Proceedings of the 15th International Green Energy Conference
IGEC2023-014
July 10-13, 2023, Glasgow, UK

THE STUDIES OF METAL DISSOLUTION IN POLYMER ELECTROLYTE MEMBRANE FUEL CELL

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ABSTRACT

This study aims to synthesize new Pd-based alloy catalysts with Iron and Cobalt and characterize their electrocatalytic properties and durability for Oxygen Reduction Reaction (ORR) in Proton exchange membrane fuel cells (PEMFC). The sodium Borohydride reduction method synthesizes a Pd-based alloy catalyst with metal loading 46wt% and atomic weight ratio Pd: M: Pt=1:1:1 (M is transitional metal). Firstly, the XC-72R Vulcan carbon black solution and the salt solution were prepared before being stirred in an ultrasonic bath for 30 min. Next, five wt% of 30µl sodium borohydride was added to the solution and stirred again for 15 minutes. The solution was kept overnight before being filtered, washed with deionized water, and dried in air. The heat treatment was done at a temperature of 500o C using a tubular oven under a flowing mixture of 10% H2 flow). The durability testing was conducted using cyclic voltammetry and a rotating disk electrode. The dynamic light scattering (DLS) technique was used to find the size of the nanoparticle catalyst in this experiment. From the result obtained, the value of the electrochemically active surface area (ECSA) of Platinum/C is higher than PdCoPt/C and PdFePt/C before and after degradation. However, the percentage loss of the PdCoPt/C is the lowest. Based on the result obtained from DSL, the size for Pt/C, PdFePt/C, and PdCoPt/C are 578.2nm, 2061nm, and 264nm, respectively. The value of the heterogeneous rate constant decreases for all three catalysts, showing that the reaction speed becomes slower after the degradation cycle. The value of the electron transfer number decreases for platinum/C and PdFePt/C catalysts. This means the reaction promotes the 2-electron pathway, removing the catalytic species for the direct 4-electron pathway. In conclusion, PdCoPt/C has better stability than Pt/C catalyst but has a lower ECSA value, while PdFePt/C is the least stable catalyst among the three and is likely to undergo dissolution.

Keywords: PEMFC, metal dissolution, Fuel Cell

Proceedings of the 15th International Green Energy Conference
IGEC2023-015
July 10-13, 2023, Glasgow, UK

DEVELOPMENT AND DEPLOYMENT OF SOLAR POWERED "NANOGRIDS" IN RURAL PHILIPPINES AND MADAGASCAR – IMPHORAA PROJECT

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ABSTRACT
The IMPHORAA consortium strives to equip rural communities with tools and knowledge for affordable, easy-to-install, and environmental-friendly solar energy solutions that are compatible with local households that require lighting, phone charging and multimedia as well as community needs such as water pumping and food conservation. Reducing battery storage needs is the key challenge to reach these economic, operational and environmental objectives. This will also guarantee the sustainability of solar energy access solutions. This paper investigates 3 ways to overcome this challenge : i) The clustering of neighboring electricity users to allow up to 6 of them to share the solar production and storage capacities of a same "solar nanogrid", ii) The use of phase-change material in refrigeration system powered by the solar nanogrid to store solar energy in thermal form and, iii) The pumping of underground well water in an aboveground tank powered by the solar nanogrid to store solar energy in potential form. This has been done thanks to the prototyping, lab testing and field deployment in Madagascar and the Philippines which utilizes smart energy management hardware communicating together, namely a smart nanogrid controller, a cool box controller and a pump controller as well as their command algorithm to optimize energy flows in real-time while ensuring a predefined level of service for the final users. The originality of this research work is to cover the technological as well as the economical and social acceptance aspects of the 3 investigated solutions in 2 different countries and allow to draw interesting conclusions on the performance of each to reduce electro-chemical storage needs and their market potential.

Acknowledgement: This project is supported by Energy Catalyst and UK aid and was awarded as a "subsidy" under the UK International Obligations for Subsidy Control and delivered under Grant 90935 from Innovate UK.

Keywords: Nano grids, Renewable energy, Solar energy, Sustainability

Proceedings of the 15th International Green Energy Conference
IGEC2023-016
July 10-13, 2023, Glasgow, UK

USING THE INTERNATIONAL GOVERNMENTAL PANEL ON CLMATE CHANGE (IPCC) INTERACTIVE ATLAS IN THE CLASSROOM

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ABSTRACT
The purpose of this paper is to demonstrate how a professor was able to use the Intergovernmental Panel on Climate Change (IPCC) Interactive Atlas to show the impacts of climate change around the globe. By using the Interactive Atlas and the submitted Nationally Determined Contributions (NDCs) of various countries, students learned how various geographical locations may be affected in the future and what those countries plan to implement to lower carbon emissions in the transportation, agricultural, and power industry sectors. Work done by students set the stage for renewable energy and power grid supply and demand topics throughout the remainder of the semester.

Keywords: Intergovernmental Panel on Climate Change, Nationally Determined Contributions, renewable energy, power industry, energy education

Proceedings of the 15th International Green Energy Conference
IGEC2023-017
July 10-13, 2023, Glasgow, UK

PHOTOVOLTAIC-THERMOELECTRIC GENERATION SYSTEM INTEGRATED WITH PHASE CHANGE MATERIALS: ROLE OF PCM ARRANGEMENT AND NUMERICAL INVESTIGATION

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ABSTRACT
This paper constructs the two-dimensional models of the PV-TEG-PCM system and the PV-PCM-TEG system respectively. Then, the performances of the hybrid system are assessed, and better arrangements of PCM in various solar irradiance are found. At last, considering typical weather in a year, a more comprehensive investigation of the optimum parameters of PCM is conducted, including melting temperature, thickness, and thermal conductivity. In conclusion, the present work will propose the optimum PCM arrangement and characteristics of the PV-TEG hybrid system corresponding to the various environmental conditions respectively. It will give guidance for designing a PV, TEG, and PCM hybrid power generation system in various solar irradiance.

Keywords: PV-TEG hybrid system, structure optimization

Proceedings of the 15th International Green Energy Conference
IGEC2023-019
July 10-13, 2023, Glasgow, UK

NUMERICAL STUDY OF A NATURAL CONVECTION COOLING LOOP SYSTEM FOR FLOATING PHOTOVOLTAIC PANELS

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ABSTRACT
Floating photovoltaic system is an innovative technology to overcome the need of a large open land area that utilises water surface as the solar panel location. Floating photovoltaic panels also have other advantages, such as being free from shading, controlling water losses and algae boom, minimising dust pollution, being easy to maintain, lowering temperature due to water evaporation, etc. In addition, the low operating temperature of solar cells will increase the system's electrical energy output and efficiency. This research will investigate the potential of a natural convection cooling loop to decrease the temperature of floating photovoltaic panels without external energy. The objective is to develop a numerical model for the entire system, which includes radiation absorption, natural convection, heat conduction and electrical power generation, to understand and optimise the thermal performance. This is achieved by first modelling a simplified natural convection cooling loop, using computational fluid dynamics, and then by gradually adding further modelling elements, to take into account the daily variation of heat input, thermal radiation exchanges, heat conduction, electrical generation, and heat losses. Preliminary results show that the natural convection cooling loop system effectively improves the cooling rate of floating photovoltaics. Simulations produced so far, provide important and new insights of how natural convection cooling can be introduced to floating PV cells and how it can be optimized.

Keywords: computational fluid dynamics, cooling loops, floating photovoltaic, natural convection, solar energy.

Proceedings of the 15th International Green Energy Conference
IGEC2023-021
July 10-13, 2023, Glasgow, UK

DESIGNING CLEANER ENERGY MIXES FOR DOMESTIC ELECTRICITY SUPPLY: A CASE STUDY IN JAKARTA AND WEST JAVA, INDONESIA

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ABSTRACT

Indonesia attempts to reduce the carbon emission from energy generation by reaching 23% and 31% of the national energy supply from renewable energy sources (RES) in 2025 and 2030, respectively. Indonesia has enormous potential for RES, but each area has a different potential for RES. Jakarta, the capital city of Indonesia, has much less potential (0.26 GW) than its neighbour, West Java (22.92), as a province next to Jakarta. Jakarta must import electricity from West Java if this province wants to consume electricity from renewable energy generation. Thus, achieving the objective is choosing cleaner energy mixes for electricity between an importer (Jakarta) and an exporter province (West Java). This research aims to investigate and explore the potential and the existing capacity of RES for electricity generation in both provinces. The results show that the current capacity of RES (3.10 GW in West Java and 0.03 GW in Jakarta) cannot meet 34.94 TWh of the annual domestic electricity demand in both provinces. However, the domestic electricity demand can eventually be covered by extending the current RES capacity by extracting from the RES potential in both provinces to become 6.51 GW. The renewable energy mixes in this research also can lower CO_2 emissions by 95.6% less than the gas-fired power plants. This research eventually provides insights into choosing and using the available RES potentials between two areas with contrasting RES capacities.

Keywords: Energy mix, renewable energy sources, domestic electricity.

Proceedings of the 15th International Green Energy Conference
IGEC2023-022
July 10-13, 2023, Glasgow, UK

EFFECTS OF VISUALIZING ENERGY CONSUMPTION ON OCCUPANTS' ENERGY SAVINGS AND INDOOR AIR QUALITY USING AUGMENTED REALITY

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ABSTRACT

Severe climate changes are observed recently and urgency to energy issues is constantly increasing. Even though an extensive body of research is improving energy efficiency in buildings and investigating methods to save energy consumption, final energy consumption greatly depends on occupants' behavior in the end. Among the factors that affect occupants' behavior such as education and energy policies, a technology that enables occupants to perceive the energy consumption can be one of the strongest methods to induce immediate behavior changes. Therefore, this study investigates effects of visualizing energy consumption on occupants' behaviors that result in energy consumption changes using augmented reality. In a climate chamber, 20 subjects are given a heating and cooling system, a humidifier and an air purifier which can be freely used to adjust environmental quality suitable for them. Then, they are provided with augmented reality that shows them immediate energy consumption of each equipment. Occupants' behavior on each equipment, environmental quality and energy consumption are measured in situations with and without augmented reality visualizing immediate energy consumption. Statistical analysis was conducted to explore the effects of visualization technology on energy savings and indoor quality. Results show that augmented reality that visualizes energy consumption of electric equipment affect occupants' behavior greatly and this leads to considerable energy savings.

Keywords: energy consumption, augmented reality, visualization, energy saving, sustainability

Acknowledgements
This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MIST; Ministry of Science and ICT) (NRF-2021R1A3B1076769).

and

This study is a basic research conducted in 2023 with the support of the National Research Foundation with the funding of the government (Ministry of Education)(2021R1A2C2013841).

Proceedings of the 15th International Green Energy Conference
IGEC2023-024
July 10-13, 2023, Glasgow, UK

MODELLING OF NEAR-ISOTHERMAL LIQUID PISTON GAS COMPRESSOR EMPLOYING POROUS MEDIA FOR COMPRESSED AIR ENERGY STORAGE SYSTEMS

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ABSTRACT
This study presents high-fidelity three-dimensional CFD (Computational Fluid Dynamics) simulations whose aim is to improve the understanding of the heat transfer and fluid flow involved in the gas compression process using a liquid piston. It also examines how various inserts perform against the baseline (empty cylinder) case. The heat exchangers in question are parallel plates and interrupted plates, all produced from aluminium. Simulations are performed for different geometrical properties of the porous medium including length and porosity. While studies on various heat exchangers have been performed before, these are usually conducted using two-dimensional simulations or using REV (Representative Element Volume) methods, whereas this paper will simulate the full cylinder/heat exchanger arrangement to investigate the physics and fluid-structure interaction, which will provide a greater understanding of this process. Results show a reduction in temperature from baseline case to parallel and interrupted plate cases by as much as 130K. This demonstrates the impact of using of these plates in achieving a near-isothermal compression process.

Keywords: Computational Fluid Dynamics (CFD), Compressed Air Energy Storage (CAES), Liquid Piston Gas Compressor/Expander (LPGC/E)

Proceedings of the 15th International Green Energy Conference
IGEC2023-025
July 10-13, 2023, Glasgow, UK

COMPARISON ANALYSIS OF COOLING SYSTEMS (EHP & FABRIC DUCT) BASED ON THERMAL COMFORT & CO_2 CONCENTRATION FOR STAIR-TYPE LECTURE ROOM USING CFD ANALYSIS

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ABSTRACT

As people spend most of their time indoors, it is important to ensure indoor thermal comfort and uniformity as it greatly contributes to human well-being. Thermal comfort is especially crucial in educational buildings as it affects the performance and productivity of teachers and students. By CFD (Computational Fluid Dynamics), this study examines the impact of two cooling systems, EHP (Electric heat pump) and FD (Fabric duct) on thermal comfort (PMV (Predicted mean vote)) and CO2 distribution in a stair-type lecture room. The findings suggest that among two cooling systems, FD is more favorable for occupant's comfort control and creating healthy educational environment. But further research is needed to effectively control the high indoor CO2 concentrations through proper ventilation systems. The results of the study will help to create a thermally prepared study environment and prevent occupant discomfort and facilitate learning.

Keywords: CFD (Computational Fluid Dynamics), PMV (Predicted mean vote), CO2, EHP (Electric heat pump), Fabric Duct

Proceedings of the 15th International Green Energy Conference
IGEC2023-028
July 10-13, 2023, Glasgow, UK

A TECHNICAL REVIEW ON THE IMPLEMENTATION OF LITHIUM-ION BATTERIES WASTE RECYCLING METHODS

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ABSTRACT

The widespread use of lithium-ion batteries (LIBs) in portable electronics such as smartphones and laptops highlight the significant need for long-lasting battery availability. The rise of electric vehicles (EVs) has further increased LIBs demand, leading to concerns about the depletion of lithium sources from the earth. Mining methods such as pyrometallurgy, hydrometallurgy, and direct methods have been introduced to extract lithium. However, these methods most often result in environmental pollution. Therefore, it is imperative for a ‘greener’ or environmentally friendly method to be established. The introduction of an electrochemical method to recycle LIBs in 2016 is a big step towards fulfilling this goal. This technical paper comprehensively examines the various techniques for recycling lithium from spent LiBs. The focus is on evaluating and discussing the extent of usage, technological readiness, efficiency, and environmental aspects of the methods. Also, the techno economy aspect of generic LIBs recycling methods has been reviewed and included.

Keywords: LIBs recycling, technical, electrochemical, pyrometallurgy, hydrometallurgy, direct recycling

Proceedings of the 15th International Green Energy Conference
IGEC2023-030
July 10-13, 2023, Glasgow, UK

COMPARISON OF DIFFERENT CONFIGURATIONS OF CO2 REFRIGERATION SYSTEMS

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ABSTRACT

CO2 refrigeration systems are emerging as feasible alternatives for developing eco-friendly refrigeration systems with the objective of addressing the pressing issues of ozone layer depletion and global warming. The primary aim of this study is to conduct a comprehensive analysis of different transcritical CO2 refrigeration systems to identify the most efficient configurations based on energy performance. A conventional system (consisting of an evaporator, compressor, gas cooler, and expansion valve) is used as the reference system and compared to other systems, such as a system with a work recovery turbine, two-stage compression, two-stage compression with fully subcooling (F-SC), two-stage compression with partial subcooling (P-SC), a system with mechanical subcooling (M-SC), ejector, vortex tube, and internal heat exchanger (IHX). The examined systems are evaluated based on their performance in various operational scenarios (with TE ranging from -35 to +5 °C and TGC ranging from 40 to 50 °C), using a developed model in MATLAB. The study shows that all examined configurations perform more efficiently than the reference system in all operating scenarios. The COP enhancement is found to be more efficient in scenarios with higher heat rejection temperatures and lower evaporator temperature levels. The study finds that the highest improvement in transcritical CO2 system efficiency can be achieved by replacing the conventional expansion valve with a work recovery turbine, followed by two-stage compression with partial subcooling. The maximum enhancement of these systems is found at T_gc=50°C and Te= -35 °C with 75.89% and 41.5%, respectively.

Keywords: Transcritical CO2 cycle, Turbine, Multi-staging, Ejector, vortex tube, Mechanical subcooling, COP improvement

Proceedings of the 15th International Green Energy Conference
IGEC2023-031
July 10-13, 2023, Glasgow, UK

DESIGN OF THERMAL STORAGE SYSTEMS USING NEURAL NETWORKS AND ARTIFICIAL INTELLIGENCE

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ABSTRACT

In the field of renewable energy use, thermal energy storage (TES) tanks have become an optimal alternative, to such an extent that the design and production of such systems are currently being optimised to expand their daily use. However, the process of developing such optimal and efficient TES tanks is time-consuming and resource-intensive due to the many variables involved. Whether it is physical, shape or material variables, changing just one of these values requires a whole new development process. One way to streamline the design process lies in the simulation phase. This phase currently uses computational fluid dynamics (CFD) software to validate the theoretical analyses and calculations. The utilization of computational resources in the simulation phase when using CFD software, can prove to be a significant expense in terms of both time and computational resources (financial costs). This is due to the prolonged duration of the simulations and the frequent need to modify parameters and repeat the simulation process in order to verify the validity of the results. The objective of this research is to reduce the cost in time and computational resources through the use of artificial intelligence (AI) in interpreting the behaviour of TES tanks. Specifically, we aim to use AI to analyse the thermal behaviour of materials and fluid dynamics inside the tank; with the goal to achieve faster and equally accurate results as those obtained with CFD simulations using dedicated computer programs.

The final objective of this study is to evaluate the effectiveness of the results obtained with the artificial intelligence developed in this research. This is done by comparing data obtained from different scenarios of a specific type of TES tank simulated with the CFD simulation program COMSOL® and the results obtained from the neural network. It is expected that a similarity and comparison between the two methods will be obtained with optimal values that will allow the use of the developed neural network for the acceleration of the design process of more complex TES tanks, resource consumption reduction, and optimization of the time required for this purpose.

Keywords: thermal energy storage, CFD Simulation, Artificial intelligence, neuronal networks

Proceedings of the 15th International Green Energy Conference
IGEC2023-032
July 10-13, 2023, Glasgow, UK

A COMPARISON OF PERFORMANCE OF A LATENT THERMAL ENERGY STORAGE UNIT USING THREE PCM MACRO-ENCAPSULATIONS

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ABSTRACT

The use of thermal energy storage (TES) was proven as an effective way to enhance the penetration of renewable energy sources into energy systems. For latent TES, phase change materials (PCM) are used as storage medium at near constant temperature to exploit the latent energy during phase transition. PCM materials has low thermal conductivity which can be tackled by using fins, micro or macro-encapsulations. Macro-encapsulation is preferred because its manufacturing is easier than micro-encapsulation. The design of storage encapsulation is important as it impacts the heat transfer rate and charging/discharging time. Current literature lacks experimental data on thermal performance of macro-encapsulations' containing PCM. This study, for the first time, shows a comparison of three macro-encapsulations' designs, based on experiments, namely TubeICE, ThinICE, and FlatICE which differ in shapes and thickness to understand the thermal behavior of a TES tank. Thermal behavior is studied in terms of critical parameters including heat transfer rate, charging and discharging times. The results obtained will help institutions and manufacturers to evaluate the suitable configuration of storage medium when TES tank has a fixed volume.
PlusICE S17 (salt hydrate), a commercial product of PCM products, is used for this scientific study. The storage tank consists of same amount of PCM inside the tank in all three encapsulations' configuration, thanks to the spacers inserted between encapsulation. The temperature range set for experiments is 7-27 ºC which is ±10 ºC from the melting point of used PCM i.e. 17 ºC. A mass flow rate of 4 litres per minute is kept fixed during all experiments. During the charging experiments, water is circulated in the tank at 27 ºC and PCM is charged from 7 ºC to 27 ºC. For the discharging experiments, water is circulated at 7 ºC and PCM is cooled down from 27 ºC to 7 ºC. Results are obtained and discussed to compare the performance of three macro-encapsulation design.

Keywords: Latent thermal energy storage, macro-encapsulation, phase change materials, experimental study

Proceedings of the 15th International Green Energy Conference
IGEC2023-033
July 10-13, 2023, Glasgow, UK

INVESTIGATION OF NANOPARTICLE EFFECT IN PHASE CHANGE MATERIAL BALLS FOR SOLAR ENERGY CONVERSION AND STORAGE SYSTEMS

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ABSTRACT

Increasing use of renewable energy contributes to sustainable energy production by reducing the negative effects of greenhouse gases and carbon emissions. Due to the ease of use and ubiquity of solar energy, it is attractive amongst renewable sources of energy. The biggest problem of solar energy technologies, however, is not being able to benefit from sunlight for 24 hours. Nonetheless, this problem can be eliminated thanks to the storage of solar thermal energy. The utilization of phase change material-based heat transfer fluid is directly heated by the solar radiation in this study. The phase change material is encapsulated by the different types of nanoparticles and dispersed in pure water. The Discrete Ordinate Method is applied as a radiation model in order to analyse the impacts of the absorption, scattering, and emitting factors. The results reveal that the capacity of the heat transfer fluid to capture solar energy enhances with the addition of encapsulated phase change material to the water. Therefore, the temperature gain and stored energy of the phase change slurry increases more than the pure water. The energy storage is also augmented by improving the mass concentration of the phase change material. However, the size of the core/shell capsules augments with increasing shell thickness, affecting the thermal barrier between them and the heat transfer fluid. This reduces the heat that the PCM can absorb and lowers the temperature of the system. As a result, this work clearly states that because the phase change material based latent functional heat transfer fluid is used as a storage medium and as a working fluid, the thermal performance of the solar collector is further enhanced.

Keywords: Phase change material, nanoparticle, solar energy conversion and storage, heat transfer enhancement, conjugate heat transfer.

Proceedings of the 15th International Green Energy Conference
IGEC2023-034
July 10-13, 2023, Glasgow, UK

COMPUTATIONAL ANALYSIS OF THE INFLUENCE OF BIO BASED PHASE CHANGE MATERIAL SLURRY ON THE THERMAL PERFORMANCE IN A VOLUMETRICALLY HEATED SOLAR SYSTEM

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ABSTRACT
Sustainable energy production from renewable energy sources contributes to net zero carbon strategies. Solar energy, which is a pervasive and an inexhaustible resource, is one of the most important helpers for this strategy. However, the most important disadvantage is that the solar energy cannot be used continuously. To avoid this problem, the solar energy can be stored as thermal energy and used both day and night. For this, the photothermal conversion performance of the phase change material based volumetrically heated solar collector is investigated in this study. The coconut-oil based nano capsules are dispersed into the pure water. The nano-encapsulated coconut oil-based slurry is the novelty of this work, and it is the first example of the investigation of this material under the flow conditions in volumetrically heated solar collectors using a new type of working fluid. It is found that the optical properties of nano capsules are higher than that of pure water due to the surface plasmon resonance effect. This enhancement in optical properties enabled the slurry to augment the temperature gain more than pure water. Combined radiative and convective heat transfer is also obtained to augment the heat gain of the slurry entering the collector. However, the enhancement in the diameter of the core increases the volume of the nano-encapsulated coconut oil and causes a decrease in the surface area. Therefore, the diminish in the surface area leads to the particles to combine and creates large particles, resulting in a decrease in the heat transfer between them and the base fluid. Moreover, it is observed that increasing the mass concentration of the phase change material from 5 to 20% enhances the top wall temperature of the collector. This causes the collector performance to diminish with improving mass concentration. Finally, the extinction capacity of the nano-encapsulated coconut oil-based slurry is higher than the host fluid, and also the enhancement of the thermal performance of the volumetrically heated collector is higher. Hence, this study demonstrates that nano-encapsulated coconut oil-based slurry can be used in solar energy applications. Moreover, it is noticed that the sensible heat storage capacity in the collector will also improves due to the enhanced solar radiation capture.

