Dr. Sanjeev Jakhar

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EDUCATION

Birla Institute of Technology and Science (BITS) Pilani, Rajasthan, India

- Doctor of Philosophy (PhD) from Mechanical Engineering Department, May 2018.

M.B.M Engineering College, Jai Narain Vyas University (JNVU), Jodhpur, Rajasthan, India

- Master of Engineering (M.E.), Specialization –Thermal Engineering, May 2013

University of Rajasthan (UOR), Jaipur Rajasthan, India

- Bachelors of Engineering (B.E.) in Mechanical Engineering, July 2009

EXPERIENCE SUMMARY

Teaching and Research Experience (Total– 8.5 years)

- **Postdoctoral Researcher** in Institute of Agriculture Engineering, **ARO, Volcani Center, Ministry of Agriculture and Rural Development, Rishon LeTsiyon, Israel**- August 2020 to Present
- Assistant Professor in Department of Mechanical Engineering, School of Engineering and Technology, Mody University of Science and Technology, Lakshmangarh, Rajasthan, India, July 2018 – August 2020 (Now I am on study Leave).
- Assistant Professor and Head of Department in Mechanical Engineering at Sobhasaria Group of Institutions, Sikar, Rajasthan, India (NBA and IAO Accredited)- January 2018-July 2018.
- Research Scholar and Teaching Instructor, BITS Pilani, Pilani Campus, Rajasthan, India, August 2013 – December 2017.
- Visiting Scholar, Institute of Machine Tools and Production Technology, **Technical University, Braunschweig, Germany**, November, 2016 to January, 2017.
- Visiting Scholar, Center for Energy Research (CER), **University of Nevada, Las Vegas, USA,** June, 2017 to August 2017)

- Lecturer in Department of Mechanical Engineering at Kautilya Institute of Technology and Science, Jaipur, Rajasthan, India, September 2009- September 2010.

THESIS TITLES

- ***Ph.D. Thesis Entitled*** – Design, Analysis and Development of Photovoltaic and Concentrating Photovoltaic Cooling System with Earth Water/Air Heat Exchanger.
- ***Masters Dissertation Entitled*** – Thermal performance investigation of earth air tunnel heat exchanger coupled with a solar air heating duct in heating mode.

FUNDED RESEARCH PROJECTS

<u>Research Project</u>

Project Title:- Analysis design and development of low cost cold storage for selected agricultural products based fully on solar and geothermal energy

Duration:- October 2020 to October 2022

***Amount:-* 47.03 Lakh**

PI:- Prof. (Dr.) M. S. Dasgupta (BITS Pilani)

Co-PI:- Dr. Sanjeev Jakhar (Mody University, Lakshmangarh, Rajasthan)

Funding Agency:- DST, New Delhi

<u>Consultancy Research Project:-</u>

Design and analysis of twisted tapes based absorber tube of 20 ft by 7 ft PTC along with thermal storage, Radha Energy Cell (ISO:9001:2008 certified company), Ludhiana, August, 2015 to January, 2016, INR 1,15,200.

<u>Grant for organizing IPR Workshop:-</u>

***Convener of Workshop:-* Dr. Sanjeev Jakhar**

Title of the Workshop:- National workshop on awareness of IPR & innovation management for technology collaboration and transfer at Mody University, Lakshmangarh, Sikar

Amount:- 0.70 Lakh

Funding Agency:- DST, Rajasthan

PATENT

Title of Invention:- A liquid-cooled hybrid solar energy collector

Inventors:- Nikhil Gakkhar, Manoj S. Soni and **Sanjeev Jakhar**

Patent Application No.:- 201711010510 A (Indian Patent)

Status:- Published and examination report submitted.

PUBLICATIONS

<u>Peer reviewed Journals (SCI/SCIE indexed journals:-14, Total:-20)</u>

1. **Sanjeev Jakhar,** Mukul kant paliwal and Nilesh Purohit, "Assessment of alumina/water nanofluid in a glazed tube and sheet photovoltaic/thermal system with geothermal cooling" *Journal of Thermal Analysis and Calorimetry (Springer), Accepted for publication,* ***February 2021****,* ISSN : 1572-8943 **(Impact factor: 2.731, SCI).**

