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REPS 2022 Programme
Day 1 – Monday, 31 October 2022

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Abstracts

Day 1 – Monday, 31 October 2022

Session 1

A PV Tied Single Core Triple Inductor Based Multi-Channel LED driver for Greenhouse Applications

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Abstract

In the case of growth of plants in a greenhouse, there is a need for multi-channel LED drivers. This could be done using a pre-regulator followed by a linear current regulator using a MOSFET. However, this presents issues such as discontinuous current and potentially a discontinuous light intensity or a slight flicker observed by the LEDs. Hence, a continuous current is required for a more stable light intensity. An issue with parallel connected converters is the magnetic component count, i.e. the inductor count required leading to a space issue. In the quest to reduce the size of the system, a multi channel converter using a single toroid core is proposed. The system is programmed to source its power from a photovoltaic array. Hence, a requirement for the driver to act as a charge controller. This paper outlines the design and implementation system made up of a triple paralleled buck converter utilising a single ferrite core.

Keywords: Single Inductor Multiple Output(SIMO), Multiple Channel LED(MCLED), Pulse Width Modulation(PWM)

EL/PL system optimization and image calibration for different PV devices

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Abstract

Electroluminescence (EL) and Photoluminescence (PL) imaging of Photovoltaic (PV) devices are well known qualitative and quantitative, non-destructive characterization techniques. The quality of an image is important in luminescence image quantification. Aside from basic optical optimisation (such as focus, relative position, lens distortion and contrast), a camera's sensor's properties can affect an image's quality. In literature, a process has been developed to corrected for these factors when capturing EL and PL images of silicon PV devices. This procedure however has not been investigated to see if it also works for other PV materials, such as perovskite, Multi-junction III-V concentrator cells, etc. It is therefore necessary to further develop this process and investigate it for other PV devices, as it would be different for each material's luminescence spectrum. This study illustrates how the process is investigated and used in correcting images acquired for Silicon, Multi-junction III-V concentrator cells, and perovskite.

Keywords : *Luminescence Imaging, Photovoltaic devices, image calibration.*

Thermo-opto-electrical characterization of Photovoltaic Devices: Performance and Longevity

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Abstract

There are many different ways to assess the performance of a Photovoltaic (PV) module; whether through electrical measurements such as dark and/or light current-voltage measurements or imaging-based techniques such as thermography (IR imaging, dark lock-in thermography, etc) and luminescence imaging (photoluminescence or electroluminescence imaging). All of these techniques can provide some information regarding the performance of the PV device; however, the application of more than a single technique can provide a more complete analysis and interpretation. PV modules often contain defects, some of which are material defects, manufacturing defects and some even handling and installation defects. The defects are often performance limiting and can over time become more pronounced, the module performance then degrades with time. However, operational failures can play a more destructive role. This paper investigates the application of these techniques at the PV cell scale and at the PV module scale to find a plausible explanation for a particular operational failure.

Keywords: Photovoltaic, luminescence imaging, thermography

A Review of Load Flow Methodologies for Constrained Networks: A South African Case Study

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Abstract

South Africa, along with the rest of the world, is becoming increasingly dependent on variable renewable energy sources which increase the uncertainties associated with operating and planning a power system. Traditionally, deterministic load flow analysis was used for modelling power systems, but it has been shown to be unable to represent the uncertainties of network states well. Commonly, probabilistic load flow analysis is suggested as an alternative to DLF. This review paper provides a comparative analysis of probabilistic load flow analysis (PLF) and DLF at the hand of prevalent literature. The advantages and disadvantages of the respective methodologies are emphasised specifically in relation to modern power networks with a large share of renewable generators to determine which is better suited to constrained systems. This paper discusses certain commonly used PLF methodologies along with their typical applications and their suitability for capacity planning in South Africa. PLF is found to be preferable to DLF for decision-making purposes, as it provides users with probabilistic information representing risks associated with modelling outcomes. PLF, however, carries a significantly larger computational burden and requires more detailed data on various network components. The added information provided by PLF potentially allows for more economic system designs during power system planning as well as more efficient utilisation of existing infrastructure during operations, as it provides a measure of the risks associated with making these decisions. Of the PLF methodologies considered, numerical PLF methods show the greatest maturity for use in system operation and network planning purposes. Analytical and approximate methods have been shown useful for specific scenarios but seem limited in their aptness for the South African system due to the amount of input variables and the complexity of correlations that can be considered, respectively.