Keywords: Nanoencapsulation, bio-based phase change materials, volumetrically heated solar collector, heat transfer enhancement, thermal energy conversion, solar energy.

Proceedings of the 15th International Green Energy Conference
IGEC2023-035
July 10-13, 2023, Glasgow, UK

DESIGN ANALYSIS OF A NEW SUSPENDED RADIANT CEILING PANEL WITH SEGMENTED AND CONCAVE SURFACE

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ABSTRACT
In this study, the parametric analysis was conducted on different designs of a new suspended radiant ceiling panel (RCP) with segmented and concave surface to improve its cooling performance. A three-dimensional CFD simulation model was developed to investigate the cooling capacity and heat transfer coefficient of the RCPs. Six parameters were used to be the design parameters. The results show that the cooling capacity and heat transfer coefficient increase with increasing curvature radius and coverage area and decreasing the panel length. The distance between adjacent panels or panel segments and the panel to the wall is most significant in enhancing cooling capacity.

Keywords: radiant ceiling panel, CFD simulation, parametric analysis.

Proceedings of the 15th International Green Energy Conference
IGEC2023-036
July 10-13, 2023, Glasgow, UK

GAS-SOLID FLOW SIMULATION DURING THERMAL RUNAWAY OF LITHIUM BATTERIES

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ABSTRACT

Based on the problem of solid particles neglect in the simulation of lithium-ion battery (LIB) thermal runaway (TR), this paper proposes a coupled simulation model which includes the processes of TR decomposition reactions, gas generation, ejection and heat transfer of solid particles, combustion. The model is validated with OpenFOAM software. The model can accurately capture the temperature change of LIB TR, the two jet processes as well as the motion and heat exchange of the solid particles. The results show that the maximum temperature of the jet flame is reduced by 7% after coupling the solid particles, and the instantaneous radiation heat transfer rate of the battery is significantly increased (135W) compared to the model uncoupled solid particles (133.5W).

Keywords: lithium batteries, thermal runaway, solid particles, jet flow.

Proceedings of the 15th International Green Energy Conference
IGEC2023-037
July 10-13, 2023, Glasgow, UK

A REVIEW ON THE LIFE CYCLE ASSESSMENT OF PCM-BASED THERMAL ENERGY STORAGE SYSTEMS IN RESIDENTIAL APPLICATIONS

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ABSTRACT

The adoption of Thermal Energy Storage (TES) systems in residential applications can play a key role in demand-side management to cope with power production intermittency, caused by the increasing penetration of the renewable technologies with intermittent power production pattern. In the last decades, numerous studies have been carried out to design and develop efficient TES systems, many of which suggest the use of Latent Heat Thermal Energy Storage (LHTES) systems with Phase Change Materials (PCM) as an attractive option. Studies considering LHTES systems are usually followed by positive results in terms of energy efficiency and savings; however, Life Cycle Assessment (LCA) results of such systems are not always positive and are often mixed. Such mixed results could cast doubts on the attractiveness of LHTES systems in residential applications in an environmental point of view.
This paper investigates, through a systematic literature review, whether the existing evidence suggests that the use of LHTES systems and PCMs in residential sector is viable and environmentally advantageous, considering all life cycle phases of the systems i.e., manufacturing, operation, and disposal. By doing so, the paper assesses what are the key factors and conditions determining positive environmental impacts of PCM-based systems. A number of cradle-to-grave LCA studies are reviewed, and the three ReCiPe damage categories (Human health, Ecosystems, Resource Availability) are monitored for the manufacturing phase, operation phase, and disposal phase of various systems. It has been noticed that the benefits of PCM utilization occur in the operation phase, due to the decrease in energy consumption, while the manufacturing and disposal phase of PCM-based systems are naturally associated with more environmental damages with respect to reference cases. Thus, the operation phase is believed to play a key role in the life cycle impact analysis of residential TES systems, and failing to devise an effective operational scenario will result in limited energy savings, and therefore, very low or no reduction of environmental impacts. Hence, the LCA results of PCM-based TES systems can sometimes be misleading and make the use of PCMs in residential systems look unfavourable. The findings of this paper, however, tries to change that perception by highlighting the importance of energy savings caused by PCMs, and how these energy savings influence the final environmental impact evaluation of PCM-based TES systems. It is demonstrated that choosing a proper operational scenario for such TES systems will decrease the system total environmental impacts by up to 30%, while inefficient scenarios could result in the same or even higher impacts.

Keywords: Phase Change Material (PCM), Latent Heat Thermal Energy Storage (LHTES), Life Cycle Assessment, Environmental impact categories, Operational scenario, ReCiPe

Proceedings of the 15th International Green Energy Conference
IGEC2023-039
July 10-13, 2023, Glasgow, UK

The performance of a heat pump assisted integrated cooling and dehumidification system for zero emission vehicles

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Abstract

An integrated cooling system by integrating the fuel cell, battery, metal-hydride, heat pump, and liquid desiccant dehumidification and regeneration system was developed for future electric vehicles to reduce power consumption and extend the driving range in summer. The energy waste of the hydrogen between the hydrogen vessel and fuel cell stack due to the pressure drop was utilized by an open metal-hydride system to produce a cooling load for cooling the liquid desiccant to the set point. A liquid desiccant hollow fibre dehumidifier and regenerator were adopted for air cooling and dehumidification and regeneration which can omit the deep cooling procedure in traditional air conditioning when the ambient air has high relative humidity. A heat pump was introduced to recover the waste heat from the battery pack and fuel cell to provide the required heat to the liquid desiccant flowing to the regenerator for regeneration and also work as a supplement when the cooling capacity provided by the open metal-hydride system is not enough. A numerical model for the proposed system and a finite element model for the dehumidifier and regenerator were developed and validated by published experiment results. A comprehensive evaluation of the impacts of the ambient air temperature and humidity, fuel cell current output, battery discharging C rate, and air mass flow rate on the Coefficient of Performance (COP), outlet air temperature, and Equivalent Effective Battery Capacity (EEBC) were conducted. Additionally, in this study, a detailed comparison of the proposed system to other published cooling systems and dehumidification systems was introduced regarding COP, EEBC, and cooling capacity. Results showed that the proposed system can provide non-compressed cooling capacity when the ratio of the feeding cabin air and liquid desiccant mass flow rate is lower than 3 when the temperature of the dehumidifier inlet liquid desiccant was set as 23oC. When the heat pump is needed for recovering more waste heat from the fuel cell and battery system and further cooling liquid desiccant, it can always operate with a COP of over 5 which is higher than the cited published results. Compared to other studies, the EEBC of the proposed system improved by 62% with the help of the fuel cell power output and reduced cooling power consumption. Overall, this study provides a potential solution for future zero-emission vehicles by utilizing the heat and electric co-generation characteristic of the fuel cell, the isothermal characteristic of the metal hydride, and dehumidification and cooling characteristics of the liquid desiccant dehumidification system to extend the driving range of the electric vehicles and reduce energy consumption for cooling.

Keywords: Fuel cell, heat pump, electric vehicle, cooling, metal hydride

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Proceedings of the 15th International Green Energy Conference
IGEC2023-040
July 10-13, 2023, Glasgow, UK

ECONOMIC, ENVIRONMENTAL AND HUMAN HEALTH IMPACT ASSESSMENT ACCORDING TO STRUCTURE TYPE OF APARTMENT

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ABSTRACT

Since the Paris Agreement on Climate Change, the world has been making various efforts to reduce greenhouse gas emissions. The Korean government established its national greenhouse gas reduction target in 2030 and announced a plan to achieve carbon neutrality in 2050. Accordingly, compared to greenhouse gas emissions in 2018, figures of 32.8% and 88.1% should be reduced in 2030 and 2050 in the construction sector respectively. According to the Ministry of Land, Infrastructure, and Transport, apartments account for 62% of all residential buildings, so it is essential to reduce the environmental load caused by apartment construction. In particular, the structure type of apartment is generally determined by economic factors, and environmental and human health impacts are not considered. Therefore, the objective of this study is to conduct an economic, environmental, and human health impact assessment according to the structure type of apartment. The method consists of three steps: (i) data collection; (ii) economic impact assessment; and (iii) environmental and human health impact assessment. First, data on cost and quantities of material for the flat-type apartment and tower-type apartment were collected from the ‘K’ construction company in South Korea. Second, the economic impact assessment was conducted based on a life cycle cost analysis. Third, this study considers six environmental impact categories (i.e., global warming potential, ozone-layer depletion potential, acidification potential, eutrophication potential, photochemical ozone creation potential, and abiotic depletion potential) and two human health impact categories (i.e., human carcinogenic potential and human non-carcinogenic potential) based on a life cycle assessment, which is a representative method defined in ISO-14040. These impacts are independent of each other. The result of this study allows an owner or facility manager to easily evaluate the economic, environmental, and human health impacts according to the structure of the apartment.

Keywords: Life cycle assessment, Environmental impact, Human health impact, Apartment.

ACKNOWLEDGEMENT

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MIST; Ministry of Science and ICT) (NRF- 2021R1F1A1049692 & NRF-2020R1A2C1010421).

Proceedings of the 15th International Green Energy Conference
IGEC2023-041
July 10-13, 2023, Glasgow, UK

THE INFLUENCE OF THERMAL ENERGY STORAGE ON THE PERFORMANCE OF A CONCENTRATED SOLAR POWER PLANT

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ABSTRACT

Power quality is one of the most important aspects of any power plant. The intermittent nature of renewable energy sources can create a mismatch between supply and demand posing a challenge in providing reliable, resilient, and an efficient power supply. Energy storage is a promising solution for this challenge. This study aims to investigate the benefits of Thermal Energy Storage (TES) on a 50 MW Concentrated Solar Power (CSP) in Kuwait's Shagaya Renewable Energy Park (SREP). The year 2020 was chosen for the relatively high level of Direct Normal Irradiance (DNI) and the contribution of TES in maintaining the high production rate and the overall energy yield from the CSP plant over the course of the year. It was found that TES enabled the CSP plant to increase energy generation by 32% with a total of 165.23 GWh energy generated in 2020. Furthermore, a comparative seasonal analysis is done for the months August and January 2020 that differ greatly in the amount of solar radiation received, DNI availability. The results revealed that in August a total of 25.12 GWh was generated, where 10.83 GWh of which are from the TES. Conversely, a total of 9.51 GWh produced in January, with 2.54 GWh of which are from the TES. Moreover, the plant's performance under three consecutive days of sandstorms in 2020 is investigated considering the influence of TES in unstable weather conditions. The results showed that, during very high wind speeds and fluctuations in DNI, stored energy in TES contributed to around 41% of the total energy. This provides compensation for energy losses during reduced solar irradiance. Overall, it can be said that TES enables CSP systems to be more flexible playing a critical role in maintaining the power load, allowing dispatchability during adverse weather conditions. The outcomes of this study allow conclusions to be reached regarding the implications of CSP plants integrated with TES. The inclusion of which improved power quality for future solar thermal power plants in Kuwait.

Keywords: Thermal Energy Storage, Concentrated Solar Power Plant, Shagaya Kuwait.

Proceedings of the 15th International Green Energy Conference
IGEC2023-043
July 10-13, 2023, Glasgow, UK

A MALAYSIAN PERSPECTIVE ON LITHIUM-ION BATTERIES RECYCLING

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ABSTRACT
Lithium-ion batteries (LiBs) have been widely used in various applications including portable devices, electric vehicles, and large-scale energy storage systems. Compared to other battery types, LiBs have a high power density, relatively higher cycle life, long run time, good discharge or charge cycles, and low cost. The use of LIBs aligns with a global-wide strategy in pursuing sustainable development and a circular economy as it helps decarbonize the transportation and power sectors. As such, Li supply has a heavy burden, and the demand will consistently hike soon. Therefore, re-circulating spent LiBs from industries or consumers' waste is a promising strategy. To secure a closed loop of Li, consumers need to embrace positive environmental stewardship by returning used e-waste to the recycling entry points. Then, the non-renewable resources would be passed over to several stakeholders and go through a sequence of recycling processes before re-entering the usage loop. This paper provides an early analysis of e-waste resource flows in Malaysia. Through document analysis of data from sixty-three e-waste recycling stakeholders' websites, the study has categorised the phases of e-waste flows, based on the recycling processes. According to the data, a noteworthy proportion of recycling stakeholders are involved in the preliminary phase of the 'resource entry point', whereas a comparatively small fraction of them engage in the subsequent phase of 'resource segregation'. Conversely, a meager number of recyclers are involved in 'resource extraction', particularly concerning the 'retrieve' activities. In a semi-structured interview, a leading recycler stated that they only utilize the cementing process for proper e-waste disposal, rather than resource extraction. E-waste management in Malaysia currently lacks closed-loop systems, leading to potential points of leakage in the process. The recycling of LiBs is particularly very limited, with few identified stakeholders in the country. To establish effective e-waste circular flows, strategic efforts are needed, including research and design of recycling interventions, infrastructure, and legislation. Such efforts would optimize e-waste circularity, particularly the extraction of valuable resources such as Li.

Keywords: LiBs Recycling, Circular Economy, E-waste Recycling

Proceedings of the 15th International Green Energy Conference
IGEC2023-046
July 10-13, 2023, Glasgow, UK

STUDY OF THE DEFROSTING OPERATION OF A FLEXIBLE HEAT PUMP CYCLE WITH A SENSIBLE HEAT STORAGE

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ABSTRACT

Heat pumps are an important tool in the effort to reduce carbon emissions in the heating industry, but there are still challenges that need to be addressed to increase their adoption. Frosting in air source heat pumps is an example. It leads to a decline in efficiency and disruptions in heating service. The author’s group recently developed a new heat pump design that incorporates heat storage into the traditional Evans-Perkins cycle to recover some of the sensible heat that is present in the hot liquid refrigerant leaving the condenser. This stored heat can then be used as a supplementary heat source for the heat pump's operation. One particularly useful application for this is for defrosting the evaporator. It is done by using the subcooled heat of the refrigerant to melt the frost in the evaporator. This can ensure continuous heating during defrosting, and at the same time, improve the efficiency of the heat pump. In this study, we present a theoretical analysis of the defrosting mode of the flexible heat pump using a sensible heat storage in the cycle. For a heat pump with a heating capacity of 3.6kW and for a condensing temperature of 35℃, when defrosting mode is operated, it can still theoretically save up to 5.5% in compressor power consumption with R410A, and 5.3% with propane compared to a heat pump using a classic reverse cycle defrosting.

Keywords: Heat pump, flexible heat pump, heat storage, defrosting, energy saving

Proceedings of the 15th International Green Energy Conference
IGEC2023-047
July 10-13, 2023, Glasgow, UK

UNRAVELING INDIA'S SOLAR POWER SUCCESS IN THE LAST DECADE AND ITS IMPLICATIONS FOR THE NEXT DECADE

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ABSTRACT

In 2021, solar power generation, globally provided more than 1000TWh or 3.6% of total electricity generation. This was possible due to solarization efforts undertaken by many countries including India. In this study, we examine how solar is fulfilling India's quest for additional energy source and expanding the nation's renewable energy portfolio to meet the climate commitments. We use mixed method approach involving qualitative and quantitative techniques such as content analysis, statistical analysis and scenario development. Our findings from content analysis of government records over last twelve years suggest that India started its solar journey considering solar as an additional source of energy that could meet the need of heat and lighting in remote parts of the country. It was only after 2010 with the launch of National Solar Mission (NSM) efforts started to mainstream solar energy, and grid solar was promoted. A combination of domestic policy and international developments helped India reach a solar capacity of 62 GW in 2022 from few MWs in 2010. Within the domestic policy, incentive schemes on the generation side, information campaigns on the generation and consumption side and regulation on the consumption side have played a big role. Currently, solar photovoltaics (PV) is driving India's growth in solar energy but there are challenges emerging which if not addressed timely can delay the future growth of solar energy. First, there is lack of domestic manufacturing capacity making the supply chain highly dependent on China. India cannot grow sustainably by substituting import dependence of coal with import dependence of solar cells and modules. For this, there is now a growing focus on creating manufacturing capacity by mandating the domestic content and high excise and custom duty on import of solar PV and solar modules, but this will slow down the near-term deployment although may prevent India's import dependence on China and pricing controls in the medium to long term. Second, a whole-of-government approach will be needed to drive the solar energy value chain. The current top-down-target based approach may not work amidst growing concerns around land acquisition and slow rooftop deployment. Organizations at the centre and state level will need to coordinate with the private sector for the next stage of growth to address the local challenges. Finally, incentives to increase demand for solar energy should cover an all-sectors-in approach. Currently, there is a push to increase solar deployment through net metering and subsidy to the residential, institutional, and social sectors while the largest consumer of electricity in India, the industrial sector has been kept out of this incentive scheme so as not to hurt the state utilities and distribution companies' revenues.

Keywords: solar energy journey, India, solar deployment, solar energy policy

Proceedings of the 15th International Green Energy Conference
IGEC2023-048
July 10-13, 2023, Glasgow, UK

OPTIMAL OPERATION OF SOPT OPEN POINT INTEGRATED WITH ENERGY STORAGE IN ACTIVE DISTRBUTION NETWORKS

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ABSTRACT- The integration of renewable energy sources into electric power distribution networks has presented a challenge for distribution network operators (DNOs). In response, DNOs are adapting from a passive to an active system management approach, to transform the network into, known as, an Active Distribution Network (ADN). Traditional distribution networks are designed with the assumption of uni-directional power flows, but ADNs have become more dynamic with bidirectional power flows as increasing distributed energy resources (DERs) are connected. As a result, power flows and voltage levels are affected not only by changes in demand, but also by the level of distributed generation (DG) penetration.

One effective solution to these challenges is to utilize an optimally combined solution with both soft open points (SOPs) and energy storage systems (ESSs). SOPs utilize an AC-DC-AC operational mode as it relies on back-to-back voltage source converters, which enables them to work alongside ESSs. Energy storage devices such as batteries can be innovatively integrated into ADNs by connecting them to various locations.

In this work, a new soft open point integrated with energy storage (SOP-ES, i.e., ESS connected to the DC link of SOPs) has been proposed to provide flexibility in ADNs in both space and time domains. The active and reactive power balance equations of SOP-ES were derived firstly. Then, an optimization model for ADNs with SOP-ES for multi-objective mixed integer nonlinear programming (MINP) was created. To make the solving process efficient, symmetrical semidefinite programming (SDP) relaxation was used to convert the MINP problem into an SDP model. The proposed model was tested and verified through case studies based on the IEEE 13-node distribution system. The results of numerical tests showed that the proposed model can achieve significant additional gains in terms of reducing network losses and voltage imbalance mitigation, as well as reducing voltage limit violations.

Keywords: Active distribution network (ADN), Soft open point (SOP), Energy storage system (ESS), Semidefinite programming (SDP).

Proceedings of the 15th International Green Energy Conference
IGEC2023-051
July 10-13, 2023, Glasgow, UK

ESTABLISHING PEM FUEL CELL SIMULATION PLATFORM FOR STRUCTURE DESIGN: FROM CELL TO STACK

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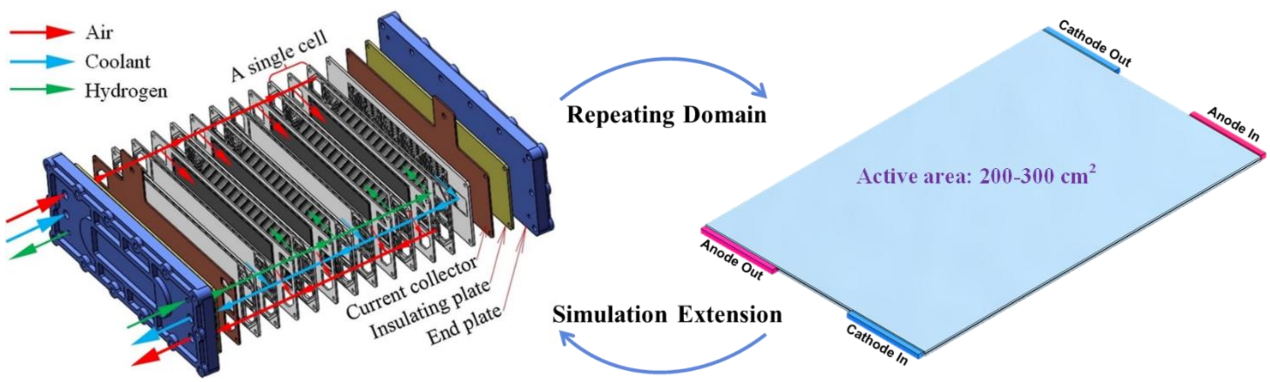
ABSTRACT
In recent years, great progress has taken place in PEM fuel cell technology development. The power density of cell stack without endplate has attained ~5 kW L-1 according to public records, which is compatible with other power devices like internal combustion engine. Nevertheless, obstacles on system cost and cell durability still block the way of large-scale commercialization. Except for developing new material, it is necessary to searching for improvement from the perspective of structure design. Modeling and simulation help shed light on unmeasurable transport phenomena in PEM fuel cell and provide valuable instructions. Three-dimensional (3D) model has advantage on reproducing cell geometry and giving a holistic view of cell operating state. Due to the limitation of calculation capability and stability, it is hard for 3D model to simulate a commercial-level single cell, let alone cell stack, which has gradually become a burgeoning need of the industry. This study first established a “3D+1D” PEM fuel cell model with decent trade-off between efficiency and fidelity. Then, a method was introduced to extend the simulation analysis of single cell to cell stack. The simulated stack was divided into two parts: one part contains several “real” cells which represented different locations from the stack and other cells were simplified. The influence of flow field structure and manifold design on cell performance and distribution of gas, liquid, heat and electricity were studied on the level of short stack. The “3D+1D” model has been comprehensively validated with experimental data regarding cell performance, ohmic resistance, current density distribution and temperature distribution under different operating conditions. It is expected to fulfil the engineering requirement on large-scale simulation as a powerful and efficient tool.

Keywords: PEM fuel cell, modeling and simulation, structure design.