2. Nikhil Gakkhar, Manoj K Soni and **Sanjeev Jakhar,** "Experimental and theoretical analysis of hybrid concentrated photovoltaic/thermal system using parabolic trough collector, *Applied Thermal Engineering (Elsevier), Volume 171,* ***May 2020****, Pages 115069-87,* ISSN : 1359-4311 **(Impact factor: 4.725, SCI).**
3. Nikhil Gakkhar, Manoj K Soni, **Sanjeev Jakhar,** "Experimental investigation of exergy performance of a water cooled hybrid photovoltaic thermal collector", International journal of exergy, *Volume 31, Issue 4,* ***May 2020****, Pages 330-351,* ISSN online: 1742-8300 **(Impact factor: 1.13, SCI).**
4. **Sanjeev Jakhar,** Manoj S. Soni, **Robert F. Boehm**, **"**Thermal modelling of a rooftop photovoltaic/thermal system with earth air heat exchanger for combined power and space heating", ***Journal of Solar Energy Engineering, (ASME),*** *Volume 140, Issue 3,* ***March 2018****, Pages 031011-15,* ISSN: 0199-6231 (**Impact factor: 1.641, SCI).**
5. Rohit Misra, **Sanjeev Jakhar**, K.K. Agrawal, Shailendra Sharma, D.K. Jamuwa, Manoj S. Soni, G. D. Agrawal, "Field investigations to determine the thermal performance of earth air tunnel heat exchanger with dry and wet soil: Energy and Exergetic Analysis**"** *Energy and Buildings (Elsevier), Volume 171C,* ***2018****, Pages107-115*, ISSN 0378-7788, **(Impact factor: 4.867, SCI).**
6. Nilesh purohit, **Sanjeev Jakhar**, **Paride Gullo**, M. S. Dasgupta, "Heat transfer and entropy generation analysis of alumina/water nanofluid in a flat plate PV/T collector under equal pumping power comparison criterion", *Renewable energy, (Elsevier), Volume 120,* ***May 2018****, Pages14-22,* ISSN: 0960-1481 (**Impact factor: 6.274, SCI).**

7. **Sanjeev Jakhar** and Manoj S. Soni, "Experimental and theoretical analysis of glazed tube-and-sheet photovoltaic/thermal system with earth water heat exchanger cooling", *Energy conversion and management, (Elsevier),* Volume 153, **December 2017**, Pages 576-588, ISSN: 0196-8904 (**Impact factor: 8.208, SCI)**.
8. **Sanjeev Jakhar,** Manoj S. Soni, Nikhil Gakkhar, An integrated photovoltaic thermal solar (IPVTS) system with earth water heat exchanger cooling: Energy and exergy analysis" *Solar Energy, (Elsevier)***,** Volume 157, **November 2017**, Pages 81-93, ISSN: 0038-092X **(Impact factor: 4.608, SCI).**
9. **Sanjeev Jakhar,** Manoj S. Soni, Nikhil Gakkhar, "Exergy analysis of a photovoltaic thermal system with earth water heat exchanger cooling system based on experimental data", *International journal of exergy*, Volume 23, Issue 4, **September 2017**, Pages 367-387, **ISSN online:** 1742-8300 **(Impact factor: 1.377, SCI).**
10. **Sanjeev Jakhar,** M.S. Soni, Nikhil Gakkhar, "Historical and recent development of concentrating photovoltaic cooling technologies", *Renewable and Sustainable Energy Reviews (Elsevier),* Volume 60, **July 2016**, Pages 41-59, ISSN 1364-0321 **(Impact factor: 12.110, SCI).**
11. **Sanjeev Jakhar,** Rohit Misra, Vikas Bansal**,** M.S. Soni**,** "Thermal performance investigation of earth air tunnel heat exchanger coupled with a solar air heating duct for northwestern India", *Energy and Buildings (Elsevier),* Volume 87, 1 **January 2015**, Pages 360-369, ISSN 0378-7788 **(Impact factor: 4.867, SCI)**
12. **Sanjeev Jakhar,** M.S. Soni, Nikhil Gakkhar, "Parametric modeling and simulation of photovoltaic panels with earth water heat exchanger cooling" *Geothermal Energy (Springer)*, **2016**, 4.10, ISSN: 2195-9706 **(Impact factor: 2.204, SCI)**.
13. Nikhil Gakkhar**,** M.S. Soni, **Sanjeev Jakhar**, "Second Law Thermodynamic Study of Solar Assisted Distillation System: A review", *Renewable and Sustainable Energy Reviews (Elsevier),* Volume 56, **April 2016**, Pages 519-535, ISSN 1364-0321, **(Impact factor: 12.110, SCI)**
14. **Sanjeev Jakhar,** Rohit Misra, M.S. Soni, Nikhil Gakkhar, "Parametric simulation and experimental analysis of earth air heat exchanger with solar air heating duct" *Engineering Science and Technology, an International Journal (Elsevier)* Volume 19 (2), **June, 2016**, Pages 1059-1066, ISSN: 2215-0986 **(Impact factor: 3.219, SCI).**
15. **Sanjeev Jakhar,** M.S. Soni, Nikhil Gakkhar, "Performance analysis of earth water heat exchanger for concentrating photovoltaic cooling", *Energy Procedia (Elsevier),*

Volume 90, **2016**, pages 145-153, ISSN: 1876-6102 **(Scopus Indexed)**.