Keywords: probabilistic load flow, review article, variable renewable energy.

Conceptual investigation of a novel air-cooled window for a recuperated solar- dish Brayton cycle using a turbocharger and short-term thermal storage

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Abstract

A recuperated solar-dish Brayton cycle using an off-the-shelf turbocharger as a micro-turbine and a rectangular cavity receiver with integrated thermal storage was considered for this study. These solar receivers have a considerable amount of heat loss to the environment. It was proposed to have a glass channel parallel to each of the four receiver walls on the inside of the cavity receiver. The glass channel is made up of two glass walls and is to be cooled by air flowing from the compressor. This conceptual study used an entropy generation minimisation technique combined with a SolTrace analysis to investigate the impact of the air-cooled window on the performance of the cycle. Results showed that the maximum solar-to-mechanical efficiencies were between 44% and 47% lower than for the cycle without the window. The exhaust temperature of the cycle with the window was higher than that of the cycle without the window, which led to a higher energy utilisation factor of between 7% and 18% if the exhaust was used for cogeneration. Therefore, this conceptual study indicated that it might not be feasible to implement the cooling window, except where a higher cycle exhaust temperature was preferred for cogeneration.

Keywords: Solar-dish, micro-turbine, cooling window, recuperator, Brayton cycle.

The Development and Testing of a Recuperator for a Solar Hybrid Micro GasTurbine System

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Abstract

The thermal efficiency of an MGT (micro gas turbine) system at Stellenbosch University was intended to be improved with the incorporation of a locally developed recuperator. A clamped plate, counter-flow design was chosen due to its simplicity. An effectiveness of
0.92 was desired and formed the design constraint on which to optimise the recuperator geometry. From this geometry a detailed design was performed. The recuperator was assembled, attached to the system and tested. To compare and validate the experimental results of the standard and recuperated MGT system, a Flownex model was developed. This large effectiveness value was not achievable, both practically and financially. An effectiveness of 0.6 was designed for instead. During experimentation, the MGT system could not self-sustain due to the additional pressure drops incurred by the recuperator, which were attributed to flow-maldistribution within the headers. A decoupled mode of testing was performed to evaluate effectiveness and cold-flow pressure drop of the recuperator. Close correlation of the experimental results was achieved analytically and with Flownex. Partial recuperation, with a bypass on the hot and cold-side, was modelled in Flownex and revealed that the system could self-sustain in this manner. An improved recuperator design is therefore proposed.

Keywords: Plate Heat Exchanger, Recuperator, Solarised, Flownex, Turbocharger

Power generation from commercial turbochargers connected in parallel

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Abstract

Countries such as South Africa are struggling to supply enough power to its citizens due to a failing power grid. This creates an opportunity for the development of small-scale power generation. This study investigates a parallel flow micro-turbine using off-the-shelf Garrett turbochargers for power generation. Two different configurations are modelled, namely, a low-temperature turbine (LTT) and a high-temperature turbine (HTT) where the only difference is the position of the power turbine. In this initial study, both configurations are modelled at steady state for unrecuperated cycles without pressure losses. It was found that the HTT is superior to the LTT configuration when no pressure losses are introduced. Results show that the GT2860RS turbocharger as gasifier combined with the GT1241 as power turbine produces the highest efficiency at the highest pressure ratio. Overall, the results show that an unrecuperated HTT can generate between 1.5 kW and 7.2 kW of power with a thermal efficiency of up to 6%.

Keywords: Brayton cycle, micro-turbine, parallel, turbocharger, turbo-generator.