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Proceedings of the 15th International Green Energy Conference
IGEC2023-052
July 10-13, 2023, Glasgow, UK

Energy Savings Owing to Insulation: Mid-Rise Commercial Buildings

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Abstract
Buildings are a significant global energy consumption and greenhouse gas producer. Buildings that use less energy and emit fewer greenhouse gases improve the air quality by reducing global warming. Only through switching from conventional to sustainable design, it can be possible. Sustainable design has been used for decades in the building industries of many countries, yet the least developed and poorest nations have lagged. Since 2001, Kabul, the capital of Afghanistan, one of the least developed countries, has seen a significant increase in population and construction. Uncontrolled building construction and rapid growth created issues from a variety of perspectives, particularly in terms of sustainability and air quality.
Given that the building industry accounts for roughly 40% of worldwide energy consumption and is the greatest producer of greenhouse gas emissions, it is well known that it has a substantial negative influence on the environment too. There are different ways to reduce the environmental burdens created by buildings. This study focuses on Insulating the buildings, which is a well-known method to improve the energy efficiency of buildings in the current setting of ongoing global energy price increases and concern to support global efforts to improve the climate.
This study involved an energy analysis of mid-rise commercial building using meteorological data, literature review, and information on heat loss, energy consumption, electricity charges, and insulation materials availability in the market. To determine the insulation effectiveness and potential for energy savings; dynamic simulations were performed in HAP software version 4.9. The study examined the energy requirements for heating and cooling of a 6-story, uninsulated mid-rise building with 345m2 of effective area at each floor, which is oriented north to south and has single-glazed windows with aluminum frames. Conventional air conditioners are currently used for heating and cooling. The study compared the annual electrical energy consumption for insulated and uninsulated conditions and performed an energy-saving comparison for different levels of polystyrene insulation thicknesses. In conclusion, adding insulation to the envelope's walls can improve thermal comfort indoors and cut the energy use of the structures under study by between 30 and 50 percent.

Keywords: Energy Savings, Building Insulation, Sustainability, Energy Consumptions

Proceedings of the 15th International Green Energy Conference
IGEC2023-053
July 10-13, 2023, Glasgow, UK

THEORETICAL STUDY ON THE PERFORMANCE OF A STANDING-WAVE THERMOACOUSTIC REFRIGERATOR UNDER VARIOUS BOUNDARY CONDITIONS

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ABSTRACT
Thermoacoustic refrigerators (TARs) are devices in which acoustic energy can be converted into heat, creating a temperature gradient and producing a cooling effect. In this paper, a detailed theoretical model of a loudspeaker-driven standing-wave TAR is established, and the influence of the various boundary conditions on the internal acoustic field and refrigeration coefficient of the refrigerator is comprehensively analyzed. The baseline loudspeaker-driven TAR system is essentially a quarter-wavelength system consisting of a loudspeaker unit, a ceramic stack, two heat exchangers and a resonant tube with variable diameter. Theoretical models are developed based on the acoustic equations and linear thermoacoustic theory. Based on the developed model, a parametric analysis is carried out to study the effect of the boundary conditions. The result shows that the acoustic impedance at the end of the resonant tube affects the acoustic characteristic and the cooling effect of the system and thus the selection of the optimal driving frequency of the loudspeaker. This work provides guidelines for designing TARs to meet specific requirements of thermoacoustic refrigeration.

Keywords: Thermoacoustic refrigerator, standing-wave, acoustic distribution, boundary conditions.

Proceedings of the 15th International Green Energy Conference
IGEC2023-055
July 10-13, 2023, Glasgow, UK

TO DEVELOP AN ECO-FRIENDLY COLD NUCLEAR THERMAL POWER PLANT BY CONSIDERING IRON-56 AS A FUEL

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Abstract
In this contribution, we make an attempt to write a theoretical proposal for designing an eco friendly thermal power plant which runs with cold nuclear fusion technology at a temperature of (1500 to 2000) deg.C. In our recently published papers, we have proposed a clear cut mechanism for understanding and implementing cold nuclear fusion technique pertaining to fusion of hydrogen with metals of mass numbers starting from 50. In this context, we would like to stress the point that, fusion of hydrogen under controllable temperature and pressure can be understood as a phenomenon of fusing neutron to the nucleus of the base atom. Part of isotopic nuclear binding energy difference of final and base atomic nuclides can be seen in the form of safe thermal energy of the order of (1 to 3) MeV per atom against 200 MeV released in nuclear fission of one Uranium atom. Due to increased heaviness and weak interaction, sometimes fused neutron splits into proton and electron. Proton seems to be retained by the base atom's nuclear core and electron seems to join with the electronic orbits of the base atom. In this way, increased mass of base atomic nuclide helps in eco friendly production of thermal energy in large quantity. For this purpose we consider Iron-56 as a fuel. In a simplified view, under strong nuclear attractive forces, Iron-56 absorbs hydrogen atom as a neutron and by emitting 1MeV equivalent thermal energy transforms to Iron-57. Thus, one gram of Iron-56 can generate 1000MJ of heat with 50% efficiency. In a shortcut approach, by bombarding powder and semi-liquid forms of Iron-56 with direct neutrons coming from neutron source, our proposal can be tried, understood and verified experimentally.

Keywords: Cold nuclear fusion; Iron-56 as a fuel; Eco friendly Thermal energy; Power plant;

Proceedings of the 15th International Green Energy Conference
IGEC2023-056
July 10-13, 2023, Glasgow, UK

ELEMENTARY REACTION KINETIC MODEL OF AN AMMONIA PROTONIC CERAMIC FUEL CELL

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ABSTRACT
Protonic ceramic fuel cell (PCFC) can effectively utilize ammonia to generate electrical power at intermediate temperature (IT) (500-600 °C). However, previous numerical studies on NH_3-PCFC simply deal with the ammonia decomposition process in fuel cells and ignore the current leakage phenomenon in proton-conducting electrolytes. To this end, a 2D model of a tubular NH_3-PCFC is developed. Specifically, the complex ammonia decomposition process is described by elementary reaction kinetics, while different charge carriers transport within the electrolyte material is described by Nernst-Planck equation. It is found that, for minimizing the current leakage, the working potential of NH_3-PCFC is suggested to be < 0.7 V (Fig1. (a)). Although increasing inlet stream fraction can enhance electrochemical performance of NH_3-PCFC and proton uptake (Fig1. (b)), the formation of electronic hole is improved by nearly 80%, which is detrimental to the faraday efficiency. Therefore, increasing the inlet steam fraction may not be an effective way to improve the performance of NH_3-PCFC. Additionally, from the investigations on the effects of inlet anode/cathode flow rate on the NH_3-PCFC, it demonstrates that under different operating temperatures, the effects of inlet anode/cathode flow rate on the NH_3-PCFC are different. By analysing the temperature distribution of NH_3-PCFC, the performance of NH_3-PCFC is substantially sensitive to the temperature distribution with the cell. In order to reduce the temperature cooling area within the cell, mixing H_2 with inlet fuel is simulated. Based on the elementary reaction kinetics, it illustrates that by mixing 5% H_2 in the inlet fuel, the temperature gradient along the cell length can be reduced by 22%, since surface reaction sites can be occupied by adsorbed hydrogen while hindering ammonia decomposition. Moreover, when nitrogen desorption kinetics is enhanced by 20%, electrochemical performance of NH_3-PCFC decreases by 3%, since enhanced nitrogen desorption enlarges the temperature cooling region within the cell (Fig1. (c)).

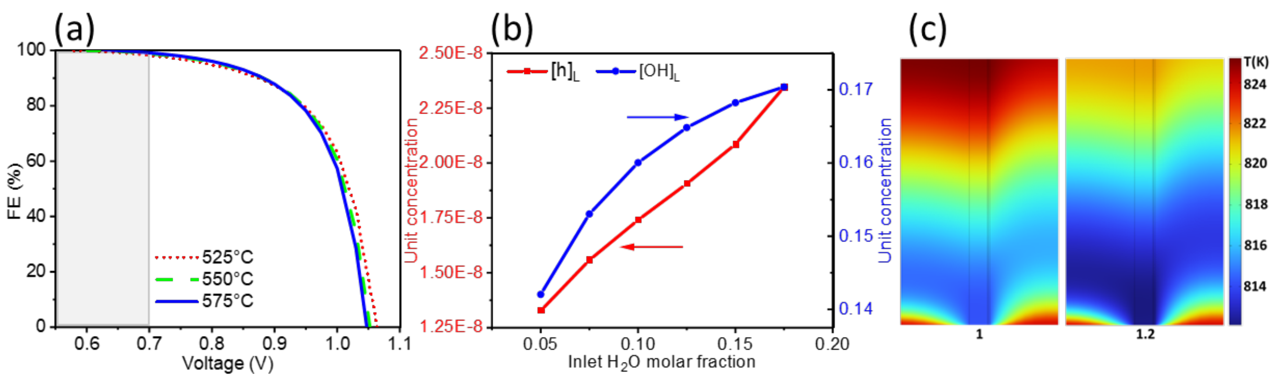

Fig1. (a) Effects of working potential on Faraday efficiency; (b) Effects of inlet steam fraction on proton and electronic hole concentration at 600 °C, 0.7 V; (c) Effects of nitrogen desorption (pre-factor increases by 20%) on the temperature distribution within the cell.

Keywords: Current leakage, Protonic ceramic fuel cell, Numerical model.

Proceedings of the 15th International Green Energy Conference
IGEC2023-057
July 10-13, 2023, Glasgow, UK

EXPLORING THE CONDUCTIVITY LANDSCAPE OF NOTABLE CERAMIC ELECTROLYTES UNDER VARYING AMBIENT CONDITIONS

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ABSTRACT

Ceramic electrolytes play a crucial role in the development of ceramic electrochemical cells. In this study, we explore the conductivity behavior of two notable ceramic electrolytes, oxide ion conducting $Ce_{0.8}Sm_{0.2}O_2$ (SDC) and proton conducting $BaCe_{0.7}Zr_{0.1}Y_{0.1}Yb_{0.1}O_{3-\delta}$ (BCZYYb), under varying ambient conditions. Using the DC four-probe method, we examined the conductivity of these electrolytes in the temperature range of 850 - 450 ºC under pure air, 3% H_2O-air, and 5% H_2O-air conditions. The results reveal that SDC has a higher total conductivity, mainly oxide ions, and electrons, than BCZYYb, which conducts protons more effectively. SDC has a higher electron density and larger crystallite size than BCZYYb, which could account for its higher bulk conductivity. BCZYYb exhibits effective proton conductivity at lower temperatures (below 750 ºC) through hydration with lower activation energies. The enthalpy of protonation in BCZYYb reaches -21.38 kJ mol^{-1} under 3% H_2O-air conditions from 450 – 550 ºC. The findings of this study provide critical insights into the fundamental mechanisms that govern the conductivity of ceramic electrolytes and can guide future efforts to optimize ceramic electrolytes for advanced electrochemical conversion and energy storage applications.

Keywords: Ceramic electrolytes, Conductivity, Proton conduction, Oxide ion conduction, DC four-probe method

Proceedings of the 15th International Green Energy Conference
IGEC2023-058
July 10-13, 2023, Glasgow, UK

GOLD AS A DOPANT FOR ROBUST STRUCTURAL PROPERTIES OF $LIFEPO_4$ CATHODE MATERIAL FOR LITHIUM-ION BATTERY APPLICATION

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ABSTRACT

Further improving the structural properties of cathode materials is strongly indispensable to produce a safer and more efficient battery. Transition metal doping strategies were proven to enhance the structural properties of cathode material. In this study, the structural properties of Au doped $LiFePO_4$ are simulated using Density Functional Theory. The calculated lattice parameter of Au-$LiFePO_4$ is almost unchanged compared to pristine $LiFePO_4$ with the polyhedral shape of FeO_6 and PO_4 are situated in the same manner which suggested no phase change has occurred. Minimal volume change of Au-$LiFePO_4$ after the lithium extraction (1.7%) compared to undoped $LiFePO_4$ (5.8%) suggests firmer structure retention during charging and discharging process, thus ensuring better stability and life cycle of the cathode materials. The enlargement of the structure after delithiation process is accommodated by the expansion of vacant space left by Li ion, in which suggested to become the desirable based for Li docking during battery operational.

Keywords: Au-$LiFePO_4$; Cathode materials; Lithium-ion battery; First principles study; Structural properties.

Proceedings of the 15th International Green Energy Conference
IGEC2023-060
July 10-13, 2023, Glasgow, UK

RESEARCH ON SOLAR-ASSISTED EJECTOR-ENHANCED AIR SOURCE HEAT PUMP CYCLE WITH DUAL-PRESSURE CONDENSATION

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ABSTRACT
Dual-pressure condensation heat pump cycle has wide application but with low performance in the cold region. A novel solar-assisted ejector-enhanced air source heat pump cycle with dual-temperature condensation (SEASHP-DC) is proposed in this study. Two types of hot water with different temperatures can be supplied for air heating and floor or ceiling radiation heating, respectively. By using the solar energy and ejector, the heating capacity of the proposed cycle can be increased while the power consumption can be reduced. The cycle can change operation mode according to the solar radiation intensity, which can turn into conventional heat pump cycle with dual-pressure condensation (CHP-DC) when the solar radiation intensity is low or at night. The performance of the proposed cycle with different refrigerants (R134a, R1234yf, and R1234ze(E)) are compared. Results show that the R1234ze(E) is a more suitable substitute for the R134a. The performance of the SEASHP-DC is investigated and compared with that of the CHP-DC under the given condition. Compared with the CHP-DC, a considerable improvement in *COP* of 55.9% can be reached by the SEASHP-DC. The largest exergy destruction occurs at the solar collector for huge temperature difference between the solar collector and environment. Moreover, the performance evaluation of the cycle in Xi'an, China during heating is performed. It is found that the cycle exhibits best at about 14:00 with relatively high solar radiation intensity and in warm month.

Keywords: direct expansion heat pump, solar energy, ejector

Proceedings of the 15th International Green Energy Conference
IGEC2023-061
July 10-13, 2023, Glasgow, UK

APPLICATION OF A HYDROPHILIC NANO-COATING TO INDIRECT EVAPORATIVE COOLING

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ABSTRACT
The wetting condition is an important factor that affects the cooling performance of an indirect evaporative cooler (IEC). In this study, a TiO_2/SiO_2 nano-coating is used to improve the hydrophilicity of polypropylene (PP) IEC. Thus, it can overcome the poor wetting of polymer and the corrosion of aluminum foil. Firstly, the hydrophilic durability of the coated PP plate was evaluated by observing the contact angle variation under both water immersion and water scouring conditions for 37 consecutive days. Secondly, drop-impact tests were conducted to comparatively study the dynamic wetting behavior of the coated plate and non-coated plate. Thirdly, the water distribution and wetting ratio inside the core under different spray time are studied by a special-designed test rig with an extractable heat exchanger core combining fluorescence tracer and digital image processing methods. The experimental results show that the hydrophilicity of nano-coated PP is durable with water scouring with a steady contact angle of 30.9°. The water droplet can be quickly dispersed and form a thin water film on the coated surface. A continuous spray of 60 seconds can almost fully wet the core heat exchanger (sectional dimension: 200 mm × 200 mm) under a water flow rate of 5 L/min, nozzle height of 150 mm and air velocity of 2 m/s.

Keywords: indirect evaporative cooling, hydrophilic coating, contact angle, wettability, digital image processing

Proceedings of the 15th International Green Energy Conference
IGEC2023-064
July 10-13, 2023, Glasgow, UK

GENERATION OF SYNTHESIS GAS VIA CO-ELECTROLYSIS OF WATER

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ABSTRACT

The Clean Forest project aims to valorize forest biomass wastes (and then prevent their occurrence as a fuel source in forests) into bioenergy, more precisely, the production of 2nd generation synthetic biofuels, such as biogas, biomethanol, bio-DME, etc., depending on the process operating conditions, such as pressure, temperature, and type of solid catalyst used. The valorization of potential forest waste biomass enhances the reduction of the probability of occurrence of forest fires and presents a significant value for local communities, especially, in rural populations. After the removal of forest wastes from the forest territory, this biomass is dried, grounded to reduce its granulometry, and liquified at temperatures between 100-200 ºC. Then, using the electrocracking technology, this liquified biomass is mixed with an alkaline aqueous electrolyte located in an electrolyzer (electrochemical reactor which performs an electrolysis process), using a potential catalyst, to produce syngas (fuel gas, mainly composed of CO, H_2, and CO_2). In a second reaction step, the syngas produced can be valorized in the production of synthetic biofuels, in a tubular catalytic reactor. The whole process is easy to implement and energetically, showing significative fewer costs than the conventional process of syngas gasification. Besides that, the input of energy necessary to promote the electrolysis process can be achieved with solar energy, using a photovoltaic panel. This paper refers to the project's actual progress, as well as the further steps which will consist of a set of measures aimed at the minimization of the occurrence of forest fires by valorizing forest wastes into energy sources. The tests show that the samples from burned wood, especially samples of heartwood andsapwood, can be used in liquefaction processes and producehigh conversion yields that originate in final products, such as bio-oils, that have a higher HHV and can be used in several industrial processes as fuels. This indicates that liquefaction is a possible way to somewhat reduce the economic impact felt by landowners who suffered due to the fires that raged through the country last summer and autumn, by using the valueless waste resulting from the burnt wood and creating a value-added product that can be used as fuel. Further on, it will continue, after the optimization processes of syngas and biogas production executed in previous tasks, by an energetic integration for all the processes, using specific software tools, as well, to modulate the process, using specific software of processes simulation. Besides that, in this task, another purpose is to perform, an economic analysis of the cost-benefit of the overall process and compare it with the conventional thermochemical processes, which are very expensive ones, and, a life cycle assessment (LCA) analysis, using, also, specific software. Another purpose of this task is to perform an environmental analysis of impacts, identifying the major environmental impacts, negative and positive ones, and compare them, also, with the conventional thermochemical processes of reforming, pyrolysis and gasification, highlighting the major importance of using renewable energy sources, like solar energy and, lignocellulosic biomass collected from the recovery and cleaning of the forest solid wastes from the forest territory, to prevent and avoid the probability of occurrence of major fires and, the potentialities of local economies for this strategy.

Keywords: Forest waste valorization; Generation of synthesis gas; Biofuels

Acknowledgements: This project is partially financed by Fundação da Ciência e Tecnologia, Portugal, through grant ref. PCIF/GVB/0167/2018

Proceedings of the 15th International Green Energy Conference
IGEC2023-065
July 10-13, 2023, Glasgow, UK

ENHANCED HYDROGEN STORAGE IN MG CATALYSED BY CU-NI-CO-FE QUATERNARY MULTI-COMPONENT ALLOY

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ABSTRACT

Magnesium has been sought after material for hydrogen storage due to its high storage capacity (7.6 wt.%) and low cost combined with easy availability. However, sluggish kinetics and high absorption temperature (>300°C) make it inherently difficult to use in commercial applications such as automobile, which require hydrogen absorption/desorption near ambient temperature and pressure. In this work, Cu-Ni-Co-Fe multi-component transition metal alloy has been used as a catalyst for hydrogen sorption in magnesium. It is seen that the Mg-Cu0.15Ni0.35Co0.25Fe0.25 composite desorbs ~6 wt.% hydrogen at 250°C at a plateau pressure of ~0.4 bar and exhibits fast kinetics with ~3.5 wt.% hydrogen absorption in 3 min at 250°C under 20 bar hydrogen. Synergistic effect of transition elements in a disordered solid solution act as pathway provider for hydrogen and therefore results in reduction in hydrogen desorption temperature, without compromising on the hydrogen storage capacity of the composite. Mg-based composites provide an economic and industrially scalable route for the commercial implementation of hydrogen-fuel cell combined system.

Keywords: Hydrogen Storage, Magnesium Hydride, Ball-milling, Transition metal multi-component alloy

Proceedings of the 15th International Green Energy Conference
IGEC2023-070
July 10-13, 2023, Glasgow, UK

ZEOLITIC IMIDAZOLATE FRAMEWORKS DERIVED NICKEL-COBALT PHOSPHIDES AS BIFUNCTIONAL ELECTROCATALYSTS FOR OVERALL WATER SPLITTING

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ABSTRACT

The depletion of fossil fuels and increasing environmental awareness have created an urgent need for sustainable energy development. Electrolytic water splitting is a promising option for green hydrogen production. However, the high cost and scarcity of noble-metal electrocatalysts, such as platinum and iridium, hinder their industrial applications. To address this challenge, researchers have turned to cheaper and earth-abundant transition metal bifunctional electrocatalysts to facilitate hydrogen evolution reaction (HER) and oxygen evolution reaction (OER) in an electrolyzer. Transition metal phosphides (TMPs) have shown promise for water splitting, but their performances are unsatisfactory. Although bimetallic TMPs were developed to optimize their electronic properties and facilitate efficient charge transfer due to their synergistic effect, supporting bimetallic TMPs on conductive substrates has been observed to significantly improve their electrocatalytic performance. Moreover, metal-organic frameworks (MOFs) have been recently touted to increase the accessible active sites of bimetallic TMPs, further enhancing their performance. Also, computational studies show that when MOF is incorporated into bimetallic TMP, it can improve its electrocatalytic performance and stability. Therefore, there is a need to increase the number of accessible active sites, gas diffusion, performance, and stability by combining conductive substrates and metal-organic frameworks (MOFs) into the synthesis of TMPs.

Inspired by these developments, bimetallic nickel-cobalt phosphides derived from ZIF-67 MOF precursors were prepared via hydrothermal, partial etching, and low-temperature gas-solid phosphorization processes and supported on nickel foam. With an optimal partial etching time of 6 minutes, Co-MOF@CoNiP-6/NF exhibits overpotentials of 180 mV and 315 mV to reach a current density of 50 $mAcm^{-2}$ in 1M KOH for HER and OER, respectively. Using the catalysts as anode and cathode in a water electrolyzer require 1.76 V to reach 10 $mAcm^{-2}$ for 115 hours in an alkaline solution with negligible degradation, exceeding the performances of many reported MOF-derived self-supported bimetallic transition metal electrocatalysts due to the increased accessible active sites due to the hierarchical mesoporous nanostructures derived from metal-organic frameworks and enhanced conductivity due to the conductive substrates, demonstrating the potential for the development of bifunctional electrocatalysts derived from MOF precursors for water splitting.

In conclusion, this study represents a significant step in developing bifunctional electrocatalysts derived from MOF precursors for water splitting, offering a promising approach to green hydrogen production.

Keywords: Hydrogen Evolution Reaction, Oxygen Evolution Reaction, Metal-Organic Frameworks, Transition Metal Phosphide, Electrocatalyst.