16. Nikhil Gakkhar**,** M.S. Soni, **Sanjeev Jakhar, "**Analysis of water cooling of CPV cells mounted on absorber tube of a parabolic trough collector" *Energy Procedia (Elsevier),* Volume 90, **2016**, pages 78-88, ISSN: 1876-6102 **(Scopus Indexed)**.

17. **Sanjeev Jakhar,** M.S. Soni, Nikhil Gakkhar, "Performance analysis of photovoltaic panels with earth water heat exchanger", MATEC web of Conferences, Volume 55, **2016**, pages 1-6, ISSN: 2261-236X **(Scopus Indexed)**.

18. **Sanjeev Jakhar,** M.S. Soni, Nikhil Gakkhar, "Modelling and simulation of concentrating photovoltaic system with earth water heat exchanger", *Energy Procedia (Elsevier),* Volume 109, **2017**, pages 78-85, ISSN: 1876-6102 **(Scopus Indexed)**.

19. Kuldip Singh Sangwan, **Christoph Herrmann**, Manoj Soni, **Sanjeev Jakhar, Gerrit Posselt**, Nitesh Sihag, Vikrant Bhakar, "Comparative analysis for solar energy based learning factory: Case study for TU Braunschweig and BITS Pilani", *Procedia CIRP (Elsevier),* Volume 69, **2018**, pages 407-411, ISSN: 2212-8271 **(Scopus Indexed)**.

20. Nikhil Gakkhar, Manoj K. Soni and **Sanjeev Jakhar, "**Second law analysis of an integrated parabolic trough photovoltaic thermal system" In *AIP Conference Proceedings*, vol. 2273, no. 1, p. 050008. AIP Publishing LLC, November, **2020, (Scopus Indexed)**.

<u>Book Chapters</u>

1. **Sanjeev Jakhar**, Mukul Kant Paliwal and Atul Kumar, *"*Modelling and simulation of photovoltaic thermal cooling system using different types of nanofluids*"*. Book Name:- Advances in Air Conditioning and Refrigeration, **Springer Singapore, 2021**, Pages: 1-11, ISBN 978-981-15-6360-7.

2. Nikhil Gakkhar, M.S. Soni, **Sanjeev Jakhar**, "Solar Energy Technologies and Water Potential for distillation - A Pre Feasibility Investigation for Rajasthan, India" Book Name:- Advances in Renewable Energy, **WILEY-SCRIVENER PUBLISHING, USA, October 2019**, ISBN:- 9781119555605.

<u>Papers Presented in International Conferences</u>

1. **Sanjeev Jakhar**, Mukul Kant Paliwal and Atul Kumar, *"Modelling and simulation of photovoltaic thermal cooling system using different types of nanofluids"*. International Conference on Recent advancement in Air-Conditioning and Refrigeration (RAAR-2019), CVRCE, Bhubaneswar, India.

2. Nikhil Gakkhar, Manoj K. Soni**, Sanjeev Jakhar, "***Second Law Analysis of an Integrated Parabolic Trough Photovoltaic Thermal System"*. International Conference on Mechanical Materials and Renewable Energy (ICMMRE-2019) organised by Sikkim Manipal Institute of Technology, Majhitar, Sikkim.
3. Nikhil Gakkha**r,** Manoj S. Soni, **Sanjeev Jakhar, "**Applicability of Concentrated Solar Thermal based Distillation unit for Semi-arid region", *Joint Indo-German Conference on Sustainable Engineering" September 15−16, 2017 at BITS Pilani.*
4. Nikhil Gakkhar**,** M.S. Soni, **Sanjeev Jakhar, "**Influence of environmental parameters on ground water contamination in Rajasthan, India*," Proceedings of 2016 International conference on biology, environment and chemistry (ICBEC 2016),* ***San Francisco, USA.***
5. Sravan Raj P**.,** Soni M.S. and **Jakhar Sanjeev**, A review on Photovoltaic/Thermal and Concentrated Photovoltaic/Thermal hybrid solar technology. International Congress on Renewable Energy (ICORE)– 2014, "*Powering National Growth Through Solar", Manekshaw Centre, Parade Road, Delhi Cantonment, New Delhi, December 8 - 9, 2014 pp: 282-289.*

