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Assessment on thermophysical properties of nano enhanced heat transfer fluid with hexagonal boron nitride nanoparticles for thermal management of photovoltaic thermal (PVT) system

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ABSTRACT

One of the most promising sources of energy to meet demand and reduce pollution from fossil fuels is solar energy. To maximize energy conversion, solar technology efficiency, whether it comes from thermal systems, photovoltaic panels, or a hybrid known as photovoltaic-thermal (PVT) systems is critical. This work looks into the formulation and thermophysical of hBN-water nanofluids, with an emphasis on how they might be used as coolants in PVT systems to improve electrical performance. After a meticulous preparation process, the nanofluids exhibited exceptional stability, confirmed through visual inspection and zeta potential evaluation. Zeta potential analysis revealed consistent values across different temperatures and volume concentrations. Density decreased with temperature, while viscosity increased with volume concentration but decreased with temperature. Thermal conductivity showed a consistent increase with volume concentration and temperature. Through optimization, the 0.5 vol% concentration was identified as optimal for the PVT system. Compared to no coolant and water-based coolant scenarios, hBN-water nanofluids effectively regulated cell temperatures between 40.25°C and 46.34°C, demonstrating superior thermal conductivity and heat transfer properties. Moreover, the nanofluid coolant enhanced the PVT system's electrical performance. Open circuit voltage remained consistent (19.67 V to 20.81 V), short circuit current and output power improved with higher irradiance levels, and electrical efficiency, thermal efficiency and overall efficiency reached 5.73–5.88 %, 54.15–62.73 % and 59.88–68.62 % respectively These findings underscore the potential of hBN-water nanofluids in enhancing thermal management and electrical performance in solar energy systems. By minimizing thermal losses and maximizing electrical output, nanofluid coolants offer promising avenues for optimizing the efficiency of renewable energy technologies.

1. Introduction

The increasing need for energy for both domestic and industrial use has led to a rise in interest in renewable energy sources as fossil fuel substitutes. Due to the usual reliance on fossil fuels, which releases greenhouse gases into the atmosphere and contributes to global warming and climate change, there are serious environmental problems (Yoro and Daramola, 2020; Sofiah et al., 2024a; Jamil et al., 2021). Diverse technologies have been created to tackle energy-related issues and lessen reliance on fossil fuels. Utilizing solar energy via photovoltaic (PV) modules, which absorb sunlight's short-wavelength radiation and transform it into electricity, is one of these methods (Wu et al., 2021; Liang et al., 2021; Tariq et al., 2020). Semiconducting materials make up photovoltaic cells, which use solar radiation to generate energy in part. The majority of the sunlight, roughly 85–90 % is absorbed as heat, with

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