Proceedings of the 15th International Green Energy Conference
IGEC2023-071
July 10-13, 2023, Glasgow, UK

THERMAL PERFORMANCE SIMULATION OF REGENERATIVE INDIRECT EVAPORATIVE COOLER FOR MARINE AIR-CONDITIONING

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ABSTRACT

Foreign trade ships have a long route across the world covering a wide variety of climate zones. Therefore, the air conditioning system is important for maintaining the internal thermal environment of the cabin for modern ships, and is an essential system to create a thermally favorable environment for the normal operation of equipment. At present, the air-conditioning system used in ships is dominated by the traditional mechanical vapor compressor air-conditioning system. Although it is mature in technology and stable in operation, it highly relies on the energy-intensive compressor to complete the refrigeration cycle and uses Freon refrigerants that would damage the ozone layer. The power used to drive the air-conditioning system on the ship mostly comes from diesel generators. Fossil energy is converted into high-grade electric energy through combustion, but the conversion efficiency of electric power is low (≈40%). More than half of the fossil energy is turned into waste heat and taken away by a seawater cooling system. Therefore, it is of great significance to find a sustainable air conditioning solution for marine applications.

The regenerative indirect evaporative cooler (RIEC) is one of the most promising sustainable air-conditioning technologies gaining increasing attention in recent years owing to its energy-efficient and environmental-friendly features. The most commonly used plate type RIEC consists of a series of thin parallel plates assembled to form a multi-layer sandwich of alternating dry and wet channels, which are also called primary air and secondary air channels. The key thermodynamic process in a RIEC is the evaporation of water into air, which cools the channel wall surfaces and allows a large amount of heat to be conducted from the dry side to the wet side. When used in a ship, seawater can be used as the natural refrigerant for evaporation instead of fresh water in normal applications. However, there is no feasibility study reported on the seawater-based RIEC in terms of thermal performance. Therefore, a comparative study is carried out to investigate the thermal performance of seawater-based RIEC and freshwater-based RIEC by numerical simulation.

In this study, a numerical heat and mass transfer model of a RIEC is established and validated under various inlet air conditions. The numerical model is used by Finite Difference Method (FDM). The highlights are placed on the properties of seawater derived from MIT library (web.mit.edu/seawater), including the density, viscosity and saturated vapor pressure, which are used as the model inputs. The outlet temperature of product air and wet-bulb effectiveness of seawater-based RIEC and freshwater-based RIEC are simulated under a wide range of influential parameters, including the intake air temperature and humidity, working air to product air ratio, channel gap, and salinity. The results show that there is a deterioration of cooling performance in seawater-based RIEC compared to freshwater-based under the same geometric and operating conditions. The outlet temperature of product air is 0.28℃ higher and wet-bulb effectiveness is 5.57% lower on average in the seawater-based RIEC.

The study results reveal that, from the thermal performance point of view, the feasibility of applying a regenerative indirect evaporative cooler for air-conditioning in ships using seawater as the natural refrigerant. However, extensive further work needs to be done for real applications, such as, the corrosion material selection, water distribution system design, water hardness detection and so on. Besides, future work can be done to investigate the combined evaporative cooling and desiccant dehumidifier for independent control of temperature and humidity and making full use of the waste heat from diesel generators for dehumidifier regeneration.

Keywords: regenerative indirect evaporative cooler, seawater, numerical simulation, thermal performance, comparative study

Proceedings of the 15th International Green Energy Conference
IGEC2023-072
July 10-13, 2023, Glasgow, UK

MACHINE LEARNING ASSISTED PERFORMANCE INVESTIGATION OF A NOVEL SUSTAINABLE COOLING SYSTEM

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ABSTRACT
An exponential rise in cooling demand occurred in the last few decades because of rising global surface temperatures, population growth, faster urbanization, and income growth. Particularly developing countries are facing major issues because of the larger impact of these cooling drivers Therefore, the associated energy consumption and emissions are influencing the economic situation to support the required infrastructure for power generation as well as environmental protection. Conventional vapor compression systems are energy intensive and involve harmful chemical-based refrigerants. Therefore, the current focus is on the development of novel cooling systems with minimal energy demand and chemical-free operation. In this regard, a novel externally humidified indirect evaporative cooling system is investigated for sustainable cooling. The proposed system employs air and water to produce humidity-controlled cooling and has significantly lower energy consumption because of compressor-free operation. The proposed system is investigated using an artificial neural network (ANN) which is reported to be one of the excellent function approximation algorithms of machine learning. The input variables like outdoor air temperature, air flow rate ratio, working air temperature, and working air wet bulb temperature are provided to construct the functional mapping with the supply cold air temperature of the system. The data set compiled using an experimental test facility under assorted operating conditions is used to train the algorithm. The data distribution space is visualized by a self-organizing feature map to confirm the data quality and diversity. Subsequently, rigorous hyperparameter tuning is performed to develop an ANN model having excellent prediction and generalization performance. ANN model having nine neurons in the hidden layer exhibits excellent modeling performance with a coefficient of determination (R^2) value of nearly one in the training, testing, and validation phases. Moreover, root-mean-squared-error (RMSE) in the three phases of the model development is calculated as RMSE_train = 0.046 °C, RMSE_test = 0.06 °C, and RMSE_val = 0.06 °C respectively. The generalization potential of the developed ANN model is evaluated on the external validation test. For this purpose, the experiments are conducted on the IEC system considering the design space of the input variables, and the corresponding supply cold air temperature observations are recorded. The external validation test is simulated on the developed ANN model and a good agreement between the experimental and model-simulated responses is found, i.e., R^2 = 0.99 and RMSE = 0.05. The sensitivity analysis is carried out on the ANN model and the percentage significance of the input variables towards the prediction of supply cold air temperature is computed. It was found that outdoor air temperature turned out to be the most significant input variable followed by air flow rate ratio, working air temperature, and working air wet bulb temperature with the following values 31.8%, 17.2%, 33.4%, and 17.6%, respectively. The developed model can be employed for the predictive analytics of IEC systems with reasonable accuracy under diverse operating scenarios. Furthermore, the identification of the variable's significance can be helpful to prioritize the operational settings of the input variables for achieving the supply air temperature for future developments.

Keywords: machine learning, sustainable development, novel cooling systems, indirect evaporative cooling

Proceedings of the 15th International Green Energy Conference
IGEC2023-075
July 10-13, 2023, Glasgow, UK

A MARKET-BASED ASSESSMENT OF INCREMENTAL WIND ENERGY DEVELOPMENT IN THE MIDCONTINENT ELECTRICITY MARKETS OF THE UNITED STATES

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ABSTRACT

Based on wind power purchase agreements and tolling agreements, this paper assesses how much incremental wind energy development (WED) may occur without reducing generation investment incentives in the day-ahead market (DAM) and real-time market (RTM) of the Midcontinent Independent System Operator (MISO) in the US. Using a large sample of hourly data for the 82-month period of 01/01/2014 - 10/31/2020, it documents that the hourly DAM incentives move with (a) the day-ahead forecast of daily natural gas price; (b) PJM's day-ahead hourly energy price; (c) MISO's day-ahead hourly requirements of ancillary services; (d) MISO's zonal day-ahead hourly schedules of nuclear generation, wind generation and must-run generation; and (e) MISO's zonal day-ahead forecasts of hourly loads. Findings based on the hourly RTM data tell a similar story. Further, the projected negative effect of incremental WED on generation investment incentives over the forward-looking period of 2023-2042 is offset by the projected positive effect of rising natural gas price, nuclear plant retirement, declining must-run generation, and growing demand. Hence, incremental WED of up to ~300% of the existing wind generation level may occur as a market-based outcome in MISO's DAM and RTM, without exacerbating the missing money problem of inadequate generation investment incentives.

Keywords: Wind energy development, missing money, generation investment incentives, Midcontinent electricity markets, United States.

Proceedings of the 15th International Green Energy Conference
IGEC2023-076
July 10-13, 2023, Glasgow, UK

LEVELIZED COST OF CARBON ABATEMENT (LCCA) STUDY ON LOW CARBON VERSUS CONVENTIONAL AMMONIA PRODUCTION FOR USE AS FERTILIZER AND HYDROGEN CARRIER

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ABSTRACT

One of the most pioneering processes in chemical engineering is the production of ammonia using the Haber-Bosch technique, with half of humanity being nourished from Haber-Bosch derived ammonia today. However, this process accounts for 2 % of global CO_2 emissions, the largest share of which is owed to the conventional fossil fuel-based hydrogen production. To reduce these emissions, low-carbon ammonia production with electrically generated hydrogen from water splitting (i.e., power-to-ammonia, P2A) is currently receiving strong interest.

This study compares the P2A system with the conventional, methane-fed Haber-Bosch process by performing a Levelized Cost of Carbon Abatement (LCCA) analysis. The LCCA measures the cost per unit of CO_2-eq emissions avoided by considering the technology development, for instance, the reduction in production costs with the increasing cumulative production quantity. This approach quantifies the potential reduction in CO_2-eq emissions from the new technology and evaluates the cost difference in capital and operating expenditures simultaneously. In this study, various scenarios for low-carbon ammonia demand in Canada from 2027 to 2050 are considered, such as low-carbon fertilizer, or ammonia as a hydrogen carrier for export to Germany, with significantly larger quantities required for the latter case. While Canada's existing infrastructure can meet the constant demand for ammonia in low-carbon fertilizer production, the increasing interest in ammonia as a hydrogen carrier necessitates the construction of a new infrastructure. This study examines the contrast between these two scenarios by comparing the replacement of methane-fed ammonia plants with electrified ones in the case of fertilizer production. On the other hand, for hydrogen carrier applications, the construction of new methane-fed plants versus building new electrified plants is regarded. Both the Canadian average as well as the individual Canadian provinces and territories are examined as the producer regions for the low-carbon ammonia.

The findings will be presented for each ammonia application individually, as well as collectively. First results show that the electricity generation mix has the greatest impact on the LCCA, with provinces like Manitoba, Quebec, Prince Edward Island, and British Columbia being most beneficial from both an environmental and economic perspective. All these provinces except British Columbia are connected to the Atlantic coast, which will provide great potential to meet Germany's goal of importing large quantities of low-carbon hydrogen from Canada and align with the Hydrogen Alliance between the two countries established in August 2022.

However, the study also indicates that the electricity consumption to meet the national P2A demand is significant, exceeding the potential electricity generation in Canada even under the evolving policy scenarios. Thus, to achieve long-term emissions reduction targets and to realize the goals of the German-Canadian Hydrogen Alliance using P2A, more clean electricity than currently anticipated is needed in Canada.

Keywords: LCCA, power-to-ammonia, low carbon ammonia, hydrogen export, hydrogen storage.

Proceedings of the 15th International Green Energy Conference
IGEC2023-077
July 10-13, 2023, Glasgow, UK

$FECO_2SE_4$ COUNTER ELECTRODE FOR APPLICATION IN DSSC: SYNTHESIS, STRUCTURAL, ELECTROCHEMICAL AND EFFICIENCY STUDIES

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ABSTRACT
Nanosheet $FeCo_2Se_4$ has been synthesized by hydrothermal method via a selenization process. The transition mechanism of $FeCo_2O_4$ to $FeCo_2Se_4$ is discussed. The formation of the $FeCo_2Se_4$ has been proven by sample characterization to support its catalytic activity as a counter electrode for solid-state dye-sensitized solar cell (DSSC). The poly(vinylidene fluoride-co-hexafluoropropylene) (PVdF-HFP)/ propylene carbonate (PC)/ 1,2-dimethoxyethane (DME)/ 1-methyl-3-propyl imidazolium iodide (MPII)/ sodium iodide (NaI)/ iodine (I_2) gel electrolytes were assembled into DSSCs with $FeCo_2Se_4$, $FeSe_2$, Co_3Se_4 or platinum (Pt) as the counter electrode. DSSC with $FeCo_2Se_4$ counter electrode showed an efficiency of 8.55 %, whereas Pt counter electrode showed an efficiency of 7.06 %. Hence, $FeCo_2Se_4$ can be used as a Pt-free counter electrode for high performance DSSCs.

Keywords: $FeCo_2Se_4$; $FeSe_2$; Co_3Se_4; Counter Electrode; DSSC

Proceedings of the 15th International Green Energy Conference
IGEC2023-078
July 10-13, 2023, Glasgow, UK

TECHNO-ECONOMIC ANALYSIS OF PEM ELECTROLYSERS AND RENEWABLE HYDROGEN GENERATION

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ABSTRACT

Analysis of the economics of renewable hydrogen generation is often complex and based on broad simplifications of economic and voltametric factors. These challenges lead to an incomplete understanding of the interrelated features governing the cost of renewable hydrogen generation. In this work, an integrated mechanistic and economic model has been developed to provide a solution of economic hydrogen production by fully describing the effects of the many influencing factors. The model takes thermodynamics and kinetics to generate an accurate current density vs. voltage polarisation curve with the consideration of various influencing factors such as temperature, pressure, catalyst loading etc., which are then used to calculate a realistic hydrogen price from an economic model framework. This novel model brings together a fundamental understanding and parameter integration and includes a detailed analysis of the price of PEM cell materials. Several scenarios were analysed in order to assess how to meet the DOE Earthshot target hydrogen price of \$1 kg^{-1} by 2030. The price change over time and when or if the DOE price target can be met for each scenario has been determined.

Keywords: Green Hydrogen, Tech-economic Analysis, PEM electrolysis.

Proceedings of the 15th International Green Energy Conference
IGEC2023-080
July 10-13, 2023, Glasgow, UK

LOW-GRADE HEAT DRIVEN WATER DESALINATION DRIVEN BY EJECTOR ENHANCED ORC SYSTEM

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ABSTRACT

Pure drinking water is the basic need of human and living populations. Sea water is the main and large resource of water but due to high concentration of salt, seawater cannot be consumed for drinking purpose. In this research, the thermodynamic study of low-grade heat driven power and cooling systems are investigated for the reverse osmosis sea-water desalination. We desalinate the sea-water as a drinking water by using reverse osmosis desalination that is driven by ejector enhanced Organic Rankin Cycle (ORC). For desalination of sea-water, we use specific filament category membrane. All the system specifications are taken into account for the thermodynamic and energy calculations. In heat-driven technology, the ejector refrigeration system (ERS) provides effective ways to convert low-temperature heat to efficient cooling. The power of reverse osmosis high pressure pump is calculated and cross checked by the different formulas. The comparison of increasing the power of reverse osmosis pump and permeate flow rate is carried out to check how much permeate water (drinking water) can be obtained by increasing the power of the reverse osmosis pump. Furthermore, the comparison of pump power and sea-water feed flow rate is performed. All the calculations of sea-water feed rate and permeate water feed rate are also performed in this study. ORC technology can also use low-temperature heat and converts it into electrical energy. In this work, low-grade heat driven ejector enhance ORC is used to drive the reverse osmosis sea-water desalination plant. We used Engineering Equation Solver (EES) to improve productivity of the desalination plants as well as the ejector enhance ORC system. Energy consumption for the production of the fresh water is also the interest of this work. In order to increase the power output and its efficiency, the ejector is introduced and ORC with Ejector (EORC) was proposed in this work. For this purpose, new model is created and analyzed on EES to find the results for system design and optimization. There is a need to study and design ERS and ORC system that can hold very low temperatures, i.e., of 50-100 °C and run the water desalination system with low-grade heat source. This research presents the novel system design to produce fresh water using low grade heat driven reverse osmosis of sea water that may be helpful to meet the fresh water demand.

Keywords: Engineering Equation Solver; Organic Rankin Cycle; Reverse Osmosis; Ejector; Desalination; Low-Grade Heat

Proceedings of the 15th International Green Energy Conference
IGEC2023-086
July 10-13, 2023, Glasgow, UK

LOCATION OPTIMISATION OF EVC POINT OF COUPLING FOR MINIMISING VOLTAGE HARMONIC LEVELS OF A UK BASED LV POWER DISTRIBUTION NETWORK

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ABSTRACT
Despite an increase in electric vehicle chargers (EVCs) connecting to low-voltage (LV) power distribution networks managed by Distribution Network Operators (DNOs) and National Grid ESO (2022) expecting approximately 33 million electric vehicles (EVs) on United Kingdom (UK) roads by 2050 under a ‘falling short’ scenario, the optimised location for installing EVCs on an LV DNO network with respect to harmonics has not been fully explored. The purpose of this paper is to investigate the optimal point of coupling for EVCs to minimise the steady-state voltage total harmonic distortion (THDv) on a radial LV DNO network under both normal and steady-state fault conditions. The conclusions will aid DNOs with future network planning and design.

Minimising harmonics is important. Balda, et al (1993) explains that harmonics can increase the risk of computer errors and cause communication interferences. Whilst Bhattacharyya, Myrzik and Kling (2007) explains that harmonics increase the risk of motor overheating and reduce the life of transformers, increasing the risk of power cuts.

Using MATLAB, a simulation system for a radial 230m LV feeder based upon a suburban residential LV DNO network was created and was divided into eleven sections (busses) with base load connected, each with the capacity for an EVC to be connected to all three phases. Each two-buses were connected with impedance which represents cables. The first and last bus represents the first and last 5% of the network length. The remaining busses each represent 10% of the network length. A broad range of scenarios were generated by changing network parameters. These parameters include:

- Transformer size at 50, 200, 500, 1000 and 2000 kVA
- Mains cable size at 35, 185 and 300mm^2
- Service length at 15 and 30m
- X/R ratio and magnitude of 11kV bus impedance representing three different 11kV networks.
- Existing photovoltaic (PV) generation and EVCs connected to the network at 1st, 11th and all busses
- A two or three-phase fault at Bus 11 forcing yellow and/or blue phase supplies to be fed via red phase
- One or two LV feeders connected to bus 1.

Using two algorithms, the optimal bus for EVC point of coupling with respect to lowering the steady-state THDv was identified. The first algorithm is based on the Elephant Herding Optimisation (EHO) technique (Wang, Deb and Coelho, 2015 and Meena and Yang, 2020). The second algorithm for comparison is based on the Monarch Butterfly Optimisation (MBO) technique (Wang, Deb and Cui, 2015). Alterations have been made to these scripts to allow them to solve the optimisation of EVC point of coupling with respect to THDv.

It was found that for all scenarios except for the ‘50kVA transformer’ and ‘PV generation connected to all busses’ scenarios, the optimal EVC point of coupling was the 1st bus, representing the first 5% of the network fed from the 11kV:400V transformer. This aligns with what would be expected since the shorter the distance current harmonics need to travel, the lower the cable impedance and the lower the magnitude of harmonic voltage drop generated as per Ohms law.

Keywords: Electricity Distribution Network, Electric Vehicle Charger, Faults, Harmonics, IGEC

Proceedings of the 15th International Green Energy Conference
IGEC2023-088
July 10-13, 2023, Glasgow, UK

SIMULATION OF HYDROGEN FIRED REHEAT FURNACE IN THE STEEL INDUSTRY

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Abstract
In the reheat furnaces of hot rolling mills, semi-finished steel products such as slabs, blooms, or billets, are brought up to the required temperature for hot rolling with as uniform a temperature profile as possible to ensure product quality. Reheat furnaces are the second largest energy consumers of integrated steel mills, and natural gas is commonly used as a fuel, making them a significant source of carbon emissions. The partial or total replacement of natural gas with a clean burning fuel such as hydrogen is a potential method for the reduction of carbon emissions, but using hydrogen as a fuel in existing furnaces comes with its own set of challenges. The change to hydrogen fuel means factors such as the impact on burner design, flame shape, heat flux to the load, load temperature profile, and production of NOx must be evaluated. The objective of this study is to use computational fluid dynamics (CFD) to model an existing natural-gas-fueled reheat furnace and investigate the impact of hydrogen addition to the fuel mixture. As the movement of the load in a reheat furnace is inherently periodically transient, to reduce computational cost and maintain result accuracy, a decoupled approach was used to model the furnace. An iterative solution procedure was adapted from the literature and applied so that the gas phase of the furnace (combustion and flow field) and load are modeled separately. Simulations were performed using the open-source software OpenFOAM. First, the simulation of the combustion and flow in the gas phase of the furnace was simulated until a steady state was achieved. Then, the resulting heat fluxes to the load were used as boundary conditions when simulating the transient heating of the furnace load. These two simulations were repeated until convergence of the temperature profiles was reached. More details on the methodology and preliminary results will be shared.

Keywords: Reheat Furnace, Hydrogen, CFD

Proceedings of the 15th International Green Energy Conference
IGEC2023-091
July 10-13, 2023, Glasgow, UK

DEVELOPMENT OF HYDROGEN LIQUEFACTION, STORAGE AND TRANSPORTATION TECHNOLOGY：A REVIEW

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ABSTRACT

As a kind of clean energy, hydrogen energy plays an important role in achieving green and clean development and reducing the impact of economic development on the environment. Hydrogen (H2) is a better alternative to fossil fuels [1] and liquid hydrogen technology has great potential to become energy commodity beyond LNG [2]. Hydrogen liquefaction, storage and transportation are essential in hydrogen engineering applications, which involve many key technologies. In addition, due to the low boiling point, liquid hydrogen leakage can lead to serious safety accidents and the flammable vapor cloud formed by liquid hydrogen spill poses serious threat to life and property [3], it is necessary to develop modern hydrogen reliability and safety technologies to ensure that accidents do not occur. Therefore, for the efficient utilization of liquid hydrogen in engineering, it is necessary to review the utilization process of liquid hydrogen.

Therefore, in order to summarize the development status of these technologies, the basic principles, storage and transportation of hydrogen liquefaction, as well as key technologies and related indicators were discussed in detail in this paper. In addition, the most widely used critical equipment, including hydrogen compressors, liquid hydrogen tanks and liquid hydrogen pumps, was discussed. The current risk assessment and prevention techniques for liquid hydrogen during liquefaction, storage and transportation were also reviewed in this paper.

The highlight of this paper is as follows: Firstly, it systematically reviews the working principle of the whole chain of preparation, transportation and storage of liquid hydrogen and the current application status; secondly, it carries out risk assessment on the safety aspects of the whole process and summarizes the preventive technology, such as using a cryogenic refrigerator to compensate for the heat leakage is expected to eliminate the risk of hydrogen vent, realizing long-term lossless storage [4]. What’s more, the key technologies promising for the future development and application of liquid hydrogen are discussed, for example, hydrogenation systems' technical and economic prospects using liquid organic hydrogen carriers (LOHCs) to store hydrogen at a large scale compared to densified storage technologies and circular hydrogen carriers (mainly ammonia and methanol) [5]. Finally, If liquid hydrogen becomes an important energy carrier in the future, it is necessary to have large-scale infrastructure, large-scale hydrogen liquefaction plant and liquid hydrogen storage device. Furthermore, the development of modern hydrogen infrastructure is needed to scale up hydrogen delivery[6]. This paper also reviews the current development of large-scale liquefaction technology and the construction of liquid hydrogen infrastructure.

