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INFLUENCE OF MASS FLOW RATE ON EXERGY AND ENERGY OF N-PVT-CPC DYNAMIC DOUBLE SLOPE SOLAR DISTILLER

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Abstract
This research investigates the impact of mass flow rate variations on the exergy and energy performance of a novel N-PVT-CPC (Photovoltaic-Thermal Concentrating Solar Collector) dynamic double slope solar distiller. The experimental setup involves a comprehensive analysis of the system under different mass flow rate conditions. The N-PVT-CPC system combines photovoltaic and thermal technologies to enhance energy conversion efficiency. The dynamic double slope solar distiller integrates concentrated solar power for water desalination or purification.
The study employs a parametric analysis to examine the effects of varying mass flow rates on exergy and energy parameters, providing valuable insights into the system's performance optimization. Results are presented, highlighting the influence of mass flow rate on the overall efficiency, productivity, and sustainability of the N-PVT-CPC dynamic double slope solar distiller.

Keywords: N-PVT-CPC, Dynamic double slope solar distiller, Mass flow rate, Exergy, Energy efficiency, Solar desalination

Introduction
The growing global demand for clean water resources and sustainable energy solutions has spurred research into innovative technologies that can simultaneously address both challenges. One such promising system is the N-PVT-CPC (Photovoltaic-Thermal Concentrating Solar Collector) dynamic double slope solar distiller. This system integrates photovoltaic and thermal technologies to harness Solar energy for both electricity generation and water distillation.
The efficiency and performance of solar distillation systems are crucial for their practical implementation, and one key factor influencing these aspects is the mass flow rate within the system. The mass flow rate plays a significant role in dictating the heat transfer characteristics, thereby affecting the overall exergy and energy performance of the N-PVT-CPC dynamic double slope solar distiller.
This research aims to systematically investigate the influence of mass flow rate variations on the exergy and energy parameters of the N-PVT-CPC dynamic double slope solar distiller. By understanding how changes in mass flow rate impact the system's efficiency and productivity, valuable insights can be gained for optimizing its performance under different operating conditions.
The study employs a comprehensive experimental setup and parametric analysis to quantify the effects of varying mass flow rates. The N-PVT-CPC system, with its dual functionality of generating electricity and distilling water, presents a unique platform for exploring the synergy between energy conversion and water purification. The dynamic double slope design further enhances the system's adaptability to varying solar conditions throughout the day.
Results from this investigation will contribute to a deeper understanding of the complex interplay between mass flow rate, exergy, and energy efficiency in the context of the N-PVT-CPC dynamic double slope solar distiller. Such insights are vital for advancing the development and optimization of

sustainable and efficient solar-driven water distillation systems, offering a promising solution for regions facing water scarcity and energy challenges.

II. SYSTEM DESCRIPTION

The N-PVT-CPC dynamic double slope solar distiller represents an innovative integration of photovoltaic-thermal technologies in a concentrated solar power system designed for simultaneous electricity generation and water distillation. The following provides a detailed description of the key components and operating principles of this system:

1. Photovoltaic-Thermal Concentrating Solar Collector (N-PVT-CPC):

- The heart of the system is the N-PVT-CPC, a concentrating solar collector that combines photovoltaic (PV) and thermal elements. It consists of parabolic trough reflectors that concentrate sunlight onto a receiver tube.

The receiver tube incorporates a hybrid design, allowing for the simultaneous absorption of solar radiation for electricity generation through embedded photovoltaic cells and thermal energy collection through a fluid-carrying tube.

2. Dynamic Double Slope Solar Distiller:

- The solar distillation component is designed with a dynamic double slope configuration, enhancing adaptability to varying solar angles throughout the day. This design optimizes solar exposure and heat transfer efficiency.
- The distillation unit typically includes a basin to hold saline or impure water, which is heated by the concentrated solar energy. The evaporated water is then condensed, yielding purified water.

3. Mass Flow Rate Control System:

- The system incorporates a sophisticated mass flow rate control mechanism to regulate the flow of the heat transfer fluid within the receiver tube. This fluid serves a dual purpose by transferring heat for distillation and cooling the PV cells for enhanced electrical performance.
- The mass flow rate control system allows for systematic variations in the flow of the heat transfer fluid, providing a means to assess the impact of different flow rates on the system's performance.

4. Experimental Setup:

- The experimental setup involves a comprehensive parametric analysis, where the mass flow rate is systematically varied to observe its effects on the exergy and energy parameters of the system.
- Sensors and data acquisition systems are employed to monitor key performance metrics, including temperature differentials, energy output, electricity generation, and water distillation rates.

