FORM 2

THE PATENTS ACT, 1970

(39 of 1970)

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The Patent Rules, 2003

COMPLETE SPECIFICATION

(See section 10 and rule 13)

TITLE OF THE INVENTION

"Concentrated Solar Thermal Power plant with independently controllable subsets of heliostats"

We, applicant(s)

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The following specification particularly describes the nature of the invention and the manner in which it is performed:

FIELD OF THE INVENTION

This invention pertains to concentrated solar power in general and the specific field of concentrated solar power (CSP). Embodiments of the present invention are particularly concerned with a solar thermal power plant that generates electricity using concentrated solar power.

DISCUSSION OF THE PRIOR ART:

Concentrated solar power (CSP) is the process of concentrating solar energy from a vast incidence area onto a small area using lenses, mirrors, or other optical devices. Afterward, the energy emitted by the Sun radiation is converted into electrical energy. With the advancement of technology, concentrated solar power can become a significant energy source in the future.

There has been a slew of ideas for concentrated Solar-energy technologies throughout the years. The central receiver solar thermal power plant is the technology that offers the most promise for producing high-efficiency electricity production in the future. Solar radiation receivers positioned on towers are used to receive solar radiation reflected to them by an array of tracking reflectors situated in a solar field surrounding the tower. This technology is used to measure solar radiation. The tracking reflectors are often referred to as heliostats, and the array of heliostats is referred to as a heliostat field in most cases.

An embodiment of a traditional direct steam concentration Solar thermal power plant is shown in FIG. 1. The reflected solar radiation warms water that is circulated in a power generating circuit directly. This results in the production of superheated steam, which is then utilized to drive a steam turbine generator set and, as a result, create electrical power by the well-known Rankine cycle. Other components of power generating circuit 8 include an air-cooled condenser and a feedwater heater in addition to the steam turbine generator set (see Figure 1).

It is only during daylight hours that direct steam concentrated solar thermal power plants can be operated effectively. Only when the available solar radiation reflected to be incident upon the Solar radiation receiver is sufficient to generate Superheated Steam at the required pressure and temperature in the power generation circuit. As a result, the steam generated at high pressure and a high temperature cannot be stored conveniently for later SC.

Direct steam cooled solar thermal power plants with energy storage capability have been suggested to overcome this disadvantage. These plants store energy using a thermal energy storage fluid with a high specific heat capacity, commonly a molten salt or a combination of several molten salts, over a long period. A power generating circuit stores thermal energy during a charging cycle by heating the molten salt. The thermal energy is then recovered during a discharging cycle and used to heat water, producing steam as part of the power production circuit. The produced steam is then utilized to drive a steam turbine generator set, which generates electrical energy.

During the charging cycle, a first heat exchanger is required to transmit thermal energy from steam that is not being utilized to drive the steam turbine to the molten salt that is being charged. During the discharging cycle, a second heat exchanger is required to collect thermal energy from the hot molten salt and transmit it to the power-producing circuit. This sort of Solar thermal power plant has several heat transfer steps, which affects its efficiency. Furthermore, when the steam cools throughout the charging cycle, it goes through a phase transition, but the molten salt does not go through a phase shift. Consequently, the amount of thermal energy transfer to the molten salt is restricted, resulting in a restriction on the highest temperature that can be reached by the molten salt and the occurrence of what is known as a pinch point loss.

Thus, when thermal energy is recovered from the hot molten salt and utilized to produce steam in the power production circuit, the steam generated has a substantially lower temperature and pressure than the steam initially used to heat the molten salt. It is as a result of this that the efficiency of this sort of solar thermal power plant is greatly reduced. Furthermore, the decreased steam pressure in the power generating circuit may not be adequate to allow the steam turbine generator set to operate at full load, resulting in the inability to meet the power generation requirements of the system.

Another form of concentrated solar thermal power plant uses a Solar radiation receiver to directly heat a thermal energy storage fluid with a high specific heat capacity, such as molten salt, to generate electricity. It is possible to recover thermal energy from molten salt and use it to heat water in a power production circuit, generating steam that may be used to drive a steam turbine generator set, regardless of the prevailing daylight conditions. When operating in the daylight hours, this type of solar thermal power plant is generally less efficient than a direct steam concentrated solar thermal power plant because the steam in the power generation circuit is generated at all times through indirect heating, which is accomplished by recovering thermal energy from the molten salt in a heat exchanger, rather than direct heating. Furthermore, this type of solar thermal power plant is generally considered less attractive than a direct steam concentrated Solar thermal power plant because its construction is more complex (and therefore more expensive) and the technology is still in its early stages of development.