Simulation of a novel combined water purification and electricity generation system

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Abstract

There is a correlation between areas with an abundance of solar resources as well as water scarcity. Novel solutions are required to alleviate water scarcity, one such solution is solar-powered water desalination. A combined water desalination and electricity production cycle is relevant for rural communities with a lack of clean water and electricity; this project aims to help with the proof of concept by developing a simulation model of a pilot system. This paper presents a selection of results from a one-dimensional simulation of an indirect solar thermal steam generator coupled to a steam expansion engine. The model was developed in Flownex SE and allows for the prediction of the system performance as a function of transient solar and ambient conditions. Results from a sunny summer and overcast winter day are presented. The pilot system can produce $74\ \mathrm{L}$ of water and $1.2\ \mathrm{kWh}$ of mechanical power at an SEC of $650\ \mathrm{kWh/m^3}$. Validation of the results against experimental measurements is pending.

Keywords: Solar thermal energy, solar distillation, desalination, steam expansion, heat engine

Session 2

Comparative analysis of the effects of different pretreatment methods on methane yield of groundnut shells

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Abstract

Groundnut shells are one of the abundant lignocellulose feedstock with a high composition of lignin, hemicellulose, and cellulose. Cellulose is tightly embedded in the lignin and hemicellulose, leading to lignification and crystallization, high resistance to methanogenic bacteria, and more recalcitrance during anaerobic digestion. Therefore, an appropriate pretreatment method is required to break down the heterogeneous matrix and make the hemicellulose and cellulose accessible to microorganisms. This study investigates the effects of thermal, nanoparticle additives, and combined pretreatments on the methane yield of groundnut shells. Groundnut shells were pretreated using conventional heating at 100 °C for 30 min, addition of 20 mg/L of Fe_3O_4 nanoparticles and a combination of particle size reduction with 20 mg/L of Fe_3O_4 nanoparticles. They were subjected to anaerobic digestion in a lab-scale batch digester for 30 days at a mesophilic temperature (37 °C ± 2). The result showed the cumulative methane yield of 31.07, 79.59, 98.01, and 23.69 ml/g VS_{added} for thermal, Fe_3O_4 additives, combined pretreatments, and untreated groundnut shells, respectively. This study confirmed that appropriate pretreatment methods improve the methane yields of lignocellulose feedstocks, and combined pretreatments released the highest methane yield. This result can be replicated at the industrial scale to establish its economic reality.

*Keywords***:** Anaerobic digestion, lignocellulose materials, groundnut shells, pretreatment methods, methane yield.

Process Configuration of Combined Ozonolysis and Anaerobic Digestion for Wastewater Treatment.

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Abstract

Industrial activities and increased human population have resulted in wastewaters not entirely amenable to conventional treatment methods. Anaerobic digestion (AD) can treat such wastewaters with the advantage of bioresource recovery. However, the presence of solids and recalcitrant compounds in most wastewaters may affect the AD process. Thus, combining AD with advanced oxidation processes is necessary. This study combined ozonolysis with AD to treat waste activated sludge (WAS) and distillery wastewater (DWW). When applied as a pretreatment, ozonolysis caused the rigid cell walls in WAS to rupture and solubilised the extracellular polymeric substances (EPS), leading to increased biodegradability. For the DWW, ozonolysis pretreatment reduced the biorecalcitrant aromatic compounds to simple aliphatic compounds, thereby increasing biodegradability. In the ensuing AD process, the WAS pretreatment improved TSS and COD reductions and a 230% increase in cumulative biogas production. For the DWW, the ozonolysis pretreatment did not significantly impact COD reduction or biogas production; however, when applied as a posttreatment, ozonolysis effectively removed the biorecalcitrant colour of the anaerobically digested effluent and solubilised the TSS washed out from the AD unit. Therefore, the AD-ozonolysis process configuration is substrate specific; ozonolysis is best applied as a pre-AD and post-AD for WAS and DWW, respectively.

Keywords: Ozonolysis, Pretreatment, Posttreatment, Solubilisation, Biogas.