5. Performance Metrics - Exergy and Energy:

- Exergy and energy parameters are critical metrics used to evaluate the system's efficiency. Exergy analysis assesses the available work potential within the system, while energy analysis quantifies the overall energy output and conversion efficiency.

6. Data Analysis and Optimization:

- Results from the experimental campaign are analyzed to understand the correlation between mass flow rate variations and system performance. This analysis provides insights into the optimal operating conditions for maximizing both exergy and energy efficiency.

So, the N-PVT-CPC dynamic double slope solar distiller is a multifunctional system that combines advanced concentrating solar collector technology with a dynamic distillation unit. The influence of mass flow rate on exergy and energy parameters is systematically explored to enhance the overall

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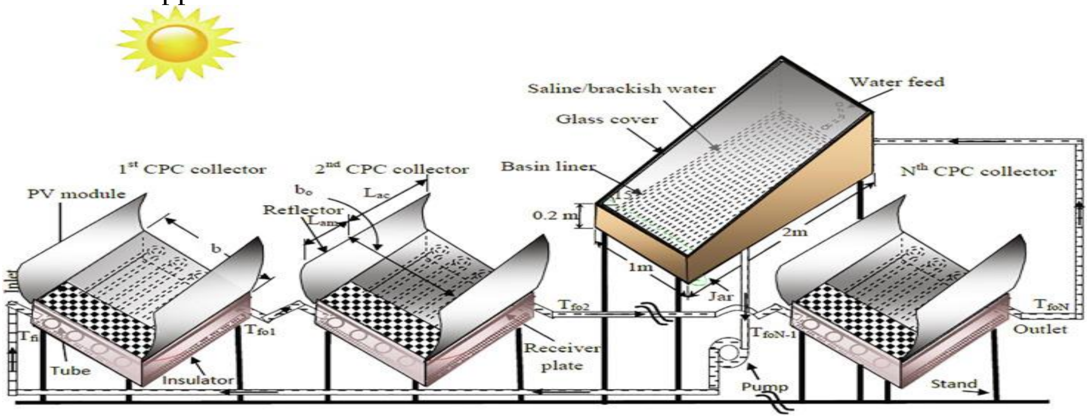
performance and sustainability of the system, making it a promising solution for solar-driven water distillation applications.



III. METHODOLOGY

The methodology to investigate the effect of $\dot{m}f$ and N on the energy metrics of NPVTCPC-SEBDSWF are as follows:

1. Experimental Setup:

- Establish a controlled laboratory environment for the N-PVT-CPC dynamic double slope solar distiller system.
- Install necessary sensors and data acquisition systems to monitor temperature profiles, electricity generation, water distillation rates, and other relevant parameters.

2. Mass Flow Rate Variation:

- Systematically vary the mass flow rate of the heat transfer fluid within the receiver tube of the N-PVT-CPC system.
- Implement a range of flow rates, ensuring coverage of both suboptimal and optimal conditions.

3. Data Collection:

- Conduct multiple experimental runs for each mass flow rate setting.
- Collect data on electricity generation, thermal energy output, water distillation rates, and relevant temperatures at different points in the system.

4. Exergy and Energy Analysis:

- Perform exergy analysis to quantify the available work potential within the system, considering both electrical and thermal components.
- Calculate energy efficiency metrics, including overall energy output and conversion efficiency, considering the electricity generated and distilled water production.

5. Statistical Analysis:

- Utilize statistical methods to analyze the data and identify trends or correlations between mass flow rate variations and system performance.
- Determine the optimal mass flow rate that maximizes exergy and energy efficiency.

6. Sensitivity Analysis:

- Conduct sensitivity analysis to evaluate the impact of other relevant parameters (e.g., solar irradiance, ambient temperature) on the observed effects of mass flow rate changes.

7. Model Validation:

- Validate the experimental results by comparing them with theoretical models or simulations of the N-PVT-CPC dynamic double slope solar distiller system.

IV. CONCLUSION

1. Optimal Mass Flow Rate:

- Identify the optimal mass flow rate that maximizes both exergy and energy efficiency of the N-PVT-CPC dynamic double slope solar distiller.
- Discuss how this optimal mass flow rate enhances electricity generation, thermal energy output, and water distillation rates.

2. Performance Trends:

- Summarize the observed trends in system performance with varying mass flow rates.
- Highlight any nonlinearities or thresholds in the relationship between mass flow rate and system efficiency.