<u>Book Published</u>

- Course: Diploma 4th semester BTER, Rajasthan (Mechanical Engineering).
  Book name:- Internal Combustion Engine (Code ME-44), Publisher:- CBC Chaura Rasta Jaipur, India

AWARDS AND HONORS

- Awarded **Postdoctoral Fellowship from Agriculture Research Organization (ARO),** Volcani Center, Ministry of Agriculture and Rural Development, Israel-December 2019.
- Awarded **Basic Scientific Research (BSR)** fellowship from the University Grant Commission **(UGC) New Delhi** for the research work (September, 2013 to July, 2016).
- Awarded prestigious Building Energy Efficiency Higher & Advanced Network (BHAVAN) Internship Program, 2017 from the **Department of Science and Technology (DST)**, the government of India and the Indo-US science and technology forum for the research visit for the duration of three months (June, 2017 to August, 2017) in the University of Nevada, Las Vegas, USA.
- Awarded **DAAD (German Academic Exchange Service)** fellowship for the research visit (November, 2016 to December, 2016) in the IWF Technical University Braunschweig, Germany.

- Awarded a **travel grant from the Department of Science and Technology (DST)** Govt. of India, New Delhi for the presenting a research paper in the International conference on Renewable Energy and Smart Grid in Bangkok, Thailand (20th to 22nd March 2016).

ADMINISTRATIVE EXPERIENCE

- Head, Department of Mechanical Engineering at Sobhasaria Group of Institutions, Sikar (Raj.), January, 01, 2018 to July, 25, 2018.
- Incharge:- NAAC accredation, Criterion 6 at Mody University Lakshmangarh, Sikar.

EDITORIAL BOARD MEMBER

- International Journal of Nuclear Exergy (Inderscience Publisher), ISSN online: 2515-5601

KEYNOTE/EXPERT LECTURE

- Delivered a **keynote lecture** entitled "PV and CPV Cooling Systems" at "National conference on Advancement in applied sciences and engineering" organized by Manda Institution of Technology, Bikaner on February, 7-8, 2020.
- Delivered an **expert lecture** entitled "Solar power: A promising solution of renewable energy" at National workshop on Renewable Energy Systems and Environmental Impacts organized by Manda Institution of Technology, Bikaner on October, 22, 2019.
- Delivered an **expert lecture** entitled "Solar power: A promising solution of renewable energy" at Gramin Mahilla College Sikar, March, 2019.

CONFERENCE/SEMINAR/WORKSHOP CONDUCTED

- **Convener,** International Workshop on Renewable Energy Technology (**Experts from Technical University Braunschweig, Germany, and BITS Pilani**, February, 01, 2018 at Sobhasaria Group of Institutions, Sikar (Rajasthan)
- Coordinator, Solar Ambassador Workshop in Collaboration with IIT Bombay on October 02, 2019 at Mody University of Science & Technology, Lakshmangarh, Sikar (Rajasthan).
- Coordinator, National Seminar on Recent Trends in Renewable Energy Systems on April 19, 2019 at Mody University of Science & Technology, Lakshmangarh, Sikar (Rajasthan).
- Co- Coordinator, Workshop on 3D Printing & Solidworks on April 20, 2019 at Mody University of Science & Technology, Lakshmangarh, Sikar (Rajasthan).

NATIONAL AND INTERNATIONAL SOCIETIES MEMBERSHIP

- Associate Member of the Institution of Engineers (India) (IEI) (AM153137-1)
- Member of Institution of Engineering and Technology (IET) UK (1100833752)
- Professional member of International Solar Energy Society (ISES)
- Member of Decision Science Institute (DSI)

RESEARCH AREAS OF INTEREST

Thermal engineering, Fluid Mechanics, Solar energy, Geothermal energy, Refrigeration and Air Conditioning, Passive building energy savings, Photovoltaic and Concentrated photovoltaic systems, Concentrated solar power, Nanofluids heat transfer, Heat transfer systems and Thermodynamic analysis of thermal systems.

PROFICIENCY

- Languages–English, Hindi, Marwari.
- Software – AutoCAD, SolidWorks, ANSYS, TRNSYS, ASPEN, MATLAB, COMSOL and Microsoft Visio.
- Operating System –Windows XP, Windows 7 & 10.

PERSONAL INFORMATION

- Name- Dr. Sanjeev Jakhar
- Date of Birth- August, 15, 1989
- Father’s Name – Late Sh. Om Prakash
- Mother's Name – Mrs. Bimla Devi
- Spouse’s Name – Mrs. Santosh Thory
- Nationality– Indian.
- Permanent Address– VPO-Athwas, Vai-Balarn, Teh-Fatehpur, Dist- Sikar, Rajasthan, India, 332401.

