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Hybrid Multijunction PV and CST based Solar Cooling System using Flat Plate Collector and Graphene based Nanofluid

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Abstract: A solar cooling system is an inspiring solution within the existing renewable energy technologies. Despite many advancements in solar cooling technology, solar energy still needs an adequate amount of changement toward improving the efficiency for both photovoltaic (PV) and concentrated solar thermal (CST). A lot of thermal energy waste occurs during the energy conversion process and due to reflection from the glass of the flat plate collector. In this paper, we enhance the management for both the PV and CST sides of the solar cooling system. The proposed technique is based on the enhancement of the existing infrastructure, on which the data monitoring and analysis are performed. The PV subsystem provides power to drive the electrical chiller during the daytime, while the CST provides energy to drive the absorption chiller during the nighttime. Multijunction solar cells are used on the PV side to improve the efficiency of the system, while on the CST side flat plate collector is used. The selection is based on better specifications. On the solar thermal side, graphene-based nanofluid is used to collect the heat from the flat plate collector. The nanofluid stores heat for a longer time. The PV side uses triple-junction solar cells which are made from different types of materials with different bandgap energies. Our purposed solution enabled desired cooling operations through day and night. In the daytime, the PV energy is used to drive the system, while at night time; the CST heat storage is used to drive the system. The proposed system with both sources shows a significant energy fit toward cooling load and reaching a peak during the hot summer days.

Keywords: Hybrid solar, solar cooling system, multijunction solar cells, flat plate collector, nanofluid.

I. INTRODUCTION

Pakistan, like other developing countries, is highly concerned with addressing problems related to energy crises, global warming, climate change, and temperature rise in the environment. The country's energy policies encourage using renewable energy technologies to overcome linked crises and reduce the use of fossil fuels; with subsequent results in the form of pollution minimization and a clean green environment. Most studies, in the research literature, rate climate change as one of the major impacts on energy demand. On hot days, a lot of energy is consumed for cooling purposes. Therefore, the cooling has a lot of impact on life, the due exhaust of harmful gases severely affecting the environment. As technology advances in thermal solar generation, it couples with the need for additional renewable sources of energy, thereby increasing the interest in CST power. Concentrating solar thermal power concentrates the sunlight onto a heat transfer fluid (HTF) which is then used to drive the steam turbine [1].

Concentrating solar power (CSP) can both generate and store energy from renewable sources, all in one plant. To store solar energy use the molten salt power tower, and use the heat exchanger to store the energy in a molten salt tank [2]. As the technology of thermal solar power advances, the CSP use for cooling purposes and drive cooling chiller by using thermal heat of the sun for this purpose, ammonia water compression-absorption cooling system is used [3]. The concentrated solar thermal heat storage in the form of heat of fusion is also a good process for sensible heat; it has high storage density and isothermal process in nature and storage heat at its melting temperature. The use of phase change material is an effective means of storing thermal and solar energy in the form of temperature rise in liquid. Before this energy is released when they are crystal [4], [5].

A solar heat storage tank is added with the adsorption cooling system to enhance the efficiency and working time of the system. In this system, lithium bromide solution is used due to the toxic nature of ammonia. The chiller is started with silica gel-water single-stage adsorption chiller is used [6]. The performance evaluation comparison solar thermal cooling system with the conventional power plants.

It provides a detailed study by the comparison of a solar cooling system, that is, solar thermal and tandem PV; thus the technology of electricity generation is better because it has less effect on the environment and its efficiency is also good as compared to the conventional plant.