Optimization of process parameters for anaerobic co-digestion of cow dung and jatropha cake using Response Surface Methodology

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Abstract

Waste-to-energy technology using agricultural residues, especially in developing countries, can assist in achieving the sustainable development goals of (SDGs) of the United Nations. Large quantities of cow dung and jatropha cakes are released annually, leading to severe environmental challenges and urgent attention. Anaerobic co-digestion of two or more feedstocks is becoming more popular because it improves biogas yield and organic waste management. This study investigates the influence of three independent variables of temperature, retention time, and mixing ratio on the biogas yield of cow dung and jatropha cake. A Central Composite Design of Response Surface Methodology (RSM) was used to optimize and predict biogas yield through an anaerobic co-digestion process. The observed result indicates that the linear model terms of temperature, retention time, and mixing ratio have significant interactive effects ($P \leq 0.05$). The optimum conditions were observed to be a temperature of 34 °C, a retention time of 29 days, and a 75:25 % mixing ratio (cow dung to jatropha cake). The model predicted 1.87 L/Kg VS_{added} at the optimum conditions with a correlation value (R^2) of 0.8390. The predicted result shows that RSM models can predict biogas yield. In general, this study has demonstrated that co-digestion of cow dung and jatropha cake is a promising way to enhance biogas yield by providing nutrient balance, and this can be replicated at the industrial scale.

Keywords: Biogas yield, Co-digestion, Cow dung, Jatropha cake, Response Surface Methodology (RSM).

Modelling of Alkaline electrolyser for hydrogen production using Simulink and artificial neural networks (ANN) for output prediction

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Abstract

The broader adoption of green hydrogen remains limited by its lower efficiency and the sector's immaturity. Several studies have investigated parameters that impact the electrolysis process and developed methods to increase efficiency. Although these systems are relatively effective, further optimisations are achievable by implementing a data-driven approach for better process control and optimisation. Simulink is used in this study to present a comprehensive analysis of input parameters' effects on the yield of hydrogen and the electrolysis cell efficiency. Findings show that process parameters such as temperature, pressure, and current density significantly impact hydrogen production and the cell's efficiency. Furthermore, ANN (artificial neural network) was effectively used to predict process variables, demonstrating that AI (artificial intelligence) could be utilised as a predictive model for a water electrolysis process. These findings can be used as a stepping-stone to developing an advanced data-oriented optimisation system for an alkaline water electrolysis process.

Keywords: hydrogen, green, optimisation, efficiency, algorithms

Performance And Economic Evaluation Of A Porous PVA Floating Wick In ASolar Still Under Concentrated Solar Energy

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Abstract

Solar still is becoming a promising solution for people in remote areas to convert brackish and saline water into potable water through distillation process. However the solar still's performance is still low. In order to improve the performance, various approaches are implemented by researchers. In the present study, solar interfacial evaporation technique is proposed. A porous PVA floating cloth is used to enhance solar-heat conversion and water absorption by capillarity action under concentrated solar energy. The concentrated solar energy is produced by beam down reflector installed at Stellenbosch University. The maximum evaporation rate observed in one of the clear days is found to be approximately 2.3 kg/m^2hr with efficiency of 71% under average concentrated solar beam of 2 kW/m^2. A mathematical model is developed by using the energy balance equations on the evaporation structure in the solar still. Fair agreement was seen between the model and experimental results. An estimated economic analysis based on the evaporation rate was also performed for the proposed solar still on a 10-year life cycle. Despite the high costing of the concentrating solar system, the proposed solar still is still economical.

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Keywords: Solar still, concentrated sunlight, interfacial evaporation.