Keywords： Hydrogen storage；Liquid hydrogen；Hydrogen transportation；Hydrogen safety

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Proceedings of the 15th International Green Energy Conference
IGEC2023-093
July 10-13, 2023, Glasgow, UK

THE TITLE: GLYCEROL-ASSISTED CO-ELECTROLYSIS IN SOLID OXIDE ELECTROLYZER CELL (SOEC) FOR GREEN SYNGAS PRODUCTION: A 2D MODELLING STUDY

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ABSTRACT
In this study, a 2D multi-physics model is developed to study the glycerol-assisted SOEC co-electrolysis process, with a novel in-tube reformer to improve the fuel utilization and reduce the temperature difference in the cell. After model validation, the effects of key operating parameters on the electrochemical performance and temperature distribution of the system are investigated in detail. It is found that glycerol assistance can significantly reduce the operating voltage of the SOEC co-electrolysis system, thus saving over 55% of electrical energy at 1073K. Besides, the increasing operating voltage, operating temperature and cathode H_2O molar fraction promote the co-electrolysis process in the system, leading to an increase in cathode H_2O/CO_2 conversion; while the anode/cathode flow rate and anode glycerol molar fraction all have the optimal values (Q_{an}=70~110 SCCM, Q_{ca}=125~175 SCCM and $X_{an,GL}$=0.05~0.15), with good electrochemical performance and uniform temperature distribution. Meanwhile, the proposed in-tube reformer can greatly reduce the temperature difference inside the cell, and by precisely controlling the structure and operating parameters of the system, a more uniform internal temperature distribution can be obtained, even allowing the system to be operated at homogeneous temperature conditions. This study provides a reference for the commercialization of efficient green syngas production and CO_2 recycling by using renewable electricity.

Keywords: Solid oxide electrolyzer cell; Numerical modeling; Fuel assisted co-electrolysis; CO_2 recycling; Thermal effect.

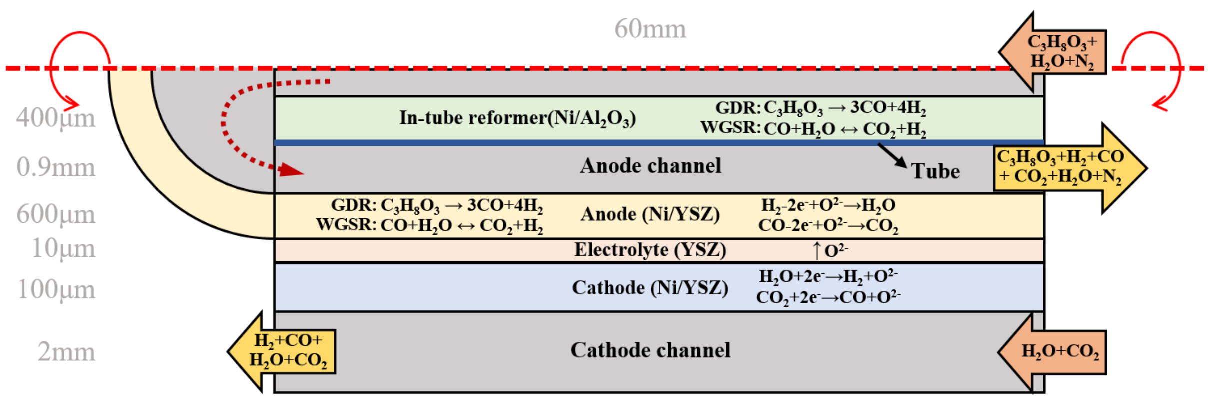

Figure1 Tubular glycerol-assisted co-electrolysis system

Proceedings of the 15th International Green Energy Conference
IGEC2023-094
July 10-13, 2023, Glasgow, UK

WASTE HEAT RECOVERY AND THERMAL MANAGEMENT OF AUTOMOTIVE ENGINE THROUGH A SPLIT-FLOW ORGANIC RANKINE CYCLE WITH COMPOSITION-MATCHING CAPABILITY

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ABSTRACT (FONT, ARIAL, SIZE 9.5, BOLD)

Enabling thermal management functions with automotive engine waste heat recovery systems (E-WHRS) is an attractive approach to lifting their potential for vehicular applications, leading to emission reduction in the transportation sector. Although the split-flow organic Rankine cycle permits both thermal management and heat recovery, the low allowable expander inlet pressure constrains its performance.

Here, we propose to exploit the temperature glide of the zeotropic mixture (R1233zd(E)/R1234ze(E)) for boosting the expander inlet pressure and to further enhance the system performance by composition matching. Namely, two-level modifications are performed in this study. Firstly, the factor limiting the expander inlet pressure of the R1233zd(E)-based split-flow cycle is identified, namely, the engine coolant heater's pinch point restricting the energy absorption from the engine coolant. Thus, we propose to add R1234ze(E) to form a zeotropic mixture with temperature glide characteristics and successfully lower the position of the pinch point, lifting the maximum allowable expander inlet pressure and boosting the net power output by 25.1 %. Furthermore, as the permissible expander inlet pressure is determined by mixture composition, separating the high-volatility mixture from the mixture in the main cycle loop seems to be an efficacious way of further increasing pressure. Hence, we substitute the normal condenser with a liquid-vapour separation condenser, enabling the separated high-volatility working fluid to absorb the engine coolant heat. The low-volatility mixture flows through another branch of the split-flow cycle. Comparative analysis verifies the feasibility of mixture separation for simultaneously lifting expander inlet pressure and maintaining condensing pressure. The liquid-vapour separation condenser-based E-WHRS achieves a 30.6 % improvement in net power output compared with pure R1233zd(E)-based E-WHRS and can fully substitute the original thermal management system of engine coolant and recirculated exhaust gas.

Keywords: waste heat recovery, thermal management, zeotropic mixture, liquid-vapour separation condenser

Proceedings of the 15th International Green Energy Conference
IGEC2023-095
July 10-13, 2023, Glasgow, UK

TECHNO-ECONOMIC ASSESSMENT OF A HYBRID RENEWABLE ENERGY SYSTEM WITH HYDROGEN STORAGE

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ABSTRACT
As the global energy matrix is currently undergoing a transition from existing conventional energy sources and experiencing energy security complexities, there has been an unprecedented focus on developing optimized and alternative power systems. Despite the incredibly prolific period for low-carbon technologies and energy transition being at the center of the European agenda, fossil fuels-based energy systems still dominate Mediterranean islands. The frequent power losses, exorbitant cost of electricity, and reliance on imported fossil fuels of most of the non-interconnected Aeolian islands in Italy render the development of renewable energy and storage technologies a necessity of primary importance.

The electricity demand of the island of Salina in Sicily, estimated at 26,000 MWh/year as of 2018, is currently satisfied by two diesel generators with respective capacities of 5.1 MW and 3.1 MW with an annual carbon footprint of 6,000 tonnes CO_2/year. Urgent action is required to improve the current energy supply of Salina, thereby rendering the implementation of a cost-effective and environmentally benign hybrid energy system comprised of various renewable vectors and energy storage technologies an attractive solution for the transition towards a sustainable development. Hybrid renewable energy systems (HRESs) are an emerging and rapidly increasing energy technology, given their several benefits, including maximizing power output whilst minimizing power losses by improving utilization rate, thus, increasing the efficiency of the system whilst contributing to a low-carbon economy. Especially for remote applications such as Salina, where grid flexibility is a major concern, such configurations have become an attractive economic and environmental electrification solution to meet the residential demand without unserved load constraints. However, multiple-degree HRESs are a relatively new employed technology requiring concrete effort to obtain promising results.

This study proposes a renewable hybrid energy system as a cost-effective and environmental solution to satisfy the residential load demand for the island of Salina. The integration of energy storage systems plays a pivotal role in bridging the gap between electrical demand and supply given the discredit of the intermittency of renewable energy systems. To this aim, the HRES comprising of wind turbines, a photovoltaic system, proton-exchange membrane (PEM) electrolysers, PEM fuel cells, and a hydrogen tank is assessed through a techno-economic analysis by optimizing for the lowest net present cost (NPC) of 1.65 M€ and levelized cost of electricity (LCOE) of 0.104 €/kWh. To ensure the system is the most viable configuration for the application site optimization sensitivity analyses, and life cycle assessments are conducted and results are compared with conventional energy systems.

Keywords: Hybrid renewable energy system, hydrogen, techno-economic analysis, optimization, low carbon emission.

Proceedings of the 15th International Green Energy Conference
IGEC2023-096
July 10-13, 2023, Glasgow, UK

PROCESS SIMULATION OF BIOMASS INTEGRATED WITH MOLECULAR DISTILLATION FOR SUSTAINABLE FUEL PRODUCTION

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ABSTRACT

The production of valuable chemicals and fuels from any biomass waste using fast pyrolysis has been widely studied by researchers. Biofuel produced from the fast pyrolysis of biomass waste can be used to replace both the depleting fossil fuels and reduce environmental pollution. This study aimed to develop a fast pyrolysis model for rice husk and forestry residues integrated with molecular distillation unit using ASPEN (Advanced Systems for Process Engineering) Plus software V12. The complex fast pyrolysis reactive system was analyzed and valuable insights into optimizing fast pyrolysis operating parameters and selectively isolating specific valuable chemicals was achieved. The process model utilized the reported experimental conditions, and a good degree of agreement was observed between the experimental and simulation results. The effect of the operating parameters such as temperature, biomass types, on the pyrolysis products yields as well as the bio-oil compounds was also studied. The molecular distillation unit was able to selectively separate valuable bio-oil compounds of interest including levoglucosan, phenol and acetic acid. It can be deduced that the developed fast pyrolysis model integrated with molecular distillation is capable of predicting pyrolysis products yield, bio-oil compounds and isolating chosen valued chemicals for different biomass waste.

Key words: Biomass waste; fast pyrolysis; bio-oil; molecular distillation; ASPEN Plus

Proceedings of the 15th International Green Energy Conference
IGEC2023-099
July 10-13, 2023, Glasgow, UK

MELTING SOLIDIFICATION BEHAVIOUR OF A FORM STABLE GREEN PHASE CHANGE BIO-CHAR COMPOSITE FOR THERMAL ENERGY STORAGE

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ABSTRACT
Thermal energy storage using phase change materials has several potential modern day applications. However, to suitably incorporate latent heat energy storage systems economically the challenges of leakage and low thermal conductivity of these materials need to be addressed. In this direction biochar derived from abundantly available biomass feedstocks has been explored to act as supporting matrix to develop form stable environmentally compatible energy storage material. Biochar has been derived from wheat straw, miscanthus and softwood has been analyzed for their surface structure and utilized in preparation of form stable phase change material. The developed green phase change-bio composite has been thoroughly evaluated for their chemical and thermal properties. The melting solidification behavior of the material has been studied through IR imaging. The properties of the form stable phase change-bio composite synthesized is found to have properties suited for its application in the field of thermal management of photovoltaic modules, electronic devices, and buildings. FTIR results showed that only physical interaction between RT28 (Phase change material) and biochar (supporting matrix) took place, no chemical change has been reported. The latent heat of fusion found to decrease as compared to pure RT, but there is considerable improvement in the thermal stability at elevated temperature.

Keywords: Phase change material, green composite, thermal energy storage, characterization.

Proceedings of the 15th International Green Energy Conference
IGEC2023-100
July 10-13, 2023, Glasgow, UK

ONE-POT SYNTHESIS OF PT-CO NANOPARTICLES ON HIGH SURFACE CARBON MATERIAL AS AN EFFICIENT BIFUNCTIONAL CATALYST

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ABSTRACT

Compatible with renewable and other sustainable forms of energy, proton exchange membrane fuel cells (PEMFCs) are considered one of the most efficient power sources due to their high-energy density, high efficiency and environmental friendliness. However, using the precious-metal platinum as the cathode catalyst limits their large-scale commercial application. Many attempts have been made to develop Pt-based catalysts with low Pt loading and high activity by incorporating other transition metals. Herein, a facile ***one-pot*** synthesis approach of $PtCo_x$ alloy supported on various high surface carbon (HSC) materials has been studied, and the developed catalyst exhibits remarkably improved catalytic activity and durability towards both oxygen reduction reaction (ORR) and hydrogen evolution reaction (HER). Preliminary characterizations, including X-ray Diffraction (XRD), X-ray Photoelectron Spectroscopy (XPS) and Transmission Electron Microscopy (TEM), suggest the uniform dispersion and adjustable composition of $PtCo_x$ alloy on the HSC. The as-prepared $PtCo_x$-HSC demonstrates outstanding catalytic performance for ORR, in which the electrochemical surface area and mass activity are higher than the conventional Pt/C in the half-cell test. When evaluated as a catalyst for HER, the prepared catalyst material requires an extremely low overpotential of 47.6 mV to drive the current density of 10 mA/cm^2. This work provides a low-cost strategy to develop high-performance Pt-Co catalysts, and confirms their potential application in practical PEMFCs.

Keywords: fuel cell, one-pot synthesis, Pt-Co catalyst, bifunctional catalytic activity, durability.

Proceedings of the 15th International Green Energy Conference
IGEC2023-102
July 10-13, 2023, Glasgow, UK

RESEARCH ON CONTROL STRATEGY OF PEMFC AIR SUPPLY SYSTEM UNDER DYNAMIC WORKING CONDITIONS

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ABSTRACT
Proton exchange membrane fuel cell (PEMFC) is considered as one of the most popular types of fuel cell. The control of oxygen excess ratio (OER) is a key issue in the fuel cell system. In this paper, OER is taken as the control target and a cathode air flow control strategy is designed based on Fractional-Order PID control. In order to improve the output performance and efficiency of the system, an OER control index based on the principle of optimal net output power is adopted, which is related to the load current. The results show that this method can achieve high accuracy and fast response real-time OER regulation. Compared with the traditional PID and Fuzzy PID control, the steady-state error of the Fractional-Order PID OER control can be reduced to 0.43 and the response time can be controlled within 10.5s.

Keywords: PEMFC, Air supply system, Fractional-Order PID control, OER, Simulation

Proceedings of the 15th International Green Energy Conference
IGEC2023-103
July 10-13, 2023, Glasgow, UK

GRID OPMIZATION AND DEMAND SIDE MANGEMENT FOR ELECTRIC VECHILES PENETRATION IN REMOTE AREA

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ABSTRACT

The distributed power system in remote and rural area is the main challenges of the future smart grid development. Compared with traditional gasoline pipelines and gas station construction for fossil fuel vehicles, the high demand of Electric Vehicles (EVs) will then consider breaking their products in the market of remote areas. While the EVs adoption is growing globally, remote areas present unique challenges such as limited charging infrastructure, long transmission distances, and varying energy demands under the EVs penetration. This paper firstly defines the typical Remote Areas where the grid density is low with poor cable properties, but the future power demand is growing fast. Besides, their distributed energy is abundant and can contribute to generating electricity for the EVs, including solar energy, wind energy or marine energy. Renewable energy can maximize the reduction of carbon footprint and consumption. Then the Trincomalee city is selected as the simulation object.

Perform national grids simulation optimization and solar power generation management as demand side optimization. Power grid model simulation: use government data to predict that Trincomalee's electricity demand will increase from the current 40MW to 640MW in five years and build a grid simulation model for Sri Lanka's national high-voltage transmission lines. Optimization will target transmission cables that provide higher voltage loads while considering cable properties includes resistance and reactance for optimal power loss and voltage drop respectively, thermal capacity, and power quality. The results show that though a lower resistance and reactance can reduce the power loss and voltage drop during transmission, the relationship does not follow a linear relationship when integrating into the whole power system. The range of resistance and reactance scenarios is set with equal intervals. The optimal point with the higher drop scenario always exists.

The demand side management aims to solve the Trincomalee's intermittency and overproduction issue to keep the supply and demand in dynamic balance. Solar energy production is surveyed for its intrinsic intermittency between day and night time. Based on the climatic conditions and NCRE data in the Trincomalee in 2013, the PV generation system is simulated by MATLAB and Excel and conclude the curves of solar irradiance, temperature and demand. the optimum rated capacity of the battery is then concluded from the demand and solar curve.

The case studies from Sri Land highlight successful examples of distributed grid management in remote and rural areas. The methods contribute to the broader conversation around sustainable transportation and energy systems, and to provide guidance for policymakers and industry stakeholders working towards sustainable and equitable EV adoption.

Keywords: Distributed Power Generation, Smart Grid, Power System Modelling and Optimization, Demand Side Management.

Proceedings of the 15th International Green Energy Conference
IGEC2023-104
July 10-13, 2023, Glasgow, UK

THERMODYNAMIC ASSESSMENT OF HIGH-PARAMETER TRANSCRITICAL CYCLE ENABLED BY CO_2-SO_2 MIXTURE

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ABSTRACT

High-parameter transcritical CO_2 power cycle is regarded as one of the most promising energy conversion systems owing to its high efficiency and compactness. However, it is possible to further improve the thermal efficiency and reduce the size of components by adding CO_2 binary mixtures. In this study, a comprehensive thermodynamic analysis of the high-parameter transcritical power cycle enabled by CO_2-SO_2 mixture is conducted. Simulation results indicate that thermal efficiency increases with the SO_2 mass fraction, while specific work does the opposite. And thermal efficiency increases abruptly as the SO_2 mass fraction is higher than 0.2. However, thermal efficiency decreases with the SO_2 mass fraction at higher maximum pressure. Additionally, system at a higher minimum temperature is more sensitive to SO_2 mass fraction. This preliminary research will serve as a guideline for the optimization of transcritical power cycle enabled by CO_2-SO_2 mixture at design and off-design conditions.

Keywords: transcritical cycle, CO_2-SO_2 binary mixture, thermodynamic analysis.

Proceedings of the 15th International Green Energy Conference
IGEC2023-105
July 10-13, 2023, Glasgow, UK

A RATIONAL EXERGY MANAGEMENT APPROACH FOR MINIMUM CO_2 EMISSIONS RESPONSIBILITY AT THE DISTRICT SCALE IN GLASGOW

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ABSTRACT
Addressing climate change is an urgent issue that requires effective and sustainable solutions at multiple scales, including districts and cities. Existing solutions have mostly focused on energy efficiency and renewable energy. At the same time, additional support to these opportunities remains to be captured based on a more rational approach to utilizing the quality of these energy sources and matching them with the quality and quantity of demand that becomes critical at the district and city scales. For example, complete electrification roadmaps envision large-scale applications of heat pumps, which require electrical energy with high unit exergy while providing heat or cold with lower exergy. Unless continued technological innovations substantially increase the coefficient of performance of the heat pumps, this solution requires attention by noting that exergy destruction can cause avoidable carbon dioxide emission responsibilities. This research focuses on a Rational Exergy Management Model-based approach at the district scale to improve districts' contribution to effective climate mitigation by also addressing exergy mismatches and ways of minimizing them. This model is linked to climate scenarios aligned with limiting global warming to 1.5°C and urban-level climate mitigation scenarios constructed specifically for urban areas. The remaining territorial scope carbon dioxide emissions are associated with Rational Exergy Management inefficiencies where exergy mismatches cause avoidable carbon dioxide emissions responsibility in the energy system. Based on the case study of Glasgow, the urban area is currently responsible for 10 MtCO2eq of territorial emissions in 2020 that need to be reduced to 5 MtCO2eq in 2025 and approach 0 MtCO2eq in 2030 based on the Climate Neutrality Mission. The main metric of this study to close the emissions gap according to the climate mitigation scenario is improvements in the Rational Exergy Management Efficiency. A new formulation is derived from linking avoidable carbon dioxide emissions with this efficiency metric directly and applied to this case study. In addition, the results are mapped to the university campus area with a district heating network. Another new metric, named Exergy Star, was developed to rate districts and buildings for a green status that can be applied to Google Earth 3-D building rendering to visualize what it would take to continue transforming the urban area by providing better exergy matches while improving energy efficiency and renewable energy use. The urban-level climate mitigation scenarios and Rational Exergy Management Model Efficiency are calculated for this portion of the built-up urban area, specifically within Glasgow's 174 km^2 built-up area. These results provide a strategic roadmap for Glasgow by coupling climate mitigation scenarios with the Rational Exergy Management Model for the first time to support efforts for decarbonization. Beyond the present case study, the results are useful for guiding other urban areas to embark on an effective approach for climate mitigation at large and bring society to a better balance with the planet.

Keywords: climate mitigation, exergy, avoidable emissions, urban areas, Rational Exergy Management Model, exergy star

MATERIAL DEVELOPMENT TO ENHANCE REVERSIBLE SOLID OXIDE CELLS FOR HYDROGEN PRODUCTION AND POWER GENERATION

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ABSTRACT

In electrolysis mode, reversible solid oxide cells (RSOCs) can use electricity from renewable sources to produce green hydrogen and, in reverse, in fuel cell mode, uses hydrogen to generate electricity.[1] RSOCs present a viable opportunity to solve renewable energy intermittency and achieve on-demand hydrogen and electricity production. However, multiple requirements including high catalytic activity, high ionic and electronic conductivity and cell component stability must be simultaneously satisfied for electrolytic to fuel cell mode switching to be effective in RSOCs. While the state-of-the-art materials for fabricating solid oxide cells cannot currently fulfil these multiple electrochemical requirements, an exsolution process can simultaneously improve such functionalities in these materials. An exsolution process entails the segregation of metallic cations to form catalytically active nanoparticles on the surface of a perovskite lattice (the support structure) – this results in highly active, anchored and therefore stable catalytic sites.[2,3] Also, the growth of such nanoparticles to reside within the bulk of the perovskite lattice (bulk exsolution) has been recently shown to improve ionic conductivity.[3] Therefore, this research seeks to develop new perovskite materials using surface and bulk exsolution to fulfil the multiple electrochemical requirements of RSOCs. An A-site deficient perovskite with a stoichiometric composition such as $(Sr,Ca)_{1-\alpha}(Ti,Fe,Ni)O_3$, known for its ability to drive B-site exsolution in their tendency to revert to a stable ABO_3 perovskite stoichiometry,[2] is targeted in this research. Parameters related to the synthesis of the new perovskite have been examined at the current stage of this research. Also, five potential precursor materials, ($Fe(NO_3)_3.9H_2O$, $Ni(NO_3)_2 6H_2O$, $SrCO_3$, $CaCO_3$, and TiO_2) have been studied to ascertain their suitability and develop a synthesis route for the new perovskite materials. The methodology adopted for the study involved the characterisation of the potential precursor materials using thermogravimetry analysis (TGA), scanning electron microscopy (SEM), and X-Ray diffraction (XRD)analysis. The TGA results revealed Fe_2O_3, NiO, SrO and CaO as the decomposition products of $Fe(NO_3)_3.9H_2O$, $Ni(NO_3)_2 6H_2O$, $SrCO_3$ and $CaCO_3$, while no substantial decomposition occurred in TiO_2.