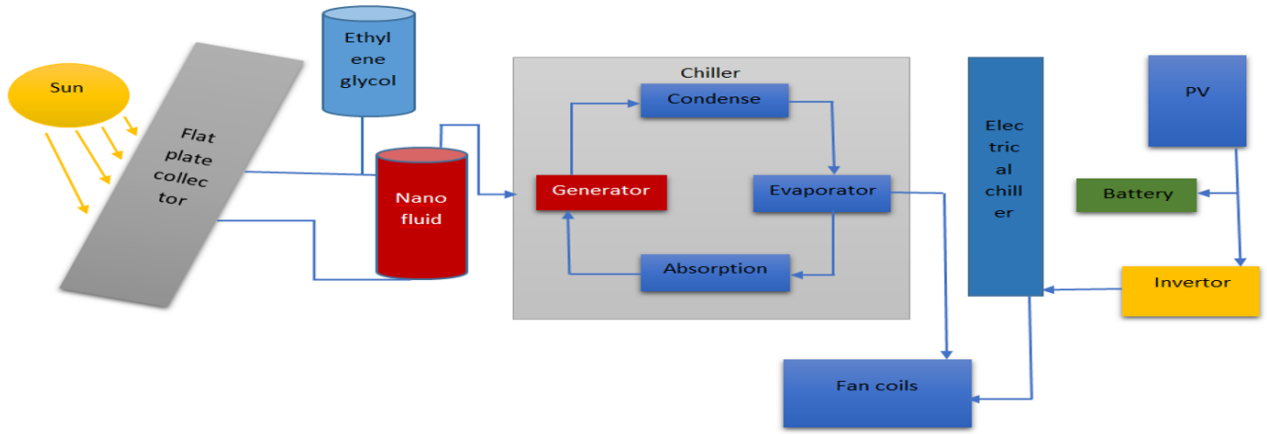

Fig. 1 Hybrid solar cooling system.

The system has a natural gas burner that feeds the absorption chiller generator and improves the system assessment [7]. In this study performance, energy efficiency, cost-competitive and global warming assessment of solar thermal and off-grid PV driven DC air conditioning and conventional air conditioning system. The first system is an integrated solar thermal cooling system with the thermal heat of solar and drive chiller. The system consists of an evacuated solar collector array which increases the efficiency of the air conditioning system, whereas the market available AC consumes a lot of energy [8]. Fig. 1 shows a hybrid solar cooling system that working day and night.

A flat plate collector is used as it has good efficiency as compare to evacuate and other available concentrating sources. Evaluation of solar thermal cooling system is performed in-office building by selecting the six different cities of Saudi Arabia its most efficient, economical and reduce the peak load using flat plate collector [9], [10]. In past, efforts were focused on the field of PCM used in a solar application for latent heat storage. Some natural substances, for example, salt hydrates paraffin waxes, fatty acid, and some other compounds having the required high latent heat of fusion in the temperature range from 0 to 150 used for solar application.

The min limitation of salt hydrates is their chemical instability when they are heated; because at the elevated temperature, they degrade [11]. The natural kinds of paraffin are a mixture of pure alkaline which have quite a wide range of phase change temperature. This paraffin has low heat conductivity [11]. Photovoltaic (PV) technology has several distinct advantages over the conventional method of electricity.

The high-efficiency tandem PV played a very significant role in reducing the cost through concentrating PV systems. The efficiency of PV cells is limited by physical and technological factors. Several efforts were made to improve the efficiency. Multispectral PV cells or tandem solar cells have attached the attention of many researchers around the world toward achieving higher efficiency. The tandem solar cell is based on a stack of many solar cells that are arranged according to the energy gap, where each cell functions with a respective solar spectrum range. Multispectral PV cells based on III-V material families are widely used due to a range of optical and material properties, especially lattice constant, for example, triple-junction solar cells GaInP/GaAs/Ga [12], [13].

A study is focused to find the less costly and most effective element to store the heat thermally. Phase change material is a unique and eco-friendly alternative to store heat. The water is used to rotate and collect the heat from the collector plate to the heat storage PCM tank. In this system, the concentrated solar thermal technology is used and a flat plate collector is used to capture the solar thermal heat [14]. The hybrid design of solar collector is designed to purify the water and heating purpose by using solar thermal and electrical energy from the sun. The collector of electricity works during day time for about 12 hours and during night time the storage heat of the flat plate collector is used to fulfill the requirement [15].

The recent research on the solar cooling system is to develop an appropriate solution for Dubai's energy crises overcome. In this system, the adsorption and

absorption chiller is used which runs with the thermal energy of the sun, and an evacuated tube collector is used to collecting the energy. In the adsorption chiller water and silica gel solution is used; while in the absorption chiller lithium bromide and water solution are used to produce the cooling effect for a building. The system is useful for building cooling purposes as it reduces the water temperature by 22 degrees Celsius [16]. A solar cooling system also designs with multi-junction solar cells concentrated solar thermal concept which working day and night [17].

Using this technique, a system is proposed (Fig. 1) to overcome the energy crises of Pakistan with environment friendly due to lesser amount of toxic gases. On the concentrated solar thermal side, a flat plate collector is used; whereas a tandem solar cell is used on the PV side to improve the efficiency.

II. PROPOSED DESIGN

The objective of the study of the proposed system is to create a cooling system that is environmentally friendly and yet provides an acceptable cooling effect. An operational hybrid solution for 24x7 not producing too many toxic gases and cover less area. The future works will compare the cooling effect of both the technology and improve the efficiency of both side PV and CST technology.