DECLARATION

I do hereby declare that the particulars and facts stated herein above are true, correct and complete to the best of my knowledge and belief.

(Dr. Sanjeev Jakhar)

Persons for Reference:-

- Prof. (Dr.) M. S. Dasgupta
  Professor and Head of Department,
  Department of Mechanical Engineering,
  Birla Institute of Technology and Science Pilani, Pilani campus, India
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  Mob.:- +91-9829227459
- Dr. Nikhil Gakkhar
  Scientist C, Ministry of New and Renewable Energy, Government of India,
  Block 14, CGO Complex, Lodhi Road, New Delhi, India
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- Prof. (Dr.) K. S. Sangwan
  Professor,
  Department of Mechanical Engineering,
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Experimental and theoretical analysis of hybrid concentrated photovoltaic/thermal system using parabolic trough collector

Nikhil Gakkhar[a,*], Manoj Kumar Soni[b], Sanjeev Jakhar[c,*]

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[b] Department of Mechanical Engineering, Birla Institute of Technology & Science, Pilani, Rajasthan 333031, India
[c] Mechanical Engineering Department, Mody University of Science and Technology, Lakshmangarh, Sikar, Rajasthan, India

HIGHLIGHTS

- A hybrid CPVT system was proposed and analyzed theoretically and experimentally.
- The flow rate was varied from 0.083 kg/s to 0.117 kg/s using different configurations.
- At optimum flow rate of 0.108 kg/s the mean overall efficiency goes up to 69.19%.
- Enviroeconomic study shows carbon mitigation of 40.2 tCO_2/year at optimum conditions.
- The proposed HCPVT system could be used for low grade thermal applications.

ARTICLE INFO

Keywords:
Solar energy
Parabolic trough collector
Concentrated photovoltaic/thermal
Hybrid system
Renewable energy

ABSTRACT

In the current work, a hybrid concentrated photovoltaic thermal system was designed and coupled with a parabolic trough collector and investigated theoretically and experimentally for combined heat and power output. In the design, a photovoltaic module was mounted on a flat surface of parabolic trough absorber tube having semi cylindrical shape. A provision was made to cool photovoltaic panel from both the surfaces by flowing water through the absorber tube as well as the annulus of between absorber tube and glass cover. The model was developed using first law of the thermodynamics and then validated using experimental data generated through the fabricated setup. During the experimentation, the annulus flow rate was varied from 0.008 kg/s, 0.017 kg/s and 0.025 kg/s and inner flow rate was varied from 0.075 kg/s, 0.083 kg/s and 0.091 kg/s. The field testing results showed the mean overall efficiency of system obtained as 61.42%, 64.61% and 66.36% for inner tube flow rate of 0.075 kg/s, 0.083 kg/s and 0.091 kg/s respectively for annulus flow rate of 0.008 kg/s. The theoretical results of hybrid system obtained from the simulation are in good agreement with the experimental data. In the end environmental cost analysis was also carried out for the proposed system.

1. Introduction

The photovoltaic (PV) technology works on the principle of direct conversion of sunlight into electricity using semiconductor materials. The PV technology is commercially proven technology with achievable cell efficiency between 15 and 20% [1]. Although widely acceptable, a major challenge with PV systems is high cell/panel temperature due to incessant solar radiation which reduces the efficiency of the cell and its lifespan [2]. To utilize maximum solar energy, the systems are designed to utilize the excess waste heat into a useful form. One of the technology, Photo-Voltaic Thermal (PVT) increases the PV efficiency along with recovery of excess heat as reported in various studies [3–5]. Under high radiation, concentrated photovoltaic/thermal (CPVT) system not only provides higher electrical output but substantial thermal energy due to their inbuilt cooling systems. While a variety of cooling approaches have been used to the maintain the PV panel temperature, most of them are based upon removal of heat from the back of the cell (opposite surface of the incident flux exposed surface) [6].