Flux Distrubution From A Beam Down Secondary Reflector: Comparsion Of Ray Tracing, Analytical, And Experiemtnal Results

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Abstract

The aim of this paper is to validate Tonatiuh ray tracing software for central receiver systems. A specific test case was investigated, consisting of one heliostat, a ground level receiver, and a secondary beam down reflector. Validation is performed by comparing the flux distribution predicted by the ray tracer model with an analytical model, and with an experimentally measured flux distribution determined with the use of a flux sensor. It was found that the shape and radial spread of the flux distribution in the secondary focal spot is well predicted by Tonatiuh. The ray tracer and analytical model peak flux results are similar, with a percentage difference of less than 1%. However, the peak flux values from the ray tracer are underpredicted by up to 63% when compared to the experimental results. The uncertainty of the peak flux values can be attributed to the flux sensor operating at the lowest end of its range. Therefore, determining the flux level accuracy of Tonatiuh will require repeating experiments with a flux measurement device with a more appropriate measurement range.

Keywords: *Concentrating Solar Power*, *Ray tracing, Beam Down Reflector, Optics*

The Automation of Quality Control for Large Irradiance Datasets

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Abstract

The automation of quality control (QC) for large irradiance datasets is presented in this article. A three-step QC procedure is presented that includes an automatic elimination process of erroneous irradiance measurements and a novel empirical formulation for automatically identifying measurement tracking errors. The first step is a time-series visualisation, the second step is the automatic removal of missing and duplicate values, and the third step is an automatic flagging and elimination step to identify erroneous data. Two South African case studies were used to illustrate the practical application of the automatic QC procedure. The automatic QC procedure successfully removes the night-time data points as well as the tracking errors. An initial flagging procedure for reviewing data was also included as part of the QC procedure; however, these data points were found to consist of closure test flags. Upon further investigation, the flagged data did not indicate that the measurements were faulty, and therefore the automated elimination process shows adequate performance in removing data without this manual review process. The automatic process proves to be a time-efficient method to remove erroneous data and is therefore recommended as a minimum QC procedure for large irradiance datasets.

Keywords: quality control, irradiance, radiation, data

Session 3

Investigating the effect of orientation and tilt angle on bifacial PV modules on vertical east-west and tilted north-south modules

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Abstract

Photovoltaic (PV) technology is an attractive renewable source for regions with many hours of sunlight. Bifacial PV modules are an evolution of PV module structure to improve the efficiency of converting solar irradiance from the back surface as well as the front surface into electricity. In a non-tracking system, bifacial modules can be mounted vertically in an east-west orientation or tilted in a north-south orientation. Modules installed vertically produce two peaks in power generated throughout the day, while the tilted modules peak around noon when irradiation intensity is at maximum. In this research, a Bifacial PV system of each configuration is to be installed at the Outdoor Research Facility at Nelson Mandela University, Gqeberha, South Africa. The performance of the system was simulated. The results obtained from the simulation show that the tilted configuration produces more electrical energy than the vertical configuration, and between April and August a single tilted module produces has higher output than two vertical modules. The vertical configuration spreads the generation over a longer period, with two peaks in a day. The results show the vertical system would best fit a grid-tied system because the generation peak is closer to times of high demand. The tilted installation would have the highest daily average energy generation making it more useful for a standalone system.

Keywords: Bifacial PV modules, vertical / tilted bifacial modules.

Spectral Influences on Performance: A South African PV Plant after 4 years of operation

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Abstract

The performance ratio (PR) of a South African photovoltaic (PV) plant, over 4 operational years, is discussed by assessing the normal and weather-corrected PR calculation under well-known spectral influences, being airmass (AM) and precipitable water (PW). The PR is determined for different intervals of AM and PW to identify scenarios in which the normal and weather-corrected PR shows significant deviations. The spectral irradiance of polycrystalline PV modules is simulated for different AM and PW values to identify the wavelengths where the PV module underperforms. Both the normal and weather-corrected PR is decreased when AM levels are higher than 3, PW is greater than 0.8 cm, and calculated cell temperatures below 30℃. The corrected PR is more stable for ideal operating conditions but shows significant deviations under nonideal circumstances. The spectrum is affected in the 0.9 to 1.0 µm wavelengths for changes from standard testing conditions in both the AM and PW. Changes in AM have a greater effect on spectral irradiance in the 0.7 to 0.8 µm wavelengths. The PV module's spectral response is higher in the 0.7 to 1.0 µm wavelengths, which results in a more pronounced effect on performance.