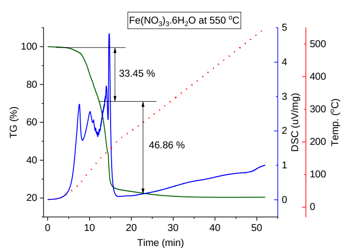

Fig. 1. A TG curve, DSC curve, and temperature response for $Fe(NO_3)_3.9H_2O$

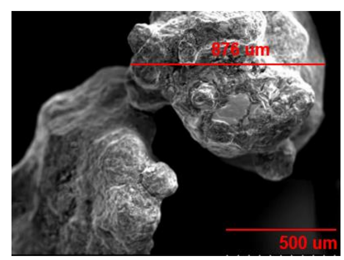

Fig. 2. The SEM image of $Fe(NO_2)_3.9H_2O$

These decomposition products have indicated the suitability of the different materials as precursors for the desired A-site deficient perovskite material. Fig. 1. shows a combine TG curve, DSC curve and temperature response for $Fe(NO_3)_3.9H_2O$, while Fig. 2. shows the SEM image for $Fe(NO_3)_3.9H_2O$. Also, the SEM images have revealed the morphologies of the respective precursor materials. Furthermore, the XRD analysis of $Fe(NO_3)_3.9H_2O$, $Ni(NO_3)_2.6H_2O$ and $CaCO_3$ have confirmed their respective crystalline composition and shall help in understanding the complex crystal changes the precursor materials will undergo to form the desired perovskite material. Considering the decomposition temperature ranges: 50 – 400 °C, 56 – 573 °C, 600 – 850 °C, and 620 – 900 °C, respectively, for $Fe(NO_3)_3.9H_2O$, $Ni(NO_3)_2 6H_2O$, $CaCO_3$, and $SrCO_3$, it is expected that all the precursors, except TiO_2, shall fully decompose into reactive oxides before 950 °C. This indicates that the desired perovskite synthesis reaction will likely occur between the temperature range of 600 – 1000 °C, following the decomposition time of $CaCO_3$ and $SrCO_3$.

Keywords: Perovskites, Exsolution, Reversible solid oxide cells, Hydrogen production, Net-zero emission.

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Proceedings of the 15th International Green Energy Conference
IGEC2023-108
July 10-13, 2023, Glasgow, UK

EXPERIMENTAL INVESTIGATION ON THE STABILITY OF BIOCOMPOSITE PHASE CHANGE MATERIALS FOR BUILDING APPLICATIONS

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ABSTRACT

According to International Energy Agency, active space cooling and air conditioning systems are essential to maintain indoor thermal comfort, which consumes approximately 16% of the building sector's final electricity consumption and contributes 3.94% of global greenhouse gas emissions. In this regard, low-cost but effective passive solutions have immense potential to improve operational energy efficiency in the building sector. The use of organic phase change materials (PCM) on building envelope can provide high thermal mass and thus can lower the temperature fluctuation inside the building. Porous biochar has been used as a matrix to compensate for the low leakage stability and low thermal conductivity of available PCM (OM35). The biochar has been obtained through pyrolysis of water hyacinth and co-pyrolysis of water hyacinth (W), sugarcane bagasse (S), and yellow oleander (Y) at a temperature of 550ºC, for a holding time of 1 hour and at a heating rate of 10ºC/min in Argon environment at a fixed bed batch reactor. Two biocomposite PCMs, namely, W-PCM and T_0_SWY-PCM, are made through simple impregnation method. The durability and dependability of the developed biocomposite PCMs need to be studied before applying them to building envelopes. In the current study, W-PCM and T_0_SWY-PCM are studied for the change of thermal, physical, and chemical properties after performing thermal cycling tests and compared with OM35. The material has been subjected to simultaneous heating and cooling cycles in a developed thermal cycling chamber within a temperature range of 25-45ºC. The temperature inside the insulated chamber is maintained with the help of a tubular air heater (500W), eight Peltier cooling elements (12 V, 60 W), and two Subzero temperature controllers (SZ7569). The samples have been tested for leakage stability, chemical stability, and thermal stability after the completion of 50,100,150 and 200 thermal cycles, respectively. The FTIR and XRD analyses confirm that no significant changes occur in the functional groups for both the biocomposite PCMs after completing 200 thermal cycles. Also, the leakage stability of the two biocomposite PCMs has been ensured through the leakage stability test on filter paper (Whatman Grad 1, 11 µm size). The DSC results showed that there is a 0.25% and 2.58% reduction in melting point and heat of fusion, respectively, after 200 cycles for W-PCM. The negligible changes in physical, thermal, and chemical properties over the thermal cycles confirm that W-PCM is a good option to be used as thermal energy storage material in building envelopes.

Keywords: Biocomposite PCM, thermal cycling, leakage stability, melting temperature, the heat of fusion.

Proceedings of the 15th International Green Energy Conference
IGEC2023-110
July 10-13, 2023, Glasgow, UK

THE DESIGN AND OPTIMIZATION OF COOLING PIPE NETWORK FOR HIGH POWER PROTON EXCHANGE MEMBRANE FUEL CELL STACK

Xi Chen, Yan Luo

ABSTRACT
Temperature is an important factor affecting the performance of proton exchange membrane fuel cell (PEMFC). Uneven temperature distribution in a PEMFC stack may seriously lead to the degradation of stack performance. In this paper, aiming to solve the heat unevenness problem, a new cooling pipe network design for PEMFC stack is proposed, and the thermal and flow characteristics are investigated using temperature uniformity index (TUI). Two models (conventional parallel flow field and new finned flow field) are proposed to investigate the maximum temperature, temperature uniformity and pressure distribution of the two flow fields under different conditions. The results show that the novel design can effectively reduce the maximum temperature of the stack by 4~5℃ and the temperature uniformity index by 37% compared with the conventional DC channel cooling network.

Keywords: High power PEMFC stack; Cooling flow field; Thermal management.

Proceedings of the 15th International Green Energy Conference
IGEC2023-112
July 10-13, 2023, Glasgow, UK

ENERGY AND EXERGY ANALYZES OF A SOLID OXIDE FUEL CELL-ENGINE-ORGANIC RANKINE CYCLE POWER GENERATION SYSTEM WITH METHANOL FOR SHIP APPLICATION

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ABSTRACT

The current marine power system has problems of low efficiency and high carbon emissions. This paper presents a solid oxide fuel cell (SOFC)-engine-organic Rankine cycle (ORC) power generation system with methanol for ship application. Methanol provides hydrogen for SOFC through online catalytic hydrogen production, and the engine further generates electricity by using the fuel in the anode tail gas of SOFC. Then the engine exhaust gas and SOFC cathode exhaust gas jointly drive the ORC system to generate electricity. A modular modelling approach was used to analyses the hybrid power generation system performance and exergy. Then, the influence of various parameters on the performance of hybrid power generation system is analyzed, mainly including excess air coefficient, fuel utilization ratio, etc. The results show that the power generation efficiency of the hybrid power generation system reaches 59.85%, which is 20% higher than that of the single methanol engine, and the carbon emission generated by the hybrid power generation system is also significantly lower than that of the current power system. The exergy efficiency of the system is 56.17%, of which the air heat exchanger and engine are the components with relatively large damage.

Keywords: Solid oxide fuel cell, Organic Rankine cycle , Methanol , Exergy analysis.

Proceedings of the 15th International Green Energy Conference
IGEC2023-113
July 10-13, 2023, Glasgow, UK

DESIGNING CO_2 MIXTURES FOR TRANSCRITICAL CO_2 POWER CYCLE WITH PREHEATER AND RECUPERATOR VIA THE CAMD METHOD

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ABSTRACT
The transcritical CO_2 power cycle with both preheater and recuperator is suitable for recovering waste heat from internal combustion engines due to the good match between CO_2 and the two heat sources, as well as its potential for miniaturization. Utilizing CO_2 mixtures as working fluids can further improve its performance. This work uses the CAMD method to identify feasible molecules and perform a global search for additives that are suitable for waste heat recovery from internal combustion engines. The optimized CO_2 mixture working fluid suitable for the preheating cycle of CO_2 with multiple heat sources is obtained, further improving the efficiency of the internal combustion engine system. The results show that the optimal working fluid, CH3-C≡CH, can increase the system efficiency from 14.11% to 16.54%.

Keywords: transcritical CO_2 power cycle, CAMD, CO_2-Based binary mixtures, PC-SAFT EoS.

Proceedings of the 15th International Green Energy Conference
IGEC2023-114
July 10-13, 2023, Glasgow, UK

DESIGN AND EXPERIMENT OF A SINGLE-LOOP ORGANIC RANKINE CYCLE ABSORBING ENGINE COOLANT AND EXHAUST HEAT

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ABSTRACT
This work focuses on the system design of the ORC-based engine waste heat recovery system. Since engine coolant and exhaust have comparable heat but apparently different temperature, applying a single-loop configuration cycle to achieve efficient heat absorption from them is challenging. Through the proposed calculation algorithm, the influence on the power output performance of the heat recovery rate of the heat source, cycle configuration, and working fluid are clearly presented. A system with a serial arrangement of recuperator, preheater, and evaporator is identified as the optimal scheme and R245fa and R1233zd are preferable working fluids with a maximum power output of 16.42 kW and 16.71 kW, respectively. The feasibility of cycle design through model analysis is validated by an R245fa ORC prototype plant experiment with a peak power generation of 12.77 kW.

Keywords: engine waste heat recovery, organic Rankine cycle, system design, prototype test.

Proceedings of the 15th International Green Energy Conference
IGEC2023-115
July 10-13, 2023, Glasgow, UK

DYNAMIC ANALYSIS OF HYBRID ELECTRIC VEHICLE COUPLED WITH WASTE HEAT RECOVERY SYSTEM UNDER DIFFERENT ROAD CONDITIONS

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ABSTRACT

Hybrid trucks with low fuel consumption, low emissions and long range are considered to be effective fuel-efficient trucks. In addition, the engine of hybrid truck is still one of the main power sources. As a large amount of energy of engine is dissipated in the form of waste heat, waste heat recovery (WHR) system is still a promising energy saving solution. The operating conditions of trucks are complex and varied. In order to evaluate the energy saving effect of hybrid electric vehicle (HEV) coupled with WHR system under different road conditions (urban, suburban and highway), the dynamic model of hybrid truck equipped with WHR system was constructed in this study. The validity of the model was then verified by experimental data. The analysis of the vehicle performance and the energy saving effect of the WHR system was carried out based on the operation results of the dynamic model under different road conditions. The study results show that the effective operation interval of the WHR system is suburban and highway conditions, while the energy saving effect is not significant in urban conditions. When the target truck is fully loaded, the WHR system can save 6.36% fuel under mixed working conditions.The urban conditions are the superior operating range for the hybrid system. The combination of two energy-saving technologies enables efficient use of energy in all operating conditions. The study of the dynamic characteristics of the HEV-WHR system is of great importance for the practical application of both systems.

Keywords: Hybrid, Waste heat recovery, Organic Rankine cycle, Energy management.

Proceedings of the 15th International Green Energy Conference
IGEC2023-116
July 10-13, 2023, Glasgow, UK

IMPACT OF BIOMASS-COAL BLENDING ON FLOW DYNAMICS IN A DUAL FLUIDIZED BED GASIFICATION SYSTEM

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ABSTRACT

The versatility in the selection of feedstock for the generation of high quality syngas has emerged dual fluidized bed gasification (DFBG) as a very promising technology. The principle of DFBG is heavily dependent on the hydrodynamics and heat transfer characteristics of the gas-solid system. Furthermore, the complexity of the hydrodynamics increases with more number of fuels of different physico-chemical characteristics due to its nonlinearity and transience. It is, therefore very essential to study the hydrodynamics of the multi-phase system. The present work focuses on two fluid model simulations of a dual fluidized bed gasifier to study the impact of biomass-coal blending with silica sand as the bed material. The simulation has been performed using the Multiphase Flow with Interphase eXchanges (MFiX) simulation platform. Six different biomass-coal (BM:C) blending proportions such as 0:0, 1:5, 2:5, 3:5, 4:5 and 5:5 are considered for the 2-D two fluid model (TFM) simulation of the gasifier. An optimum superficial air velocity of 0.2 m/s is considered for the entire simulation for a grid of 6000 computational cells. The impact of biomass-coal blending proportions on the static pressure and pressure drop, axial and radial voidage, suspension density, radial solid velocity profile and granular temperature are analysed using the Paraview software. The numerical investigation has revealed that the static pressure decreases with an increase in biomass-coal blending proportion for a fixed height within the gasifier. The axial bed voidage has also dropped with a surge in biomass-coal blending proportion up to 0.6 m height from the bottom and then has started to rise until it becomes unity at a height of about 0.9 m. Moreover, suspension density has enhanced with a rise in blending proportion due to the density difference between biomass and coal. The difference in density and particle size of biomass and coal has also contributed towards a decrease in the radial voidage and solid velocity with increased blending proportion. An escalation in granular temperature has been observed with the decline in solid volume fraction for all the blending proportions. However, the granular temperature has dropped with an increase in blending proportion. This numerical study will act as a platform for the experimental investigation of the biomass-coal blending performance of the DFBG system.

Keywords: Dual fluidized bed gasification (DFBG), Multiphase Flow with Interphase eXchanges (MFiX), Two-fluid model (TFM), hydrodynamics, biomass-coal blending**.**

Proceedings of the 15th International Green Energy Conference
IGEC2023-117
July 10-13, 2023, Glasgow, UK

MICROALGAE MASS CULTIVATION FOR COMMERCIAL BIOFUEL PRODUCTION : CHALLENGES FROM MASS CULTIVATION TO LIPID EXTRACTION

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ABSTRACT

Microalgae, especially oleaginous species have emerged as a promising source of biofuel due to their high photosynthetic efficiency, fast growth rate, and ability to grow in various environments. The production of biofuels from microalgae are considered promising for third-generation biofuels as they are renewable alternatives to conventional fossil-based fuels. Alternatively, microalgae also can potentially reduce greenhouse gas emissions and alleviate the global energy crisis. However, the commercialization of microalgae-based biofuels still faces various challenges, such as cost-effective cultivation and harvesting methods, efficient lipid extraction techniques, and development of high-performance conversion technologies.

Started from 2020, PETRONAS embarked on the full-fledged studies of microalgae mass cultivation with the aim to produce sustainable fuel as an alternative to hydrocarbon fuel. The 3 years experiences recorded various technical challenges, including but not limited to, seeding preparation, mass cultivation methods, facilities requirement, harvesting efficiency, as well as lipid extraction difficulties.

Selection on microalgae seeds and mass cultivation strategies are crucial steps prior to commercialize. Based on our studies show that consortia of microalgae population produce high dynamic growth performance affected by environmental condition, especially in tropical condition. Besides, an efficient harvesting method as well as extraction method designed with low-cost must be deployed to maximize biomass acquisition with optimize recovery rate.

This review summarizes the current state of research on microalgae for biofuel production and discusses the opportunities and challenges in the development of sustainable and economically viable microalgae-based biofuels.

Keywords: microalgae, biofuel, renewable oil

Proceedings of the 15th International Green Energy Conference
IGEC2023-118
July 10-13, 2023, Glasgow, UK

SPATIO-TEMPORAL AND WEATHER CHARACTERIZATION OF ROAD LOADS OF ELECTRIFIED HEAVY DUTY COMMERCIAL VEHICLES ACROSS U.S. INTERSTATE ROADS

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ABSTRACT

Adoption of battery electric vehicles (BEV) in heavy duty (HD) commercial freight transportation is difficult due to technological and economic hurdles. Beyond safety and compliance, fleet and operational logistics necessitate both high uptime and parity with diesel system productivity/Total Cost of Ownership to support widespread deployment of electric powertrains. However, relatively high energy storage costs, along with the higher weight of BEV systems, limit the viability of HD commercial freight transport to shorter-range applications where smaller batteries will serve for mission energy requirements (single operational shift). Knowing the energy consumption and operating variations of these commercial vehicle systems is crucial for effectively sizing the energy storage systems. This paper is the first in a series of studies to understand the regional specific operating design domain variations of commercial Class 8 HD trucks and the associated impact to their energy requirements. In particular, the local weather conditions are shown to influence the total vehicle energy usage. Further, the impact of temperature, pressure, and humidity changes are shown to impact the local air density. This is needed to calculate aerodynamic drag on vehicles and has been found to play a significant role in the overall performance of a vehicle. Although the methodology of calculating air density varies only slightly throughout the literature, the application to transportation has still been limited. This study provides a means by which air density can be estimated for the contiguous U.S. using the NOAA MADIS dataset. These air density estimates were then used to determine vehicle performance in varying regions of the country to highlight the importance of consideration of weather variables when monitoring vehicle performance, but also to provide recommendations based on these locales upon fleet conversion to BEVs.

Keywords: heavy duty electric vehicle, energy use, sensitivity, weather model, air density, aerodynamic drag

Proceedings of the 15th International Green Energy Conference
IGEC2023-119
July 10-13, 2023, Glasgow, UK

THE MECHANICAL AND PIEZOELECTRIC PROPERTIES OF La-DOPED ZnO

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ABSTRACT
In recent years, there have been many applications for piezoelectric as part of energy harvesting devices. It has attracted much attention as a promising method to convert waste energy into usable energy. Energy harvesting using piezoelectric material is one of the research topics due to its high scalability, simple device design, and high biocompatibility. Optimizing lanthanum (La) doping in the zinc oxide (ZnO) structure increases piezoelectricity, producing better energy harvesters. We have focused on the mechanical properties and piezoelectric coefficient (d_{33}) of La-doped ZnO based on the study of first-principle calculations with density functional theory (DFT). The generalized gradient approximation with Perdew-Burke-Ernzerhof and for solids (GGA-PBEsol) functional was employed using CASTEP and GULP simulation codes. The lattice parameter and volume of ZnO and La-doped ZnO using CASTEP computer code obtained are in good agreement with the experiments and employing GULP, the mechanical properties (elastic constants (C_{ij}), bulk modulus (B), shear modulus (G), Young's modulus (E), Pugh's ratio (B/G) and Poisson's ratio (v)) of La-doped ZnO are slightly lower than of pure ZnO. The value of the piezoelectric coefficient (d_{33}) and the piezoelectric potential generated from the pure ZnO and La-doped ZnO was found to increase from 10.00 pC/N to 14.46 pC/N. The calculation results are in good agreement with the previous experimental findings, and the research can provide a theoretical basis for applying La-doped ZnO as a piezoelectric nanogenerator material in the future.

Keywords: Density Functional Theory (DFT), mechanical properties, piezoelectric properties, zinc oxide

Proceedings of the 15th International Green Energy Conference
IGEC2023-120
July 10-13, 2023, Glasgow, UK

PEROVSKITE SOLAR CELLS WITH TUNABLE BANDGAPS FOR BEAM-SPILTTING PHOTOVOLTAIC-THERMAL SYSTEM

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ABSTRACT
Solar energy is clean and abundant, and it has been considered as a green energy. Solar energy can be utilized by photovoltaics (PV) or concentrating solar power (CSP) generation. PV converts solar energy into electricity cost-effectively, but it is sensitive to environmental conditions, such as weather, and unable to utilize spectrum outside the spectral response range. In contrast, CSP is less sensitive to environment conditions, but more costly than PV. Their advantages can be combined by integrating PV and CSP into a beam-splitting photovoltaic-thermal (PV-T) hybrid system, which splits incident solar radiation and projects the photovoltaic spectrum onto solar cells and the rest to CSP. In this way, full spectrum of solar radiation can be utilized, and the overall conversion efficiency is enhanced by increasing the efficiency of solar cells and heat. The beam-splitting PV-T system has shown a great potential in solar energy production; however, few studies consider hybrid systems with the newly emerging perovskite solar cells. This paper reports a perovskite solar cell (PSC) with various bandgaps by replacing Iodine ion (I^-) in $FA_{1-x}MA_xPbI_3$ with Bromine ion (Br^-) in different proportions. In addition, the spectral response ranges of PSC were adjusted to 300-700 nm, 300-730 nm, 300-780 nm, 300-800 nm and 300-830 nm in external quantum efficiency (*EQE*) curves. We also analyzed the trends of photovoltaic properties of PSC, measured with solar simulator, validated with characterization of perovskite films. Furthermore, a beam-splitting PV-T system with PSC of different spectral response ranges was simulated and optimized using the experimental data. Results show that the beam-splitting PV-T system can achieve a theoretical solar-to-electric efficiency of 25.74%. This efficiency is higher than those of single CSP and single PSC, which are 23.97% and 17.27% respectively. The efficiency tends to decline with ratio of Br^- increasing, because though the open-circuit voltage boosts and *EQE* remains unchanged, the declined quality of PSC reduces the fill factor, which is detrimental to the overall efficiency. Even though introducing Br^- cannot increase the overall efficiency, the changed spectral response range brings about shift of the optimum cutoff wavelength, and the efficiency just slightly decreases with low ratio of Br^- mixing, which is important for matching beam splitters in beam-splitting PV-T system.

Keywords: solar energy, photovoltaic-thermal hybrid system, perovskite.

Proceedings of the 15th International Green Energy Conference
IGEC 2023-121
July 10-13, 2023, Glasgow, UK

Anion exchange membrane electrolyser with highly active oxygen evolution reaction self-support electrode: Sulfidation of $CoCuO_x$/NF with heterostructure and oxygen vacancies

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ABSTRACT

Anion exchange membrane water electrolyser (AEMWE) is catching more attention for hydrogen generation due to the ability to employ non-precious metal catalysts. Nevertheless, the design of high-performance and durable electrodes for the anodic oxygen evolution reaction (OER) of the AEMWE system is deficient and complicated in current research. In this study, a S-CoCu-oxide self-supported OER electrode with heterostructure prepared on nickel foam (NF) substrate by the hydrothermal method was applied as the anode of the AEMWE. The formation of abundant oxygen vacancies and heterostructure, which further enhanced the electron and charge transfer process, was introduced by the sulfidation reaction. The S-$CoCuO_x$/NF exhibits a low overpotential of 313 mV at 100 mA cm^{-2} and 200 h (100 mA cm^{-2}) long-term durability in 1 M KOH solution. In the lab-scale AEMWE system, the S-$CoCuO_x$/NF served as the anode, revealing enhanced performance (1000 mA cm^{-2}@1.87 V). Furthermore, the low mass transfer resistance at high current density attributed to the unique structure results in superior durability at 500 mA cm^{-2} for 50 h at 60 ℃. The incorporation of sulfur could lead to more activity sites originating from the formation of oxygen vacancies and heterostructure, demonstrating the feasibility of the application of the S-$CoCuO_x$/NF in the commercial AEMWE system.

Keywords: Oxygen evolution reaction; Electrocatalyst; Hydrogen energy; Anion exchange membrane water electrolyser

Proceedings of the 15th International Green Energy Conference
IGEC2023-123
July 10-13, 2023, Glasgow, UK

EXPERIMENTAL STUDY OF GRAPHENE-COATED NICKEL FOAM AS FLOW FIELD IN LOW-PLATINUM CATALYST FUEL CELLS

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ABSTRACT
As mankind realizes the problem of fossil fuel scarcity and environmental pollution, the global energy structure is transforming. Clean renewable energy will gradually replace traditional fossil fuels and become the energy of the future. Hydrogen is currently recognized as the future energy source, and the hydrogen fuel cell is a relatively promising clean energy conversion device for converting hydrogen energy to electrical energy. At present, the urgent challenge of the fuel cell stack for vehicles is to further improve its volumetric power density and reduce its cost, namely, boosting the power density, reducing the thickness, and platinum loading. And the improvement of the flow field and electrode is the key to enhancing the cell power density.