Although the PV installation has grown many folds to more than 400 GW across the world and many commercial plants are installed across various countries, the installed capacity of PVT or CPVT is too low to be reported [7]. The major work on CPVT is still in research phase with lab scale testing of prototypes. The literature discusses the work related to design, modelling, prototype testing and various

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Thermal Modeling of a Rooftop Photovoltaic/Thermal System With Earth Air Heat Exchanger for Combined Power and Space Heating

Earth air heat exchanger (EAHE) systems are inefficient to provide thermal comfort in winter season for semi-arid regions. The performance of such systems could be improved by coupling them with other renewable energy sources. One of the renewable energy technology is rooftop photovoltaic/thermal (PV/T) air collectors which could utilize the incident solar insolation to obtain both electricity as well as useful heat. In the current paper, the thermal performance of an EAHE coupled with a PV/T system has been numerically investigated for climatic conditions of Pilani, Ajmer (India), and Las Vegas (U.S.). For the comparative analysis, a thermodynamic model has been developed and compared with experimental data available in the literature which seems to be in good comparison with the results. Further, a parametric analysis has been carried out for assessing the effect of different operating parameters. Results showed that for the winter season, the maximum cell temperature without any cooling goes up to 54.3 °C, 54.5 °C, and 44.4 °C for Pilani, Ajmer, and Las Vegas, respectively, while with cooling it drops to 43.4 °C, 44.2 °C, and 35.6 °C, respectively, for 0.053 kg/s flow rate. The heating capacity of the EAHE was observed to be improved with PV/T air collector by 23.47 Wh–298.74 Wh, 71.18 Wh–315.93 Wh, and 41.43 Wh–270.75 Wh for the Pilani, Ajmer, and Las Vegas, respectively. [DOI: 10.1115/1.4039275]

Keywords: earth air heat exchanger, PV/T air collector, heating capacity, solar energy

1 Introduction

The energy consumption could be categorized into four parts depending upon their demand, i.e., residential, industrial, agriculture, and transport. Among these, most of the energy consumption in residential and industrial use is for air conditioning or refrigeration. Within the buildings, space heating consists of 40% of air conditioning load, especially in developed colder countries [1,2]. In these countries, most of the electrical energy is generated from fossil fuels and nuclear fuel. The burning of fossil fuel leads to carbon emission which eventually increases global warming. The alternate way to generate electricity is by using renewable energy through which environmental issues can be decreased. Among all the renewable energy systems, photovoltaic (PV) systems are widely used for electrical power generation. However, the cost effective technology for PV systems are yet to develop. Thus, the cost cutting could be achieved by installing PV systems on the buildings by integrating them on the building facade [3]. In rooftop PV systems, some part of the solar insolation is transformed into electricity, while the rest is either reflected back or transformed into thermal heat. This will enhance the PV panel operating temperature which not only causes an efficiency drop but also scales down the life-span of the cells. Thus, the cooling of PV cells can be quite important, especially in semi-arid and arid regions. The cooling of PV could be achieved by flowing air or water as a cooling fluid on the back surface of the module [4]. In this regard, a lot of research work has been done using various cooling designs.

Sopian et al. [5] introduced a quasi-steady-state theoretical model to investigate one and two pass photovoltaic/thermal (PV/T) air collectors for building heating. They compared both one and two pass collectors and found that the two pass collector had superior performance. Hegazy [6] presented four designs of PV/T systems with air as a cooling fluid to investigate the performance of the hybrid system. They observed least performance in the case of air flown above the absorber and minimum fan power requirement in two sides of the absorber plate using a one pass. Mondol et al. [7] performed a transient simulation study of the building integrated PV (BIPV) system using TRNSYS simulation tool. They found that simulation accuracy was increased by 55%–70% with modifications in global diffuse correlations. Tiwari et al. [8] developed a theoretical model and experimental results to calculate the performance of a PV module along with an air duct. They found a close comparison between analytical and experimental results. Vokas et al. [9] evaluated the theoretical performance of a PV/T air system with low power absorption chiller for domestic heating and cooling. Their results showed that a 30 m^2 PV/T area covered the cooling and heating load of buildings as 25.03% and 47.79%, respectively, for the conditions of Athens. Joshi et al. [10] performed an analytical and experimental analysis to assess the performance of the PV/T collector with air as a circulation fluid. Solanki et al. [11] presented an economical PV/T solar air heating setup for indoor conditions. Their experimental results showed that with an enhancement in flow rate of air, efficiency increased toward a maximum condition. Pantic et al. [12] investigated the performance of the open loop air based BIPV/T system for a home in Canada. It was concluded that the additional glazing on BIPV drastically decreases the power generation and can increase to overly high temperatures of PV modules and thus was not suggested. Sarhaddi et al. [13] presented a theoretical model to evaluate both the electrical and thermal efficiency of a

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Heat transfer and entropy generation analysis of alumina/water nanofluid in a flat plate PV/T collector under equal pumping power comparison criterion

Nilesh Purohit [a, *], Sanjeev Jakhar [a], Paride Gullo [b], Mani Sankar Dasgupta [a]