Keywords: Performance ratio, weather-corrected performance ratio, airmass, precipitable water, spectrum

Evaluation Of Operating Parameters To Improve The Efficiency Of A Proton Exchange Membrane Fuel Cell

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Abstract

This paper presents the modelling and simulation of a proton exchange membrane fuel cell (PEMFC) for the improvement of its efficiency. Short life span and low efficiency is a general issue of fuel cell systems. Therefore, designing and simulating a system capable of measuring crucial parameters of a PEMFC is essential for achieving an improved system performance. A polarization curve is utilised to evaluate the performance of a fuel cell, so this paper is focused on a variety of critical parameters and their output is traced specifically on a polarization curve. The system design was simulated in Matlab-Simulink and the data agreed well with the published data. The output of this study has the potential to contribute in renewable energy sectors, and industry.

Keywords: Efficiency, polarization curve, PEMFC, Matlab-Simulink

Solar dish and thermal energy storage for pre-heating in combustion processes

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Abstract

The global pursuit to integrate renewable energy systems with industrial and domestic applications to reduce reliance on fossil fuels renders concentrated solar power solutions attractive. A solar dish has been designed and constructed for integration with a small-scale air Brayton cycle (recuperated) at the University of Pretoria; however, the solar dish has not yet been experimentally investigated for other direct heating applications. The current solution (cogeneration and hybrid cycle) has been designed to produce electric power using liquid petroleum gas that compensates, via combustion, for the solar irradiation variabilities. The current work focuses on the experimental investigation of the system's solar receiver integrated with a thermal energy storage unit and its performance for air preheating in combustion applications (unrecuperated). This enables the full characterization of the system's thermal efficiency as a function of solar irradiation. The solar dish setup uses air as the heat transfer medium extracting solar heat from the receiver and transferring it to a small-scale thermal energy storage module using solar salts for latent heat storage. This ensures stable temperature throughput despite solar variabilities. This paper shows the results that were found after initial testing.

Keywords: Concentrated solar power, thermal efficiency, solar energy, thermal energy storage.

Thermal and stored heat energy for the generation of power

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Abstract

This research aim is to design, simulate and produce a prototype of a combined solar- thermal and sensible heat energy powered by a Stirling engine. The research philosophy is applied research and the empirical study conducted is experimental in nature. The output of the research prototype will be compared to a standard photovoltaic installation of a similar power output. Data collection methodology is quantitative in nature. The results for this paper will be generated from the simulation software package MATLAB, as the prototype is still under construction at this stage. The output expectation is that the compatibility of the prototype is at least equal if not higher than the standard photovoltaic construction. The advantage of the prototype result may include energy availability from the prototype during the evenings, when a standard photovoltaic system is incapable of producing energy.

Keywords: Stirling engine; Solar thermal energy; Thermal energy storage; Photovoltaic system

A CFD/DEM Approach to Determination of Tortuosity Through Packed Bed of Crushed Rock Particle

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Abstract

Packed beds of crushed rock particles are employed in solar thermal power plans as thermal energy storage systems. To model crushed rocks with irregular shapes is tedious; therefore, ellipsoids are used to approximate the shape of the crushed rocks. Discrete element modelling (DEM) is used to generate packed beds using the representative ellipsoids particles. The flow through the voids between the particles is simulated with computational fluid dynamics (CFD). However, the CFD simulations underestimate the flow resistance across a packed bed. The paper introduced tortuosity in an effort to reduce the deviation of pressure drop between real and simulated packed beds. The path lines data for flow velocity across the bed were extracted. The average length of the flow path lines divided by the bed length occupied by particles approximates tortuosity. The tortuosity predicted by the CFD model was validated with a diffusion experiment set up through a packed bed.

Keywords: Thermal Storage; Packed bed; Tortuosity; DEM/DEM.

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