We investigated the use of graphene-coated nickel foam instead of the conventional trench ridge flow field for low-platinum catalytic layers and found that the PEMFC output performance with graphene-coated nickel foam as the flow field is higher and the mass transfer loss is lower at the same low-pressure drop compared to the parallel flow field, and we found that the metal foam flow field was more suitable for low-platinum catalytic layers. We also investigated the sensitivity of low-platinum catalyst PEMFC with metal foam flow filed to the operating conditions.

Keywords: PEMFC, Low platinum, Metal foam, experiment.

Proceedings of the 15th International Green Energy Conference
IGEC2023-124
July 10-13, 2023, Glasgow, UK

NANOSTRUCTURED ANODIC WO_3 FILMS FOR PHOTOELECTROCHEMICAL WATER SPLITTING

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ABSTRACT

Tungsten oxide (WO_3) is a strong candidate as the photoanode in photoelectrochemical (PEC) water splitting owing to its moderate bandgap (2.6-3.2 eV) for wide light absorption and stable physicochemical properties. This work reports a morphology engineering strategy to fabricate nanostructured tungsten oxide film and its performance as a photoanode for PEC water splitting. By controlling the anodization voltage, the morphology of anodic WO_3 film was altered, and their photoelectrochemical performances were compared. Anodization of tungsten film in fluoride-containing H_3PO_4 leads to the growth of either irregular porous tungsten oxide layers or terrace-like tungsten oxide layers, depending on the anodic potentials. The possible growth mechanism of the porous oxide layer during anodization is proposed with a combination of the field-assisted dissolution model and the oxygen bubble mould model. Under light irradiation, the photocurrent density was 3.0 mA cm^{-2} at 1.23 V *vs.* RHE (V_{RHE}) for annealed terrace-like WO_3, which was almost 3 times larger than that of annealed porous WO_3. As photoanode, terrace-like WO_3 films could generate hydrogen at 58 μmol cm^{-2} h^{-1} under simulated solar light, while porous WO_3 films produced hydrogen with a slower rate of 28 μmol cm^{-2} h^{-1}. The terrace-like WO_3 films experience higher photoelectrochemical performance and incident photon-to-electron conversion efficiency (IPCE) than porous WO_3 due to more regular nanostructure, smaller band gap, fast charge transfer rate and alleviated recombination rate. This study shows that morphology control can effectively enhance the photocurrent density and the IPCE of photoanodes and suggests a practical direction for finding the optimal WO_3 films for PEC water splitting.

Keywords: PEC water splitting, photoanode, anodization.

Proceedings of the 15th International Green Energy Conference
IGEC2023-125
July 10-13, 2023, Glasgow, UK

Size Effect of Cubic Co-N-C Particles on Cathode Oxygen Reduction for PEMFC

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ABSTRACT

Metal-nitrogen-carbon (M-N-C) materials, a kind of platinum-free catalysts, have the potential to replace platinum-group-metal (PGM) catalysts in proton exchange membrane fuel cells (PEMFC). Nevertheless, the relationship between M-N-C catalyst particle morphology and electrochemical behavior is still unclear. Herein, the Co-N-C catalysts with a particle size in the range of 1 μm~100 nm are adjusted by changing cetyltrimethylammonium bromide (CTAB) content during the synthesis of zeolitic imidazolate framework (ZIF) precursor. The effect of particle size on the ORR performance of the catalysts was detailed studied by analyzing the double layer capacitance values, charge transfer capacity, and mass transfer capacity. The result indicates particle size of cubic Co-N-C catalyst has a dominant impact on the utilization rate of active sites and the gas transport resistance, while its influence on the pore sizes and the specific surface area is not apparent. The Co-N-C catalyst with a particle size of 100 nm has a highly limited current density of 5.01 mA cm^{-2} in the RDE test and a high peak power density of 304 mW cm^{-2} in the PEMFC test. This study provides important information for the future development of PGM-free ORR catalysts for PEMFC.

Keywords: Size effect, Oxygen reduction reaction, Proton exchange membrane fuel cells, Co-N-C catalyst

Proceedings of the 15th International Green Energy Conference IGEC2023-126
July 10-13, 2023, Glasgow, UK

TUNING ELECTRONIC AND MAGNETIC PROPERTIES OF Zn-Ni-Co TERNARY SPINEL OXIDES FOR SUPERCAPACITORS ELECTRODE

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ABSTRACT
Modifying the spinel Co_3O_4 via doping with other 3*d* transition metals provides a rich redox reaction, hence improving the electrode's performance. Herein, a theoretical work of the Zn-Ni-Co spinel oxides is performed using density functional theory (DFT) implemented in the CASTEP to calculate the structural, electronic, and magnetic properties. The doped Zn into $NiCo_2O_4$ with different doping ratios (x=0.25, 0.50 and 0.75) were calculated to form the ternary spinel oxide. The introduction of Zn has provoked atomic bonding and structure due to the unsatisfied antiferromagnetic spin arrangement at the tetrahedral site as the substitution of Co^{2+} with non-magnetic Zn^{2+} ions. The density of states (DOS) analysis shows that the value near the Fermi level at a higher doping ratio x=0.75, namely $Ni_{1.00}Zn_{0.75}Co_{1.25}O_4$ (16.13electron/eV) has increased from binary oxide, $NiCo_2O_4$ (12.30electron/eV). Such an increase in this value leads to an enhancement of electrical conductivity. The variation of doping concentration enables adjustment of the suitable content and consequently can tune the material's properties.

Keywords: density functional theory, Co_3O_4, doping, electronic properties, magnetic properties

Proceedings of the 15th International Green Energy Conference
IGEC2023-127
July 10-13, 2023, Glasgow, UK

QUATERNIZED POLYMERS OF INTRINSIC MICROPOROSITY AS ANION EXCHANGE IONOMERS

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ABSTRACT

As an essential component of the triple-phase-boundary for electrocatalytic reactions in fuel cells, anion exchange ionomers (AEI) should not only serve to bind catalysts and conduct anions, but also efficiently transport water and gases. The rigid and twisted backbone structure within the polymers of intrinsic micropores (PIMs) provides a large number of micropores that confer excellent gas permeability. The average pore size of our synthesized PIM-1 was 1.5 nm, and the BET specific surface area reached 717 $m^2\ g^{-1}$ (77 K, N_2 adsorption). Here, anion exchange ionomers (AEIs) for catalysts layers derived from quaternized PIM-1 (QPIM-1) was reported for the first time. The intrinsic microporosity of QPIM-1 facilitates the rapid and efficient transport of anions. The use of QPIM-1 as AEIs showed excellent performance in rotating disk electrode (RDE) tests. An ultimate current density of 7.4 mA cm^{-1} was obtained at 25 °C, which is 34.5% higher than that of FAA-3-SOLUT-10, a commercially available quaternary ammonium AEI by FuMA-Tech. Furthermore, the mass transport resistance of QPIM-1 was 71.4% of that measured with FAA-3-SOLUT-10 under the same conditions. The results indicates that QPIM-1 has outstanding mass transfer capability. The materials are promising as ionomers that can be used in anion exchange membrane fuel cells and electrolyzers.

Keywords: Polymer of intrinsic microporosity, Anion exchange ionomer, Hydroxide ion conductivity, Fuel cell.

Proceedings of the 15th International Green Energy Conference
IGEC2023-128
July 10-13, 2023, Glasgow, UK

POLYMERIC PHOTOCATALYST FRAGMENTATION LEADING TO ROBUST CARRIER DYNAMICS WITH SINGLE-WALLED CARBON NANOTUBES FOR CO2 PHOTOREDUCTION

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ABSTRACT

CO_2 photoreduction to CH_4 provides an attractive way to transform the greenhouse gas into value-added fuels. Unfortunately, conventional polymeric photocatalysts suffer from charge inertia and deep trapping and pose great challenge on pursuing high selectivity. Herein, we show that VUV light-generated hydroxyl radicals (•OH) transform bulk graphitic carbon nitride into small fragments (CNF), hydroxyl groups also doped into the skeleton at the same time. To further enhance the photocarrier separation and transfer properties, the single-walled carbon nanotube (SWNT) is introduced, which served as the electron transfer bridge to string CNF up. Transient absorption decay kinetics reveal that the firm hybrid structure presents robust carrier dynamics. The emerging hole trap in SWNT/CNF is derived from the introduced SWNT and small pieces of CNF. The effective connection between SWNT and CNF contributes to the prolonged recombination lifetime of photogenerated carriers, demonstrating the suppressed electron deep trapping and reactive electron transfer. Density functional theory (DFT) studies show the enhanced CO_2 adsorption energy of SWNT/CNF as compared to its SWNT/CN counterpart. As a result, SWNT/CNF presents an improved CO_2 photoreduction activity of 148.3 μmol/g and a superior selectivity of 96.6% for CH_4 production.

Keywords: Polymeric photocatalyst, CO_2 photoreduction, charge transfer, hole trap, charge separation.

Proceedings of the 15th International Green Energy Conference
IGEC2023-129
July 10-13, 2023, Glasgow, UK

DESIGN OF ZIF DERIVED MICROPOROUS LAYERS FOR IMPROVING WATER MANAGEMENT OF PEMFC

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ABSTRACT
To improve the water management in proton exchange membrane fuel cells (PEMFCs), ZIF-derived microporous layers (Z-MPLs) with different structures were designed and prepared. By conveniently introducing Co and Fe elements into a ZIF-8 framework precursor, porous particles with high conductivity were obtained after pyrolysis at 950 ℃. The nanoscale porous particles were controllably sprayed onto hydrophobically treated carbon fiber paper to form a microporous layer, which effectively improves water transport and ensures excellent performance and stability under extreme conditions. Synchronous electrochemical impedance spectroscopy (EIS) scanning was used to study the dominant factors for performance loss. At a Pt loading of 0.3 mg/cm^2, PEMFCs equipped with Z-MPLs achieved a power density of 2.10 W·cm^{-2} at 100% RH and 1.63 W·cm^{-2} at 30% RH. This study demonstrates the importance of the conductive and porous material that derived from ZIF for improving the performance of the PEMFCs under extreme conditions.

Keywords: Microporous materials; PEMFCs; Water management; Microporous layers; EIS.

Proceedings of the 15th International Green Energy Conference
IGEC2023-130
July 10-13, 2023, Glasgow, UK

COMPLEX POWER LOSS ALLOCATION IN UNBALANCED POWER DISTRIBUTION NETWORKS

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ABSTRACT

The electricity distribution network accounts for significant amount of power losses in power systems. In an electricity market environment, these power losses incur distribution costs and should be allocated to all users in the grid. Therefore, how to fairly and reasonably allocate power losses in distribution networks has become a key issue affecting the healthy development of the electricity market. In this paper, a current-based approach is used to propose a complex power loss allocation method for unbalanced distribution networks. In addition, three methods of allocating current multiplication cross terms are discussed and applied to the IEEE13 node system for simulation. The simulation results reflect that the proposed loss allocation method is effective and can be influenced by different cross term allocation methods.

Keywords: Loss allocation, complex power, cross-terms allocation

Proceedings of the 15th International Green Energy Conference
IGEC2023-131
July 10-13, 2023, Glasgow, UK

COMPARATIVE ANALYSIS OF SOLAR-ASSISTED COGENERATION SYSTEMS WITH STIRLING ENGINE PRIME MOVERS

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ABSTRACT

The recent rise in household energy bills and a desire to transition to a low-carbon fuel supply for the provision of heat and power have catalysed an interest in the integration of solar energy with engine-based cogeneration systems. Different designs for such hybrid energy systems will lead to different techno-economic results and, therefore, strongly influence their respective market penetration. However, a comprehensive analysis for a range of such designs from energetic, economic and environmental perspectives is lacking. In this study, a solar-assisted Stirling engine-based combined heat and power (SA-SECHP) system integrating a Stirling engine (SE) and photovoltaic (PV) panels, a SA-SECHP system integrating a SE and solar thermal collectors (STCs), a SA-SECHP system integrating PV panels and solar thermal collectors (STCs), and a SA-SECHP system integrating a SE and photovoltaic-thermal (PVT) collectors, are assessed and compared using the same modelling assumptions and approach, and in the same application scenario (a detached house located in London). Real hourly thermal energy and electricity demand profiles as well as local weather data are used as inputs to transient models developed in TRNSYS, to conduct year-round simulations. The results show that based on a total solar installation area of 29.5 m^2 for all cases, the SA-SECHP system integrating a SE and PVT collectors outperforms the other three systems in terms of electricity self-sufficiency, with an annual electricity self-sufficiency of 87%. In addition, choosing a suitable alternative system from the four options will depend greatly on the specific end-user needs. If the end-users pursue a shorter payback time, the SA-SECHP system integrating a SE and PV panels is preferred, whereas if the focus is on the potential environmental benefits of the alternative system rather than the initial cost, the SA-SECHP system appears to be a good option especially when the household has a higher annual heat demand. This work provides guidance for the design of solar-assisted cogeneration systems and therefore contributes to achieving the UK's greenhouse gas emission reduction targets.

Keywords: cogeneration, photovoltaic, photovoltaic-thermal collector, solar thermal collector, Stirling engine.

Proceedings of the 15th International Green Energy Conference
IGEC2023-133
July 10-13, 2023, Glasgow, UK

The challenge of rural energy decarbonisation of heat in the UK

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ABSTRACT

The UK Government's attention has shifted towards decarbonising heat with particular research attention towards transitioning away from natural gas as a heating fuel, moving to decarbonised alternatives such as hydrogen. This research will serve useful to looking at the best way to decarbonise heating in but not specifically rural energy and heating, where this work focuses on. Over 20% of UK homes are off the natural gas grid of which 76% use heating oil, coal and other similar fuels to heat their homes. Little research has been conducted to look at what technologies and approaches can work best for rural decarbonisation.

There are unique challenges to rural energy, and particularly heating, that have been scarcely addressed in government policy and wider research, such as older infrastructure, older non-standard buildings and a generally older demographic that add extra consideration to community understanding and cost to decarbonise rural energy. This paper will look at the specific challenges of rural energy decarbonisation and potential approaches to mitigate some of these challenges, such as consolidating electricity, heating and transport fuels with fewer types of biofuels and e-fuels (e.g. green hydrogen) to optimise the unit cost of energy across the different modes.

Furthermore, investigation into what techno-socio-economic factors may further encourage greener energy technology adoption not just on a carbon basis but on what may work better for people in the community to reach net zero, will be highlighted. This will be different to those on key factors such as what heating fuel is currently used, the fabric of the building (how heat efficient/insulated the building currently is), the cost margins of current technologies, community attitude and affordability towards green technologies. A point often said is that there is no one size fits all approach. This paper will look at how to approach rural energy heat decarbonisation. Finding heat pump and wood biomass fuels/technologies to be both the least polluting and most cost effective when solely considering operational cost and emissions across three building types.

Keywords: Rural, UK, Feasibility, Modelling, Heat, pump, Oil, LPG, Hydrogen, Policy, off, grid

Proceedings of the 15th International Green Energy Conference
IGEC2023-135
July 10-13, 2023, Glasgow, UK

IDENTIFYING THE CARBON DEPOSITION MECHANISMS OF SOLID OXIDE FUEL CELLS BASED ON TOTAL HARMONIC DISTORTION ANALYSIS

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ABSTRACT
Identifying the corresponding degradation mechanisms at the early stage of operation is important for the long-term stable operation of solid oxide fuel cells (SOFCs). Compared to conventional testing methods, total harmonic distortion analysis (THDA) can significantly reduce the test time for identifying performance degradation during SOFC operation. In this study, a one-dimensional transient elementary reaction kinetic model of an SOFC fueled with syngas is developed. This model incorporates the coupling effect of heterogeneous elementary chemical and electrochemical reactions, the electrode microstructure, the charge and mass transport processes and the detailed evolution reaction of surface adsorbed carbon. A THDA simulation calculation method is developed and applied to detect the failure mode of anode carbon deposition. The amplitude, duration and harmonic number of the perturbation signal are determined to improve fault detection for THDs. The results show that the use of THD can not only detect the carbon accumulation behavior at the early stage of SOFC operation but also distinguish the specific carbon deposition mechanism: the hindered SOFC charge transfer reaction can be detected in the frequency range of 100-1000 Hz, and the hindered gas diffusion process inside the anode can be detected in the frequency range of 0.01-10 Hz.

Keywords: SOFC, THDA, anode carbon deposition, degradation, elementary kinetics modeling

Proceedings of the 15th International Green Energy Conference
IGEC2023-136
July 10-13, 2023, Glasgow, UK

INTEGRATED POWER GENERATION AND ENERGY STORAGE SYSTEM WITH SOLAR AND COAL ENERGY

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ABSTRACT
Nowadays, there are many types of power generation systems, each with its pros and cons. Concentrated solar-thermal power and coal-fired power systems are two of the main power generation systems. To prolong the storage duration of concentrated solar-thermal power and integrate coal energy into other energy systems, carbon dioxide can be a solution as a greenhouse gas rather than a problem. Therefore, compressed carbon dioxide energy storage has drawn much attention. This study explores the feasibility of integrated power generation and energy storage systems with solar and coal energy based on carbon dioxide, proposes the configuration of the integrated system and evaluates the integrated system's performance. The results show that the cycle efficiency increases with the rise of the turbine inlet temperature and main compressor outlet pressure, while it reaches the highest value when the main compressor inlet temperature and pressure are near the critical point. The present work provides new understanding of integrating concentrated solar energy and coal energy with power generation and energy storage, and may guide the industrial practices.

Keywords: Integrated power generation and energy storage system, concentrated solar-thermal power, coal-fired power, compressed carbon dioxide energy storage

Proceedings of the 15th International Green Energy Conference
IGEC2023-137
July 10-13, 2023, Glasgow, UK

SYSTEM EFFICIENCY OPTIMIZATION OF VANADIUM REDOX FLOW BATTERY BY USING GENETIC ALGORITHM AND FULL ZERO- DIMENSIONAL MODELING

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ABSTRACT
The use of VRFBs is limited due to their low system efficiency, so any optimization that leads to an increase in their system efficiency could improve their application range. Therefore, a full zero-dimensional modeling approach is developed in this work. In this approach, the initial concentrations of electrolyte species produced by electrolysis, the volume change of anolyte and catholyte during charging and discharging, and the diffusion of all species across the membrane, the viscosity changes due to the change of species concentrations during charging and discharging, the efficiency drop of the system due to heat sources at a constant temperature, and the use of a thermal management system is considered. In addition, the Darcy-Forchheimer equation is used instead of Darcy's law for $Re > 0.2$. A genetic algorithm was also implemented to find the variables of fiber diameter, porosity, electrode width, and current density for the highest system efficiency.
The model was first validated using experimental data available in the literature. Then, a parametric study was performed to find an optimum for the system efficiency concerning the variation of each parameter. Moreover, GA was used to determine the maximum system efficiency considering the simultaneous variation of all parameters. The results showed that with an optimal combination of battery operating parameters, the system efficiency could be improved by about 7% compared to the case where only one parameter was optimized.

Keywords: Vanadium Redox Flow Battery, Optimization, Genetic Algorithm, Full Zero-Dimensional Modeling,

Proceedings of the 15th International Green Energy Conference
IGEC2023-139
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NUMERICAL STUDY ON TAB LAYOUT OPTIMIZATION OF LITHIUM-ION BATTERY BASED ON A THREE-DIMENSIONAL ELECTROCHEMICAL-THERMAL COUPLING MODEL

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ABSTRACT
As an energy storage battery for energy storage power station, the heating phenomenon of iron phosphate lithium-ion battery (hereinafter referred to as " lithium-ion battery ") is very easy to cause potential safety hazards to the operation and maintenance of energy storage power station. Analyzing the heating status of lithium-ion battery under different working conditions can effectively reduce the generation of its heating phenomenon. Based on the three-dimensional electrochemical-thermal coupling model, the heat production, temperature rise distribution and electrochemical characteristics of each part of the battery monomer at different charge and discharge rates were studied. The simulation results show that the temperature at the positive tab is the highest and the heat generation power is the highest. With the increase of charging rate, lithium ions accumulate in the positive electrode. Then, creating four layouts marked as A, B, C, D to analyze the battery monomers and modules under different tab arrangements, it was concluded that the temperature distribution of group B and group C was more uniform, and the average temperature was lower. The temperature of group D is the highest, the monomer in the middle of the module has the problem of heat concentration. The temperature distribution of group B is the most uniform and the temperature rise is the smallest, which is 2.09 K lower than the maximum temperature of group D. The maximum temperature of group C is 1.57 K lower than group D. This means that the more dispersed the tab distribution, the better the heat dissipation effect of the battery module. The research results can improve the safety of electrochemical energy storage power station and provide reference for subsequent research on energy storage battery module.

Keywords: Lithium-ion battery, Electrochemical-thermal coupling, tab layout, Numerical simulation

Proceedings of the 15th International Green Energy Conference
IGEC2023-141
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PERFORMANCE EXPLORATION AND OPERATION ANALYSIS OF A METHANOL-REFORMING PEMFC-BASED DISTRIBUTED TRIGENERATION SYSTEM DRIVEN BY DUAL HEAT SOURCES

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ABSTRACT

The combined cooling, heating, and power (CCHP) system is a key trend in achieving energy efficiency improvement and carbon emission reduction, which is crucial for meeting carbon-neutral targets. Solar energy has recently emerged as a promising renewable energy source and is being integrated into various energy systems. A novel CCHP system driven by dual heat sources, including a solar field (SF), a methanol steam reforming (MSR) reactor, a proton exchange membrane fuel cell (PEMFC), and a single effect absorption chiller (AC), is proposed for improving the energy and economic performances simultaneously. The proposed CCHP system and three solar integration schemes based on predetermined locations of solar energy utilization are optimized under thermodynamic and economic objectives, respectively. Performance comparison shows that the proposed CCHP system can achieve an energy efficiency of up to 91.73% and the lowest LCOE of 0.1969 $/kWh. Operation analysis of supply-side load variation reveals that the proposed CCHP system can achieve better thermodynamic and economic performances by operating within a range of 6-8 for the ratio of heat converted by methanol to solar radiation.

Keywords: CCHP, solar energy, methanol steam reforming, PEMFC.