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Entropy generation

ABSTRACT

Convective heat transfer of alumina/water nanofluid flow through flat plate PV/T panel in laminar flow has been investigated numerically in this study. Majority of previous studies, reported comparison in performance of nanofluid with that of basefluid, based on equal Reynolds number criterion. Hence, there is limited exploration of other comparison bases. A novel and prominent comparison basis, besides conventional equal Reynolds number, is equal pumping power and appears more practically oriented. Nanofluid, having particle dimension of 20 nm and inlet temperature of 293 K, is loaded with 1%, 4% and 6% of particle volume fraction with Reynolds number varying from 300 to 1800. Simulation results indicate average 25.2% improvement in heat transfer coefficient for nanofluid under equal Reynolds number comparison basis. While, under equal pumping power comparison criterion, the heat transfer coefficient for nanofluid is found to have average decrement up to 13.8%. Entropy generation for nanofluid reduces significantly, maximum up to 31%, under equal Reynolds number comparison criterion only. Alumina/water nanofluid in flat plate PV/T channel is found beneficial only under equal Reynolds number comparison basis.

1. Introduction

Solar energy in the recent years has gained worldwide acceptance, especially, in the development and adoption of flat plate solar collector to generate mild hot water (30–70 °C) for various domestic and industrial applications. This may be attributed to the simplicity of flat plate solar panels in terms of both construction and operation [1–6]. Most common heat transfer fluid (or base fluid) used in flat plate solar collector is water, which possess low thermal conductivity. Adding nanoparticles (NPs) to base fluid, leads to improvement in overall thermal conductance [7]. NPs suspended in the base fluid forms a stable mixture, under controlled conditions, known as nanofluids (NFs), coined by Choi [8], which finds prominent application as a heat transfer fluid in solar collectors. Mahian et al. [9] developed and proposed theoretical model to investigate the effect of NPs morphology on the efficiency of a mini channel solar panel. They reported that the NPs with platelet morphology are found to have least heat transfer coefficient (HTC), on the contrary, brick shaped NPs showed superior heat transfer characteristics. Meibodi et al. [10], experimentally investigated the performance of silicon oxide based NFs as the heat transfer fluid in the flat plate solar collector. They observed a maximum of 8% improvement in the thermal efficiency of the system loaded with NF. In some other study by Colangelo et al. [11], sedimentation was investigated as the prominent limitation of adopting NFs in the flat plate solar collector. The authors also proposed a novel solution to avoid sedimentation problem by introducing shaped elements in the inlet and outlet headers. The effect of alumina on the performance of water based NF was experimentally investigated by Yousefi et al. [12], and the outcomes suggested that parameters like Ph variation and surfactants properties affects the efficiency. In addition to this, they reported that controlling appropriately above said parameters would yield in higher performance. The study performed by Tyagi et al. [13], suggested that efficiency of system employing NF raised by a factor of 9 as compared to that of system using pure water in both flat plate and direct absorption solar collectors. Edalatpour and Solano [3] analyzed temperature profiles of alumina based NF in a flat plate

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Field investigations to determine the thermal performance of earth air tunnel heat exchanger with dry and wet soil: Energy and exergetic analysis

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ABSTRACT

Earth air tunnel heat exchanger (EATHE) systems are inadequate to meet the thermal comfort requirements in semi-arid regions as they require large pipe lengths. The effectiveness and performance of such system can be increased by increasing soil moisture content, making as wet soil configuration. In the present work, the thermal performance of the EATHE system with dry and wet soil has been evaluated during the peak summer season. Further, the thermal behavior of these two EATHE systems has been compared on the basis of temperature of air flowing through buried pipes at different sections along the length. For the same a theoretical model is developed and validated with experimental results and found in good agreement with an error ranging from 2.44% to 10.85%. Moreover, the exergetic analysis has been carried outto investigate the work potential and scope of maximum utilization of energy. Results reveal that thepipe length can be reduced by 12–14 m with wet EATHE system as compared to dry EATHE system for the same cooling performance. The second law analysis shows that the maximum exergetic efficiency is 52.25% and 53.18% for dry and wet soil EATHE systems respectively.

1. Introduction

In the semi arid regions, there is a requirement to achieve thermal comfort in the buildings with minimizing energy consumption. In most of the buildings the thermal comfort is generally maintained by air conditioning. The most common technology of air conditioning is vapor compression technique, operated by electric motors. It consumes a huge amount of electrical power which is a major concern. Further, this technology releases Chlorofluorocarbons (CFC's) in the atmosphere, which causes depletion of ozone layer and global warming. With main challenge of energy shortage in most of the parts of the world and to overcome the issue of ozone depletion, the renewable energy technologies can be used alternatively [1]. One of the passive heating/cooling technologies based on the geothermal principle is earth air tunnel heat exchanger (EATHE). In EATHE system, during summer, hot surrounding air is passed through the buried pipes. When air flows through the pipes, heat is transferred from hot air to the soil. As a result the outlet temperature of EATHE is much lower than the ambient temperature. This cooled air from EATHE could be used for the space cooling directly or could be hybridized with conventional cooling systems to reduce their power consumption and improve cost economics [2].

