic solar thermal panel as claimed in claim 7, wherein the molded body encapsulates the perimeter of the laminated photovoltaic panel exposing the transparent top cover and encapsulates the heat absorber assembly to form the underside of the integrated photovoltaic solar thermal panel.
9. The integrated photovoltaic solar thermal panel as claimed in claim 7, wherein the molded body is polyurethane polymer.