The provision of a solar thermal power plant with greater efficiency and operating flexibility would, as a result, be very desirable in this situation.

While the present invention is described herein by example using embodiments and illustrative drawings, those skilled in the art will recognize that the invention is not limited to the images of drawing or drawings described and are not intended to represent the scale of the various components. Further, some features that may form a part of the invention may not be illustrated in specific figures for ease of illustration. Such omissions do not limit the embodiments outlined in any way. It should be understood that the drawings and detailed descriptions are not intended to limit the invention to the particular form disclosed. Still, on the contrary, the story is to cover all modifications, equivalents, and alternatives falling within the scope of the present invention as defined by the appended claims. As used throughout

In this description, the word "may" is used in a permissive sense (i.e., meaning having the potential to) rather than the mandatory sense (i.e., meaning must).

Further, the words "a" or "an" mean "at least one," and the word "plurality" means "one or more" unless otherwise mentioned. Furthermore, the terminology and phraseology used herein are solely for descriptive purposes and should not be construed as limiting in scope. Language such as "including," "comprising," "having," "containing," or "involving," and variations thereof, is intended to be broad and encompass the subject matter listed after that, equivalents, and additional subject matter not recited, and is not intended to exclude other additives, components, integers or steps. Likewise, the term "comprising" is considered synonymous with the words "including" or "containing" for applicable legal purposes. Any discussion of document acts, materials, devices, articles, and the like is solely included in the specification to provide a context for the present invention. It is not suggested or represented that any or all of these matters form part of the prior art base or were common general knowledge in the field relevant to the present invention.

In this disclosure, whenever a composition or an element or a group of elements is preceded with the transitional phrase "comprising," it is understood that we also contemplate the same design, component or group of elements with transitional words "consisting of," "consisting," "selected from the group of consisting of, "including," or "is" preceding the recitation of the composition, element or group of elements and vice versa.

The present invention is described from various embodiments concerning the accompanying drawings, wherein reference numerals used in the accompanying drawing correspond to the like elements throughout the description. However, this invention may be embodied in many different forms and should not be construed as limited to the embodiment set forth herein. Instead, the image is provided so that this disclosure will be thorough and complete and fully convey the invention's scope to those skilled in the art. The following detailed description provides numeric values and ranges for various aspects of the implementations described. These values and ranges are treated as examples only and are not intended to limit the claims' scope. Also, several materials are identified as suitable for various facets of the implementations. These materials are to be treated as exemplary and are not intended to limit the invention's scope.

SUMMARY OF THE PRESENT INVENTION:

According to one aspect of the invention, the current invention provides for a solar thermal power plant that includes a tower, a plurality of heliostats, and other components. A heliostat field is encircling the tower and forming an electrical generator to generate electrical power; a power generation circuit including a steam turbine for driving an electrical generator to produce electrical power, water in the power generation circuit being capable of being heated directly by solar radiation reflected onto the solar radiation receiver by the heliostat field to generate steam to drive an electrical generator to produce electrical power; and a heliostat field encircling the tower and forming an electrical generator to generate electrical power.

It is particularly efficient during sunny conditions when the solar radiation reflected by the heliostat field onto the solar radiation receiver is sufficient to generate Superheated Steam in the power generation circuit. The solar radiation receiver and associated power generation circuit provide highly efficient direct steam generation during daylight hours, particularly during sunny conditions. Thermal energy can also be stored in the energy storage circuit simultaneously as the charging cycle is taking place for later recovery during the discharging cycle, resulting in increased operational efficiency and flexibility compared to a conventional direct steam solar thermal power plant of the type described previously. A heat exchanger is not required to transfer heat from the steam circulating in the heating circuit to the thermal energy storage fluid in the energy storage circuit because the thermal energy storage fluid circulating in the energy storage circuit is heated directly by solar radiation rather than indirectly from the steam circulating in the heating circuit. This results in a significant improvement in the operational efficiency of the solar thermal power plant. A further advantage is that the heat exchanger used to recover thermal energy from the thermal energy storage fluid is significantly smaller than the heat exchanger used in the type of dedicated molten salt power plant described above.

It is permissible to use any of the thermal energy recovered from the thermal energy storage fluid during the discharging cycle for any purpose.

When insufficient solar radiation is reflected onto the solar radiation receiver to generate steam, typically Superheated Steam, at the required temperature and pressure in the power generation circuit of the solar thermal power plant, such as during non-daylight hours or cloudy conditions, the recovered thermal energy can be most conveniently used to generate steam for the power generation circuit of the solar thermal power plant.