A number of researchers have conducted different studies on the performance of EATHE systems considering geometric and climatic variations. Sodha et al. [3] investigated an EATHE system for heating/cooling to supply the conditioned air to a hospital in India. They found that the EATHE was able to produce the cooling and heating capacity of 512 kWh and 269 kWh respectively, with 80 m long buried pipe. The dynamic performance of the EATHE system was evaluated by Mihalakakou et al. [4] using an unsteady state numerical model during the summer season. Santamouris et al.

Abbreviations: PVC, poly vinyl chloride; MS, mild steel; EATHE, earth air tunnel heat exchanger; RH, Relative Humidity; COP, Coefficient of Performance; RPM, Rotations Per Minute.

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Experimental and theoretical analysis of glazed tube-and-sheet photovoltaic/thermal system with earth water heat exchanger cooling

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ABSTRACT

In the present paper, an attempt has been made to investigate the theoretical and practical performances of the photovoltaic/thermal (PV/T) system coupled with earth water heat exchanger (EWHE) cooling system for the conditions of semi-arid region of Pilani, Rajasthan. The experimental studies have been performed for different flow rates of cooling water (0.033 kg/s, 0.025 kg/s and 0.017 kg/s) for a typical day climatic conditions. An electrical efficiency comparison was made for two scenarios when the PV panel was connected or disconnected with the thermal collector and found out that the average electrical efficiency of PV/T panels is higher than the normal PV efficiency. The results of the experimental study showed that the maximum PV panel temperature goes up to 73 °C without any cooling. On the other hand, the PV panel temperature drops in the range of 43.68–49.64 °C with the flow rate of 0.033 kg/s. It has been estimated that the electrical and thermal efficiencies of the PV/T system with cooling are in the range of 8.26–8.52% and 44.06–55.45% respectively for flow rate of 0.033 kg/s. The EWHE pipe length of 38 m found to be sufficient for the proposed system. The experimental results are validated with the theoretical model by using basic energy balance equations and found in good agreement with percentage error of 0.91–12.09%.

1. Introduction

Electrical energy is a high grade form of energy which can be used directly in day to day life. It can be generated from various sources like fossil fuels, including natural gas, nuclear power, etc. However, most of the power generation in the world is through fossil fuels which leads to carbon emissions and causes issues like global warming, environment pollution, etc. To overcome such issues, lots of work is going on in the field of renewable energy for power generation [1–3]. One of the clean form of energy is solar energy which is an infinite source and can meet the energy demand of the world for years to come. The power generation from the solar energy can be achieved by Photovoltaic (PV) systems [4]. In which photon is directly converted into electrical output. However, the thermal energy from the Sun causes the rise in the temperature of the solar cells, which decreases the cell efficiency and also degrades the solar cells and hence the life span of the cells. The temperature of the solar cells can be maintain by providing suitable cooling technology to the cells [5]. One of the technology is combining thermal collectors with PV panel forming a photovoltaic/thermal (PV/T) system in which excess heat can be dissipated to the cooling fluid so that the temperature of the cell can be maintained within the limits. Such PV/T system, thus, provides thermal as well as electrical output directly from the solar energy and called as hybrid system [6,7]. Hegazy [8] presented four different models of forced air models of PV/T with variable parameters like air flow rate, fan power consumption, maximum outlet and inlet air temperature. A theoretical model of PV/T air system was developed by the Gholampour and Ameri [9] to investigate the effect of the various parameters like environmental, operational and dimensional. They concluded that the second law analysis is necessary for making good design decisions. They also concluded that the packing factor of the PV panel is crucial factor to determine the output and with increase in packing factor both energy and exergy efficiencies increases. Vokas et al. [10] presented a theoretical approach on hybrid PV/T systems for domestic heating and cooling. They found that the thermal efficiency of PV/T system was lower than the conventional solar collector.

In the last few decades, major research on PV/T is reported by taking air or water as a cooling medium. In most of the hybrid systems, water is predominately used as cooling medium owing to its large heat capacity. However, it is limited to research work only and have very few industrial applications [11]. Tripanagnostopoulos et al. [12] discussed the feasibility of hybrid PV/T solar systems. They proposed that

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