3. Effect on Exergy and Energy:

- Discuss the impact of mass flow rate variations on exergy and energy parameters, emphasizing the interplay between thermal and electrical components.

4. Practical Implications:

- Provide insights into the practical implications of the study for the design, optimization, and operation of N-PVT-CPC dynamic double slope solar distillers in real-world applications.

5. Future Research:

- Suggest areas for future research and improvements, such as exploring additional parameters, optimizing control strategies, or integrating advanced materials for enhanced performance.

6. Concluding Remarks:

- Conclude by summarizing the key findings and emphasizing the significance of understanding the influence of mass flow rate on the exergy and energy performance of the N-PVT-CPC dynamic double slope solar distiller.

REFERENCES

[1] Rai SN, Tiwari GN, Single basin solar still coupled with flat plate collector, Energy Convers Manage 1983;23(3):145–9.

[2] Kumar S, Tiwari A., An experimental study of hybrid photovoltaic thermal (PV/T) active solar still, Int. J Energy Res 2008; 32:847–58.

[3] Kern EC, Russell MC. Combined photovoltaic and thermal hybrid collector systems. In: Proceedings of the 13th IEEE photovoltaic specialists, June 5–8, Washington, DC, USA. p. 1153–7.

[4] Singh G, Kumar S, Tiwari GN. Design, fabrication and performance of a hybrid photovoltaic/thermal (PVT) double slope active solar still. Desalination 2011; 277:399–406.

[5] Singh DB, Yadav JK, Dwivedi VK, Kumar S, Tiwari GN, Al-Helal IM., Experimental studies of active solar still integrated with two hybrid PVT collectors. Sol Energy 2016; 130:207–23.

[6] Tiwari GN, Yadav JK, Singh DB, Al-Helal IM, Abdel-Ghany AM., Exergoeconomic and enviroeconomic analyses of partially covered photovoltaic flat plate collector active solar distillation system, Desalination 2015; 367: 186–96.

[7] Singh DB and Tiwari GN, Enhancement in energy metrics of double slope solar still by incorporating N identical PVT collectors, Solar Energy 143 (2017) 142–161

[8] Singh DB, Exergoeconomic and enviroeconomic analyses of N identical photovoltaic thermal integrated double slope solar still, Int. J. Exergy, Vol. 23, No. 4, 2017
[9] Singh DB, Kumar N, Harender, Kumar S, Sharma SK, Mallick A, Effect of depth of water on various efficiencies and productivity of N identical partially covered PVT collectors incorporated single slope solar distiller unit, Desalination and Water Treatment, 138 (2019) 99–112
[10] Singh DB, Improving the performance of single slope solar still by including N identical PVT collectors, Applied Thermal Engineering 131 (2018) 167–179
[11] Singh DB, Kumar N, Kumar S, Dwivedi VK, Yadav JK, Tiwari GN, Enhancement in exergoeconomic and enviroeconomic parameters for single slope solar still by Incorporating N Identical partially covered photovoltaic collectors, Journal of Solar Energy Engineering, 2018, Vol. 140 / 051002-1
[12] Sahota L, Tiwari GN, Exergoeconomic and enviroeconomic analyses of hybrid double slope solar still loaded with nanofluids, Energy Conversion and Management, Volume 148, 15 September 2017, Pages 413-430
[13] Atheaya D, Tiwari A, Tiwari GN, Al-Helal IM., Analytical characteristic equation for partially covered photovoltaic thermal (PVT) – compound parabolic concentrator (CPC), Sol Energy 2015;111:176–85. 42
[14] Tripathi R, Tiwari GN, Al-Helal IM. Thermal modelling of N partially covered photovoltaic thermal (PVT)–Compound parabolic concentrator (CPC) collectors connected in series. Sol Energy 2016;123:174–84.
[15] Singh DB and Tiwari GN, Performance analysis of basin type solar stills integrated with N identical photovoltaic thermal (PVT) compound parabolic concentrator (CPC) collectors: A comparative study, Solar Energy 142 (2017) 144–158
[16] Singh DB and Tiwari GN, Exergoeconomic, enviroeconomic and productivity analyses of basin type solar stills by incorporating N identical PVT compound parabolic concentrator collectors: A comparative study, Energy Conversion and Management 135 (2017) 129–147
[17] Prasad H., Kumar P, Yadav RK, Mallick A, Kumar N, Singh DB, Sensitivity analysis of N identical partially covered (50%) PVT compound parabolic concentrator collectors integrated double slope solar distiller unit, Desalination and Water Treatment, 153 (2019) 54–64