The heat exchanger may, as a result, be configured to generate steam for the power generation circuit while also, and more specifically, is configured to transfer the recovered thermal energy to the power generation circuit to assist in the generation of steam in the power generation circuit. The thermal energy recovered and transferred to the power generation circuit can heat the fluid circulating in the power generation circuit, which can be either water or steam, to produce steam at the desired temperature and pressure. Using the thermal energy recovered by the heat exchanger, steam can be generated indirectly and used in the reheat cycle of the steam turbine, in the high-pressure stage of the steam turbine, to power the entire operating cycle of the steam turbine or to pre-heat the feedwater for the steam turbine. Using the recovered thermal energy in this manner will be recognized as a considerable improvement in the operating efficiency and flexibility of the solar thermal power plant.

Sufficient solar radiation is reflected onto the solar radiation receiver to generate steam at the required temperature and pressure to drive the steam turbine, for example, to support the start-up of a solar thermal power plant, to reduce the plant start-up time, during transient operation of the solar thermal power plant, or to precondition one or more plant components, such as the solar radiation receiver.

The thermal energy recovered from the solar thermal power plant could theoretically fuel a hybrid power plant or a desalination plant, both of which would be located close to the solar thermal power plant. In most cases, the thermal energy storage fluid is a viscous liquid. The thermal energy storage liquid may be a molten salt, which can, for example, be heated to a maximum working temperature in the area of 580° C to be effective at storing thermal energy. The molten salt should be either a nitrate salt or a carbonate salt, but other types of molten salt, such as a combination of salts, are perfectly within the scope of the present invention.

The energy storage circuit may include two fluid storage locations, each of which may consist of two thermal energy storage fluid tanks, one of which may be a high-temperature fluid storage tank and the other of which may be a low-temperature fluid storage tank. The high-temperature fluid storage tank and the low-temperature fluid storage tank may be the same. It is also possible for the energy storage circuit to include both fluid storage locations in a single thermocline fluid storage tank, for example, with high-temperature fluid at the top and low-temperature fluid at the bottom. However, these single tank storage solutions are still in the early stages of development. Heat exchangers, which are positioned between high temperature and low-temperature fluid storage locations in an energy-storage circuit, allow for the recovery of heat from the thermal energy storage fluid as it circulates through the energy-storage circuit, moving from the high-temperature fluid storage location to the low-temperature fluid storage location, to improve the efficiency of the energy-storage circuit.

a site where you store your fluid

A solar thermal power plant may be configured so that the thermal energy storage fluid is heated directly by solar radiation reflected onto the solar radiation receiver positioned on the tower. On top of the tower, a single radiation receiver is used in this design. Thus, the Solar radiation receiver may include one or more first receiver panels for receiving solar radiation reflected by the heliostat field and transferring thermal energy provided by the reflected solar radiation directly to a fluid, such as water or steam, circulating in the power generation circuit, as described previously. Furthermore, the solar radiation receiver can include one or more second receiver panels capable of receiving solar radiation reflected by the heliostat field and transferring thermal energy provided by the reflected solar radiation directly to the thermal energy storage fluid circulating within the energy storage circuit.

The solar thermal power plant may also include a further solar radiation receiver, which may be configured to receive solar radiation reflected by the heliostat field and transfer thermal energy provided by the reflected solar radiation directly to the thermal energy storage fluid circulating in the energy storage circuit in another configuration.

The additional solar radiation receiver may be positioned on the tower so that it collects solar radiation reflected by the heliostat field that surrounds the whole tower. Because the sun radiation receiver for the power generating circuit and the additional solar radiation receiver for the energy storage circuit are both positioned on the same tower, only one tower is required.

The solar thermal power plant may also feature an additional tower, on which a second solar radiation receiver may be put to receive more solar radiation. The heliostat field may include the tower as well as the subsequent tower. Because the sun radiation receiver for the energy storage circuit is often lower in size than the solar radiation receiver for the power generating circuit, the building of the solar thermal power plant may be simplified. Consequently, the size of the additional tower is reduced, which is a favorable and consequential reduction.

This may be accomplished by adjusting the location of a subset of the plurality of solar heliostats within the heliostat field to selectively direct solar radiation to deliver thermal energy directly to the power production circuit or directly to the energy storage circuit, respectively. As a result, the operating efficiency of the solar thermal power plant may be tailored to meet specific needs.

When the solar thermal power plant includes a solar radiation receiver with one or more first and second receiver panels, the position of a subset of the plurality of heliostats in the heliostat field may be adjustable so that solar radiation is selectively directed onto either the first receiver panel(s) or the second receiver panel(s).

