Cooling Techniques of Photovoltaic Panels

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One of the important ways to reduce pollution resulting from the increasing consumption of fossil energy is to enhance the sources of solar energy, of which photovoltaic cells (PV) are one of its most important tools. Therefore, it was necessary to pay attention to improving its efficiency for it to become a promising source of clean energy. PVs turn solar energy into electricity; however, the amount of electricity generated decreases as the temperature of the cells rises in response to the sun's heat. Cooling of the optical surfaces is one of the most important elements to consider while running solar PV systems to obtain maximum efficiency.

Keywords: Solar Energy ; Photovoltaic Thermal Systems (PV/T) ; Cooling Materials ; Photovoltaic Panels (PVs) ; Solar Power efficiency ; Nanomaterials for Cooling PVs

1. Introduction

Fossil fuels produce more than 80% of the world's energy. Combustion residues of these fuels negatively affect the environment by producing acid rain and causing global warming, which increases rapidly with development and increases in the world population because of the increasing demand for energy [1][2][3], so it was necessary to search for renewable energy sources [4]. Solar energy is one of the most significant renewable energy sources since it can readily be turned into thermal and electrical energy, in addition to being sustainable, available and clean energy [5].

2. Improving the Generation of Clean Energy by Cooling Techniques to Reduce Environmental Effects

PV panels convert solar energy into electricity. However, if the temperature of the cells rises owing to the sun's temperature, the output of electricity falls. Therefore, different cooling techniques were used for solar cells to control their temperature, as shown in **Table 1**.

Table 1. Photovoltaic cooling techniques.

Techniques	Advantages	Limitations
Air cooling Photovoltaic/Thermal [6][7][8][9][10]	• Easy-to-use technology. • Air is always accessible. • Improves the overall efficiency. • It is economically feasible. • Heated air is employed in HVAC systems. • Reduces corrosive danger.	• Has limited thermal capacities and requires a lot of energy to circulate air blowers (in active cooling). • Has low mass-flow rates, so little effect on PV temperatures.

Techniques	Advantages	Limitations
Water cooling Photovoltaic/Thermal [11][12][13][14]	• Overall efficiency has improved. • Increased electric energy conversion efficiency. • Hot water is utilized for residential purposes. • Space requirements are less than for individual systems.	• High start-up costs. • System life is reduced. • In chilly weather, it is possible that you will freeze. • Pumping power consumes a lot of electricity. • Possible corrosion, fouling and leaking.
PV/water spraying [15][16][17][18]	• Increased conversion of solar energy. • Higher thermal conductivity and heat capacity (low thermal resistance).	• The PV panel's surface area is partly cooled. • A higher price (maintenance, pumping power) • Heat is a waste of resources.
PV/water immersion cooling [19][20][21]	• Extremely effective. • Friendly to the environment • Both the front and rear surfaces transmit heat.	• The depth of submersion has an impact on efficiency. • Higher price. • Because the item is insulated inside the water, the system is complicated to build.
PV/Phase-Change Materials cooling [10][22][23]	• At modest temperature changes, huge amounts of heat may be stored. • Phase-change happens at a steady temperature; therefore, the system can work even when the sun is not shining. • The heat that is absorbed can be utilized to heat structures.	• PCM has a low heat conductivity in its solid form. • Some PCMs are poisonous and provide a fire hazard. • After the conclusion of the life cycle, there is a difficulty with disposal. • The quantity of active volume available for thermal storage is limited by segregation.
Cooling of PV/Heat Pipes [24][25][26][27]	• Heat fluxes that are extremely high. • Heat exchange that is passive. • Transfer of heat across large distances. • It is simple to combine. • Longer life span.	• High price. • Difficult to produce. • Non-condensable gas production. • Working agent leakage.

Techniques	Advantages	Limitations
PV/Microchannel heat sink cooling [28][29][30][31][32]	• Removes a lot of heat from a tiny space. • Low inventory of fluids is necessary. • Low electricity consumption; thermal resistance is low.	• Limitations on pressure decrease. • Corrosion is an issue. • Manufacturing at a high cost.
PV/Nano-fluids cooling [33][34][35][36][37]	• There are nanofluids on the market. • Thermal efficiency that is higher.	• Technology in its infancy. • Influences are unknown (interaction with base fluids and characteristics). Nanoparticles are expensive.
PV/Spectrum filter [38][39][40]	• The operating temperature has been reduced. • Hybridization with concentrating or other systems is possible.	• Technology that is not completely developed. • High-priced (glass filters)

Because of the increasing demand for energy and the excessive use of traditional energy sources, this has led to an increase in environmental pollution due to emissions from burning fuels. Cooling solar cells increases their potential to create clean energy and use it as an alternative to traditional polluting energy sources.

Researchers provided an in-depth analysis of the design components of a concentrated photovoltaic thermal, heat transfer medium and new application sectors. The findings show that CPVT systems are a promising system for producing high amounts of clean electrical and thermal energy that are in line with the seven sustainable development goals by using this energy in a variety of thermal applications such as space heating and cooling, desalination, electrical energy generation, greenhouses and so on [41][42][43]. Other researchers compared the performance of a water-based photovoltaic system (thermal), a PV/T system with PCM, an air-based PV/T system and a conventional PV panel in different studies.

In comparison to alternative kinds of cooling, it was found that the efficiency of the systems in producing energy depends on the type of material used, and all the arrangements proved to be more important solutions for delivering superior thermal and electrical efficiency systems (compared with the conventional system), thus serving as a promising source as an alternative to fossil energy that gives rise to air pollution and an increased earth temperature [44][45][46]. Some researchers focused on the increasing consumption of fossil energy and the accompanying emissions and pollution as a result of urban transformation and expansion of the construction and service sectors in developing countries in particular. Accordingly, the researchers' efforts focused on improving the performance of photovoltaic cells, whose efficiency is affected by atmospheric conditions, to make them a suitable substitute for the production of clean energy [47][48][49][50][51].

Researchers [3][52][53] looked at the energy-increasing and environmental impacts of using nanofluids (NFs) in PVTS by measuring their physical and thermal properties. The researchers discovered that dispersion of nanoparticles in the base fluid increases the PVTS' thermal and electrical performance, which improves the systems' environmental characteristics. In fact, a nano-fluid-based solar system may avoid the release of greenhouse gases emissions, particularly carbon dioxide (CO_2), into the environment more effectively than pure heat pumps by producing more energy. The performance of the integration of the Kalina cycle with CPVT for a multi-generation and hydrogen production system was investigated utilizing air and water as a cooling medium and three distinct mass flow rates. According to the findings of these studies, electricity, hydrogen and hot air production were increased. These kinds of systems would be used to minimize pollution in the environment because the emissions will decrease significantly [54][55].

The steady increase in population numbers and the need to address the problem of food insecurity in some countries made some researchers search for quick, effective and environmentally friendly ways to dry food, as the drying process consumes energy intensively, and the use of fossil energy in the drying process increases pollution. In these cases, the focus was on improving the performance of solar energy systems to provide the appropriate energy [56][57][58]. On the other hand, water is also a paramount necessity for human life, and the need to provide for drinking water in water-poor countries requires desalination since desalination consumes a large amount of energy. Some researchers have developed ways to use solar energy when desalinating water as well as storing energy for use when needed. This reduces the consumption of fossil energy and the emission of gases [59][60].

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