A. Novelty

The design proposed in this work is the addition of an electrical chiller that drives the solar panel and the tandem solar cell to further improve the efficiency of existing technology. Graphene-based nanofluid used which has good heat bearing capacity as compared to other heat collecting material contains carbon long chain. A flat plate collector is used because it is good efficient as compare to another collector. To reduce the thermal heat losses double glazed glass is used in a flat plate collector.

B. Benefits

During the summer days, a lot of energy is consumed toward building cooling. This energy is generated by using expensive fuel and technology which puts a burden on the economy of any country. When these resources have a shortfall or costly then energy crises are started; while on the other hand, the solar cooling system is cheap reliable, and environment friendly, especially during summer days. The solar cooling system has many global benefits and impacts as ac air-conditioned and other cooling devices generate radiations that have an impact on life. These devices also increase in thermal temperature of the environment. Therefore, a solar cooling system is a good solution, especially for a developing country like Pakistan.

III. METHODOLOGY

The solar cooling system in this research work uses 38 flat plate collectors to drive a 17 kW double-effect absorption chiller associated with a cooling tower.

A. Flat Plate Collector

A flat plate collector is the most fundamental and probably uses a solar heat collector. Flat plate collectors have different components which describe in the diagram given below. Flat plate collector has dark surface and fluid passes through it, collect heat from the surface and store or utilize. The double glaze is used on the top layer of the collector to reduce the reflection losses of the sunlight. Flat plate collector reaches the temperature of 30 to 80 o with the light of the sun. The double glazed selective coating has been used, due to that, the temperature of the flat plate collector reached up to 200. Flat plate collector has high volumetric heat capacity, imp compressible, and high mass density. The main motive of a flat plate collector is to absorb maximum heat, minimum heat reflection, radiation reflection, and maximum heat transfer from collector to fluid.

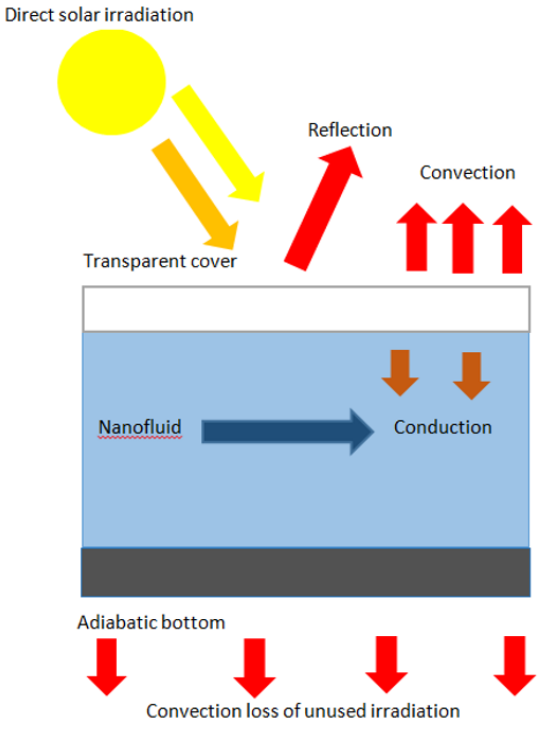

Fig. 2 Flat plate collector.

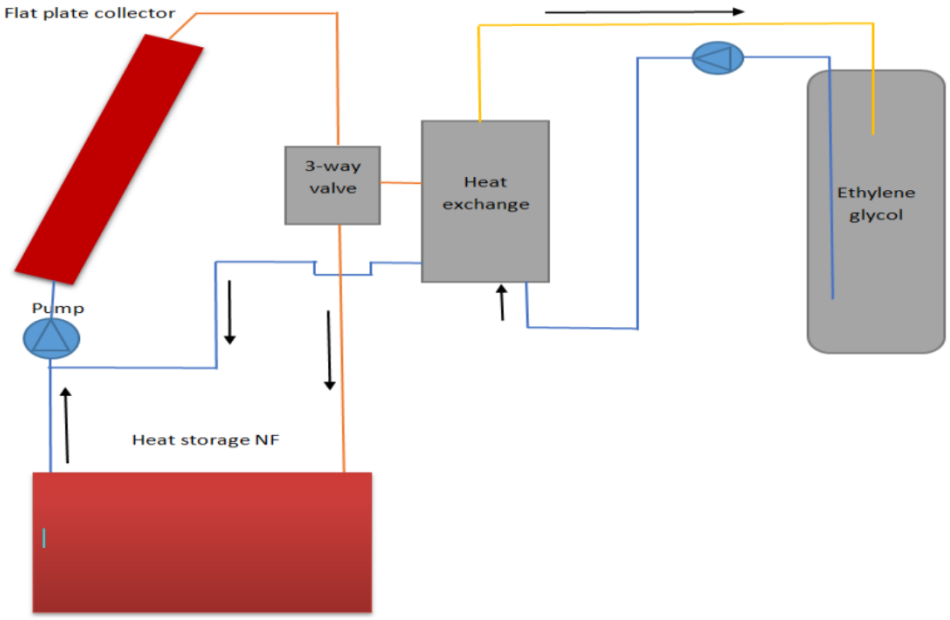

Fig. 3 Thermal heat collection process.