It may be possible to adjust the position of a subset of the plurality of heliostats in the heliostat field to selectively direct solar radiation onto either the solar radiation receiver or the further solar radiation receiver if the solar thermal power plant includes both a primary and a second primary solar radiation receiver. To offer selective adjustment of a subset of heliostats, putting a second solar radiation receiver on either the same tower as the first solar radiation receiver or a separate tower from the first solar radiation receiver is possible.

A more particular description will be rendered by referencing specific embodiments illustrated in the appended drawings to clarify various aspects of some example embodiments of the present invention. It is appreciated that these drawings depict only illustrated embodiments of the story and are therefore not considered limiting its scope. The invention will be described and explained with additional specificity and detail through the accompanying drawings so that the advantages of the present invention will be readily understood. A detailed description of the story is discussed below in conjunction with the appended drawings, which should not be considered to limit the scope of the invention to the accompanying drawing.

Further, another user interface can also be used with the relevant modification to provide the results above with the same modules, its principal, and protocols for the present invention.

It is to be understood that the above description is intended to be illustrative and not restrictive. For example, the above-discussed embodiments may be used in combination with each other. Many other embodiments will be apparent to those of skill in the art upon reviewing the above description.

The benefits and advantages which the present invention may provide have been described above about specific embodiments. These benefits and advantages and any elements or limitations that may cause them to occur or become more pronounced are not construed as critical, required, or essential features of any or all of the embodiments.

While the present invention has been described concerning particular embodiments, it should be understood that the images are illustrative and that the invention's scope is not limited to these embodiments. Many variations, modifications, additions, and improvements to the embodiments described above are possible. It is contemplated that these variations, changes, additions, and improvements fall within the invention's scope.

We Claim:

1. A solar thermal power plant, according to the invention, comprises:— the first tower; a plurality of heliostats adjacent to the tower and forming a heliostat field, the plurality of heliostats comprising a first separately controllable subset of the heliostats and a second separately controllable second subset of the heliostats; and a solar radiation receiver mounted on the tower to receive solar radiation reflected by the heliostat field, the solar a power generation circuit comprising a steam turbine for driving an electrical generator to generate electrical power, water in the power generation circuit being capable of being heated directly by solar radiation reflected onto the first receiver panels by the heliostat field to generate steam to drive the steam turbine; and a heliostat field for directing solar radiation onto the first receiver panels to generate solar power.

When there is insufficient solar radiation to heat the second receiver panels, an energy storage circuit including a thermal energy storage fluid that circulates through the second receiver panels and is capable of being heated directly by Solar radiation reflected by the second subset of heliostats of the solar thermal power plant onto the second receiver panels is used. A heat exchanger for recovering thermal energy from the thermal energy storage fluid in the energy storage circuit is used when insufficient solar radiation is used to heat the second receiver panel.

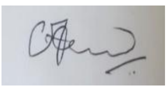
2. The solar thermal power plant described in claim 1, in which the thermal energy storage fluid is a liquid, is described in claim 2.

3. Claim 2 describes a solar thermal power plant in which the thermal energy storage liquid comprises one or more molten salts or a combination of molten salts, as described above.

4. By claim 1, the energy storage circuit includes high temperature and low-temperature fluid storage tanks, which are used to store high temperature and low-temperature thermal storage fluid, respectively, or a single thermocline fluid storage tank used to store both high temperature and low-temperature thermal storage fluid.

5. The solar thermal power plant described in claim 4, where the heat exchanger is positioned between the high temperature and low-temperature thermal fluid storage locations, is described in detail.

Dated this 09th day of November 2021

Signature: 

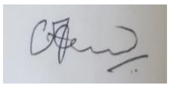
Applicant(s)

Prof. Dr. K. Muthuchelian et. al.

ABSTRACT

It comprises a solar radiation receiver positioned atop a tower surrounded by an anti-heliostat field to collect solar radiation reflected by anti-heliostats. Water in a power generation circuit is heated directly by solar radiation reflected onto the solar radiation receiver by the heliostat field to generate steam, which is used to drive the steam turbine in a power generation circuit to produce electrical power. The steam turbine is driven by the steam generated by the steam turbine. A thermal energy storage fluid, such as molten salt, is used in an energy storage circuit because it can be heated directly by solar radiation reflected by the heliostat field, which is used to store energy. A heat exchanger is also supplied for the recovery of thermal energy from the thermal energy storage fluid. The thermal energy that has been recovered may then be utilized to produce steam, which can then be used to drive the steam turbine.

Dated this 09th day of November 2021

Signature: 

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