The purpose of top glaze is to minimize radiant heat loss from the absorber, Transmit heat to the absorber with less heat loss and protect the absorber from environmental effects. To keep the reflection and absorption low and transmission is high we can get maximum energy from the flat plate collector. Like this, the efficiency of the flat plate collector has become higher. Flat plate collector is commonly used due to good efficiency, low price and easy installation, and long life as compared to others. The Efficiency of a flat plate collector is directly depending upon the working fluid of the system.

Carbon-based Nanofluid

Carbon-based nanofluids have been used to enhance the thermal capacity of solar thermal. Graphene-based nanomaterial has good thermal heat transferring capacity as compare to other families of metal or oxide, compare to this diamond has the best heat transferring and heat bearing capability because it has high melting and boiling point and good capacity of heat transfer. Nanofluid has been prepared by mixing commercially available nanodiamond powder and ethylene glycol. Before mixing the nanofluid graphene in fluid the chemical, physical and thermal properties have been measured by using x-rays diffraction. The mass of the nanoparticle should be balance in the fluid. Graphene is an atomic sheet of a honeycomb of a carbon atom which is arranged as a chain reaction of the carbon atom and formed a small unit, it is the building block of all graphite and carbon atoms. In this structure, every carbon atom has a diameter of 0.33. Graphene is a good heat bearing capacity as compared to others, in this paper ethylene glycol mixed with graphene and formed a nanofluid of graphene-based which is used to collect the heat.

Heat Collection Process

Heat collected in a heat storage tank for a later purpose, in this process nanofluid of graphene-based used with ethylene glycol mixture. Fig. 3 shows the thermal heat collection process from the flat plate collectors.

Graphene-based nanofluid is used to collect heat from the flat plate collector, at start nanofluid passed from flat plate collector tube to collect the heat of the sun, and this heat store in the heat storage tank for the night time purpose used. In day time flat plate collector to heat exchanger and heat storage tank cycle work to collect heat and on the other hand in night time heat storage tank to absorption chiller cycle run. Absorption chiller drives from the storage heat to produce the cooling process lithium bromide solution used to produce this effect. Three-way valves are used to control the heat flow in the circuit and heat exchange is used to exchange the heat between two different temperatures fluids, after the exchange of the heat the remaining fluid send to the cooling tank, cooling tower cycle used to cool the generator section.

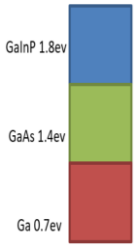

Fig. 4 Multijunction solar cell.

B. Multijunction PV

Multijunction solar cells are made up of different material and their bandgap energy and their response to a different wavelength of light and absorb the different color of light and convert it into electrical energy. Multijunction solar cells have the capability to an absorbed different type of light which is coming from the sun and convert it into electrical energy; it formed a different type of the layer which absorb the different color of light and have more efficiency as compare to single-junction solar cells. Multijunction solar cells have high production cost material and continuous research on it these not commercially available. Here used triple-junction solar cells which used different material and different layer the top layer is blue in color, middle layer green in color and bottom layer red in the layer, and different bandgap energy as shown in the diagram given below.

Multijunction solar cells are commonly formed of multiple p-n junctions, each material has its bandgap and different properties. A multijunction solar cell is relatively efficient as compare to others and may absorb a large portion of the solar spectrum. The multijunction solar cells are epitaxially grown; large bandgap material is on top of the panel and lowers on the bottom.

IV. CONCLUSION

This study has a primary focus on power generation from solar thermal technology and integrated both the PV technology and concentrated solar thermal toward building a cooling system. The existing design is extended by the introduction of an electrical chiller to drive solar panel tandem solar cells and a PCM tank to store the heat. The proposed design has been developed by adding the electrical cooling system working in parallel with the thermal solar cooling system powered by the PV plant to take advantage of both technologies. The PV plant work in the day time and CST system work with absorption chiller and store thermal power in the storage system which works day and night. In the future, the proposed design is simulated on computer simulation as an intermediate step toward prototype development.

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