Proceedings of the 15th International Green Energy Conference
IGEC2023-142
July 10-13, 2023, Glasgow, UK

A NOVEL OMNI-DIRECTIONAL AUGMENTATION DEVICE FOR CROSS-AXIS-WIND-TURBINE

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ABSTRACT

Wind energy is one of the renewable energies utilized in 27% of the total renewable energy consumption. Horizontal-axis-wind-turbines (HAWT) are commonly used to generate electricity from wind energy due to their higher efficiency. However, it has several disadvantages that vertical-axis-wind-turbines (VAWT) can overcome, such as a lower centre of gravity, fewer parts to be maintained, and omni-directional. However, VAWTs have low performance and self-starting capability, which limits their effectiveness. A cross-axis-wind-turbine (CAWT) complements the HAWT and VAWT to extract on-coming wind energy from horizontal and vertical directions, maximizing the wind energy generation. A novel omni-directional augmentation device called a deflector is developed further to increase the performance and self-starting capability of CAWT by deflecting horizontal wind upwards to supply the wind vertically to the HAWT. This study aims to evaluate the performance of the deflector using numerical CFD modelling and experimental approaches, aiming to improve wind energy efficiency towards sustainable clean energy. Computational fluid dynamics (CFD) was used for numerical analysis, while experiments were conducted to validate the results obtained from the numerical study. Both approaches showed that the deflector could deflect the wind vertically up to 76% of the initial wind speed, which means the deflector can deflect from the initial wind speed of 6 m/s to vertically with a value of 4.56 m/s. The velocity output on certain points exceeds the initial velocity of 6 m/s. The findings of this study have important implications for the design and development of CAWT. The results demonstrate that the deflector can significantly improve the performance of CAWTs compared to the previous study that had been done. Initial CFD analysis was done to analyze the performance coefficient of the CAWT with the omni-directional deflector. The integrated system achieves a performance coefficient of 0.15, an improvement of 233% compared to the previous stand-alone CAWT study. Utilizing this technology can improve the efficiency of wind energy generation and contribute to a sustainable and clean energy supply.

Keywords: Renewable energy, cross-axis-wind-turbine, wind power augmentation, computational fluid dynamics, experimental validation

Proceedings of the 15th International Green Energy Conference
IGEC2023-144
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MULTI-OBJECTIVE SELF-OPTIMISATION OF A CO_2 CAPTURE PROCESS VIA ENHANCED WEATHERING IN RESPONSE TO FLUE GAS FLUCTUATIONS AND INTERMITTENT RENEWABLE ENERGY SUPPLY

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ABSTRACT

The drive for efficiency improvements in CO_2 capture technologies continues to grow, with growing importance given to the need for flexible operation to adapt to the strong fluctuations in the CO_2-rich flue gas flow rate and CO_2 concentration. Additionally, CO_2 capture technologies are expensive and require extensive energy, which is a major challenge impeding the advancement of these technologies. Using renewable energy can improve the environmental benefit of CO_2 capture technologies; however, renewable energy resources often suffer from the challenge of non-uniform power generation as a result of weather and seasonal variations. In this work, we aimed to dynamically model and self-optimise the CO_2 capture process in a renewable energy system via enhanced weathering of calcite with fresh water in a packed bubble column (PBC) reactor, in which CO_2 from flue gas produced by a power plant is converted into bicarbonate and stored in the ocean.

Data-driven surrogate dynamic models of the PBC reactor are developed to predict the reactor CO_2 capture rate (CR) and energy consumption (EC) and are trained using the data generated by published physics-based models. Additionally, the physics-based models are used to validate the data-driven surrogate models' results. Two deep learning models are considered to capture the dynamics of the PBC reactor: a long short-term memory network (LSTM); and a two-stage multilayer perceptron network (MLP). Results showed that the LSTM model best predicted the CR (R^2: 0.984), while the MLP model best predicted the EC (R^2: 0.979). Data-driven models based on LSTM were developed to predict wind energy (R^2: 0.908) and inlet flue gas CO_2 concentration (R_2: 0.981) using publicly available datasets. A multi-objective NSGA-II genetic algorithm is then applied that utilised the inlet flue gas CO_2 concentration and wind energy predictions to pre-emptively self-optimise the reactor process conditions (i.e., superficial liquid flow rate and superficial gas flow rate) to maximise the carbon capture rate and minimise non-renewable energy consumption. The results show that by using the dynamic modelling and predictive multi-objective optimisation framework proposed within this study, the PCB reactor CR increased by an average of 16.7% over a one-month operation, whilst simultaneously reducing the proportion of now-renewable energy consumed from an average of 92.9% to an average of 56.6%. Overall, this study demonstrates the effectiveness of a dynamic data-driven modelling and multi-objective optimisation approach to increase the operational flexibility of CO_2 capture reactors to adapt to strong fluctuations in flue gas and intermittent renewable energy supply.

Keywords: Enhanced weathering; CO_2 capture; dynamic modelling; multi-objective optimisation; deep learning

Proceedings of the 15th International Green Energy Conference
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COMPARING CATHODE LIQUID WATER REMOVAL MECHANISMS FOR PIN-TYPE AND CONVENTIONAL PEMFC FLOW FIELD DESIGNS

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ABSTRACT
Proton-exchange membrane fuel cells (PEMFC) are regarded as one of the cleanest and most efficient energy conversion devices available today. During its operation, if the created liquid water is not created uniformly and removed smoothly, flooding or overflow can occur. It creates significant problems regarding the cells' durability and reliability. In this study, comparisons are made for the water transport mechanisms within staggered and inline rounded pins, and conventional parallel and serpentine flow fields at PEMFC cathodes. The Volume of Fluid method and a validated dynamic contact angle model are adopted in this study. Thus, the liquid water evolutions inside PEMFC cathodes can be modeled and tracked more accurately by accounting for their dynamic behaviors. The results show that the pin-type flow fields provide even distributions of liquid water, velocity, and pressure with relatively low pressure drop. The staggered-pin configuration provides better water removal capability than the inline configuration. The pins inside the flow field facilitate the removal of liquid water and the convections of reactants while keeping the pressure drop low with 0.602 kPa and 0.3 kPa for the staggered- and inline-pin configurations, respectively. The serpentine flow field provides good water removal capabilities at an extremely high pressure drop (19.46 kPa) as a tradeoff. However, the risks of local flooding and dehydration are significantly higher in the serpentine flow fields due to the uneven distributions of liquid water and airflow velocity. The parallel design has the worst water removal capability but has minimal pressure drop. By investigating the two-phase flow inside the different flow field designs, the staggered-pin design shows its potential for improving the cell performance with the ability to provide even distributions while improving the PEMFC system efficiency of reactants because of its low pressure drop.

Keywords: PEMFC, flow field design, dynamic contact angle, VOF model.

Proceedings of the 15th International Green Energy Conference
IGEC2023-147
July 10-13, 2023, Glasgow, UK

A NOVEL INORGANIC PHASE CHANGE MATERIAL COMPOSITE FOR COLD ENERGY APPLICATION

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ABSTRACT
Global warming and energy crisis are driving the rapid development of clean energy. Latent heat storage as one of the efficient energy storage methods has reached a relatively high technology readiness level. This technology enables peak-loads shifting and ambient temperature regulation, therefore it attracts attention in data-centre and cold-chain fields to achieve energy cost reduction, temperature control and fresh goods transportation. This study compared the thermophysical properties of different phase change energy storage materials for these application scenarios. Regarding the cost-effectiveness and operation safety, a formulation of salt hydrate-based inorganic phase change material (PCM) was prepared with a phase change temperature of 5 to 15°C and a latent heat of 90-140 J/g. There is no obvious degradation of this composite PCM after at least 200 thermal cycles.

Keywords: Phase change materials (PCM), cold energy storage.

Proceedings of the 15th International Green Energy Conference
IGEC2023-148
July 10-13, 2023, Glasgow, UK

PORE-SCALE SIMULATION OF TURBULENT FLOW AND HEAT TRANSFER IN AN OPEN-CELL METAL FOAM

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ABSTRACT

The enhancement of heat transfer using extended surfaces has been widely applied in various engineering sectors, such as energy storage, thermal management systems, and automotive. From sophisticated aerospace applications to computer heat sinks thermal management systems are implemented. Metal Foam (MF) can be used as a thermal dissipation tool in such cases, and thus the exploration of the heat transfer mechanisms of its internal design is needed. A Computational Fluid Dynamics (CFD) model was established to investigate the thermal hydraulics of the MF at the pore-scale level. The geometry has been extracted from the micro-tomography scanning process to represent the actual stochastic shape of the MF. The MF's porosity and pore density (PPI) are 86% and 5 PPI, respectively. Varying the blockage ratio is essential to minimize the pressure drop, which is a common obstacle for a channel filled with a porous structure. However, the pressure drop reduction must not come at the expense of the heat transfer rate. Hence, three blockage ratios (BR) for a channel filled with MF were considered in this study (i.e., BR = 50%, 80%, and 100%). The enhancement of the heat transfer not only depends on the surface density of the MF but also on the flow regime, which is a critical factor. As a result, a steady-state three-dimensional Reynolds Averaged Navier-Stokes (RANS) simulation was performed for this channel, which is heated from the bottom. Conjugate heat transfer was considered to understand the blockage ratio's effect on the MF's heat transfer rate. Three Reynolds numbers (Re) based on the pore diameter were adopted in this study, and they all are within the turbulent regime of the porous media (i.e., Re = 500, 1000, and 2000). A comparison between the cases in terms of pressure drop, temperature distribution, and the Interstitial Heat Transfer Coefficient (IHTC) was accomplished. The main outcome of this study is that the BR of 80% might possess the balance between the pressure drop and heat transfer of the considered foam structure.

Keywords: Interstitial heat transfer coefficient, Metal foam, Thermal management, Turbulent flow, Conjugate heat transfer.

Proceedings of the 15^{th} International Green Energy Conference
IGEC2023-149
July 10-13, 2023, Glasgow, UK

RENEWABLE ENERGY CONVERSION USING NOVEL ENGINEERED MATERIALS FOR SOLID OXIDE CELL

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ABSTRACT
The global net-zero emission target can be achieved and sustained by the development of novel energy conversion devices or by the improvement of features of existing technologies that harness intermittent renewable sources to supply power on demand. This has resulted to a renewed interest towards research on solid oxide cells (SOCs) particularly due to its unparalleled efficiency of conversion and its flexibility to function reversibly as an electrolyzer and a fuel cell. Effective operation of SOCs requires three fundamental operational properties which include ionic and electronic conductivities as well as catalytic activity and improvements of these cells therefore require enhancing these properties. [1]

In this study we explore the enhancement of oxide ion conductivity for potential application in SOC by the introduction of three-dimensional strain, which is the physical deformation of the host material through the embedding of nanoparticles into its lattice. The study employs computational modelling to relate strain to ionic conductivity enhancement and experimental work to validate the model developed. The model was developed using data from two previous studies that involved embedding nanoparticles into a host lattice by sintering (S) particles together with perovskites and exsolution from perovskites (E), for the fields of SOC and chemical looping (CL), respectively. [2], [3] For the model, a voxel of edge 100 nm size was randomly populated with nanoparticles of sizes and concentrations observed in the experimental studies and the configurations were used to calculate the average inter-particle distance, the local strain between particle pairs, and then the overall volumetric strain across the voxel.[1] The volumetric strain was then related to internal pressure and then to conductivity enhancement of the material. [1] The results indicate that conductivity enhancement scales logarithmically with volumetric strain relative to the amount of nanoparticles embedded. Figure 1 shows that the expansive strain experienced in E system is approximately ~0.9–2%, leading to an increased conductivity by a factor of approximately ~2–6.

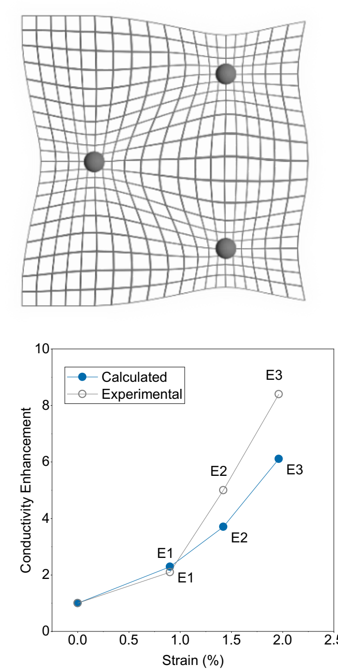

Figure 1. Strain-conductivity model visual representation and validation against experimental data for the E systems.

The experimental work involved the synthesis of perovskites from precursor materials of calcium carbonate, titanium (iv) oxide, strontium carbonate, nickel (ii) nitrate hexahydrate and iron (iii) nitrate nonahydrate and exsolving nanoparticles from the perovskite matrix and socketing them both within the matrix and on the surface of the host matrix. 10 g of perovskite materials of varying stoichiometry were prepared by first drying precursors to remove moisture at 300 °C for a hold-time of 3 hours and ramp rate of 5 °C/min; sonicating the mixture and calcinating at 1000 °C at a ramp rate of 5 °C/min and runtime of 12 hours. The X-ray diffraction spectra of the perovskites synthesized were analysed. The peaks of the spectra showed the phase purity and crystallinity of the perovskite types with strontium titanate displaying sharp peaks indicating good crystallinity. This has demonstrated that three-dimensionally strained materials enhance the conductivity of materials which is an important aspect for efficient energy conversion considerations in SOCs.

Keywords: Hydrogen, Solid Oxide Cell, Electrolyzer, Perovskites, Strain, Exsolution, Nanoparticles, Conductivity.

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Proceedings of the 15th International Green Energy Conference
IGEC2023-150
July 10-13, 2023, Glasgow, UK

OPTIMAL SIZING CAPACITIES OF SOLAR PHOTOVOLTAIC AND BATTERY ENERGY STORAGE SYSTEMS FOR GRID-CONNECTED COMMERCIAL BUILDINGS IN MALAYSIA

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ABSTRACT

This article proposes a technique for determining the optimal capacities of solar photovoltaic (PV) and battery energy storage (BES) systems for grid-connected commercial buildings in Malaysia. The method utilizes real-time data on load patterns, solar irradiance, ambient temperature, and Malaysian power rates to establish the lowest life cycle cost (LCC) of the PV and BES systems over a 20-year lifespan. The proposed system configuration includes rule-based energy management with peak shaving. The study also considers limitations on the maximum export power of Malaysian commercial buildings for optimization. The proposed system uses the price of electricity as an index, and a case study demonstrates that it reduced the cost of electricity by 34.25% for the commercial building case with the C1 tariff. Additionally, annual energy consumption and peak demand are reduced by 20.53% and 15.25%, respectively, while selling 10128.6274 kWh of electricity back to the grid. Further, the optimal sizing capacities of PV and BES for Malaysian commercial buildings are presented and evaluated which provides a general demonstration for customers. This article is relevant to the field of electrical engineering and offers practical solutions for optimizing solar PV and BES systems in grid-connected commercial buildings, reducing the cost of electricity, and minimizing energy consumption.

Keywords: Efficient energy management system, energy storage management, Commercial buildings, Rooftop photovoltaic, optimal capacity, Life cycle cost

Proceedings of the 15th International Green Energy Conference
IGEC2023-151
July 10-13, 2023, Glasgow, UK

HIGH-PERFORMANCE 2D MOS_2 CATHODE FOR AQUEOUS AL-ION BATTERIES

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ABSTRACT

Aluminum, as the most abundant metal in the Earth's crust, has excellent electrochemical properties despite its low price. The emerging Al-ion batteries exhibit several advantages, including high power densities and high operating voltages, which have attracted considerable research interest. Recently, a novel "water-in-salt" electrolyte system has been developed by our group to further reduce the cost of Al-ion batteries and increase their capacity, which is expected to become the next-generation rechargeable battery technology. Although it has demonstrated excellent performance, the insertion mechanism of ions in the concentrated electrolyte are complex, and only low-dimensional carbon materials represented by carbon nanotubes and graphene exhibit high working voltage. However, graphene materials are not only expensive, but also exhibit relatively low specific capacity. Therefore, it is necessary to further develop efficient two-dimensional cathode materials and study the insertion and extraction mechanism of high potential ions in them. New two-dimensional materials represented by MoS2 have high specific surface area, high surface activity, and adjustable electronic structure, which are very suitable for the multiple ion insertion in Al-ion batteries and have enormous application potential and broad development prospects. This study found that ion insertion can significantly increase the interlayer spacing of MoS2 material, which not only enables Al ions to undergo redox reactions more effectively with the action potential, but also greatly improves their transport rate as well as their electrochemical performance, thus achieving a high-voltage discharge plateau of 1.8V, which is higher than the counterpart of other MoS2 based Al-ion batteries. Therefore, the in-situ expansion of interlayer spacing by ion intercalation method is of great significance for the development of high-performance aqueous Al-ion battery cathode materials.

Keywords: Aqueous Al-ion battery, 2D material, MoS2 cathode.

Proceedings of the 15th International Green Energy Conference
IGEC2023-152
July 10-13, 2023, Glasgow, UK

A one-dimensional model for Pt degradation and Pt band formation in proton exchange membrane fuel cells

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ABSTRACT

As fossil fuel reserves dwindle and global warming gets worse, renewable energy source is receiving growing attention, and the hydrogen is regarded as one of the most suitable replacement mainly due to the zero emission characteristics. The proton exchange membrane fuel cells (PEMFCs), which directly converts chemical energy in hydrogen into electricity with water as the only byproduct, has been widely applied in vehicles, stationary power plants, and portable power devices. However, the problems of high cost and short lifetime still exist, hindering the commercialization of PEMFCs. Both aspects have to do with Pt catalysts which account for a significant portion of the overall cost, and its degradation seriously affects the cell performance.

To reduce the Pt loading without sacrificing the mass activity, Pt catalysts are dispersed on the carbon support in nanoparticles form. However, these nanoparticles are instable during PEMFCs operation. At high potential, the Pt atoms on the surface of smaller particles are oxidized to Pt ions, part of which can simultaneously be reduced to Pt atoms and deposit on the particle surface with larger size again. Thus, the mean size of Pt particle gradually grows over time, which is called Ostwald-ripening. Meanwhile, other Pt ions can diffuse into the proton exchange membrane (PEM) under the action of concentration gradient, and then be reduced to atoms by the crossover hydrogen, finally precipitating in the PEM. Ostwald-ripening reduces the specific surface area of Pt catalysts, and precipitation directly leads to mass loss, both of which decrease the ECSA and cause severe performance degradation of PEMFCs.

Currently, most Pt degradation studies just regarded the Pt precipitation as mass loss and its detailed mechanism in the PEM was ignored. However, the Pt precipitation, especially the Pt band is an important issue in long-term fuel cell operation. Therefore, a one-dimensional mathematical model is developed focusing on the Pt degradation and Pt band formation in cathode CL and PEM.

First, this model describes the Ostwald-ripening process in the cathode CL. As shown in Fig. 1, the Pt size distribution (PSD) has a significant variation after 10000 voltage cycles (0.6-1.0 V), and the mean size gradually increases. Second, the Pt atoms originates from hydrogen reduction aggregate together to form particles in the PEM. Once the radius of these particles exceeds 1 nm, the hydrogen-oxygen reaction can occur on the particle surface, which changes the hydrogen concentration distribution in the PEM. Correspondingly, the aggregation rate is affected, and the size growth of particles in somewhere is obviously faster, where the Pt band gradually forms, and the local potential distributed in a cliff pattern, as shown in Fig. 2.

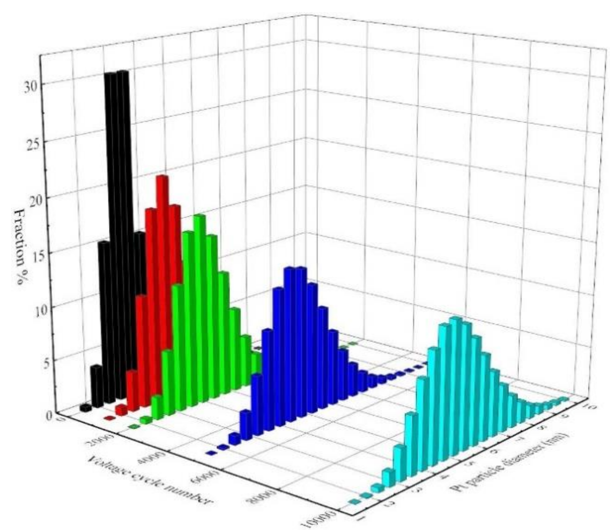

Fig. 1. PSD evolution during 10000 voltage cycle

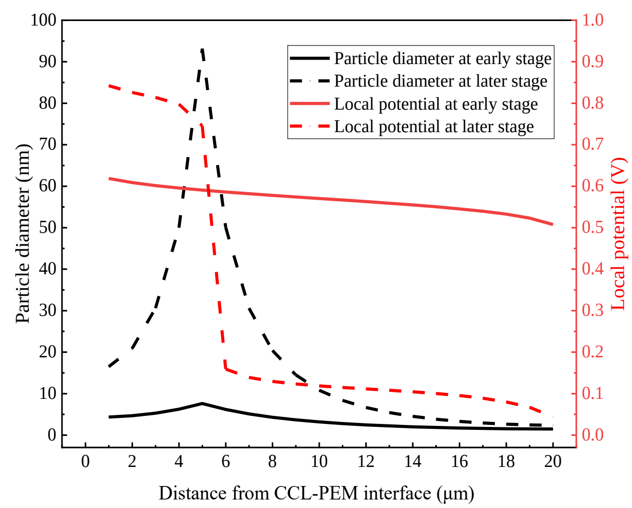

Fig. 2. The distribution of Pt size and local potential in the PEM

Keywords: PEM fuel cell, Pt degradation, Pt band formation, numerical simulation

Proceedings of the 15th International Green Energy Conference
IGEC2023-157
July 10-13, 2023, Glasgow, UK

PREDICTION OF TEMPERATURE FIELD IN A T-JUNCTION BASED ON DEEP LEARNING

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ABSTRACT
Temperature field prediction is important for monitoring of the complex turbulent flow and heat transfer in the field of energy and power. In this paper, a temperature field prediction method based on deep learning is proposed. Three neural networks (Transformer, Long Short-Term Memory (LSTM) and Convolutional Neural Network (CNN-LSTM)) are used to extract temperature field features and compare their temperature field predictions. Time series data of the temperature field of the T-junction were obtained using Large Eddy Simulation (LES). Comparing three temperature field prediction results, it was found that the maximum error of LSTM method was 2.41%, while that for CNN-LSTM method was 2.87% and that for Transformer method was only 0.49%. By adjusting the network structure of the Transformer reasonably, the Transformer network is most suitable for temperature field prediction.

Keywords: T-junction, temperature field prediction, deep learning, Transformer

Proceedings of the 15th International Green Energy Conference
IGEC2023-159
July 10-13, 2023, Glasgow, UK

NUMERICAL ANALYSIS OF TWO-PHASE FLOW USING 2-D AXI-SYMMETRIC APPROACH FOR AN EFFERVESCENT ATOMIZER

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ABSTRACT

Effervescent atomization is a type of twin-fluid atomization in which a small amount of gas is bubbled into the liquid before it is ejected from the atomizer. The technique of directly bubbling gas into the liquid stream inside the atomizer body differs significantly from other methods of twin-fluid atomization (either internal or external mixing) and results in significant performance improvements in terms of smaller drop sizes and even relatively lower injection pressures. The internal two-phase flow behaviour inside the injector will significantly affect the downstream spray characteristics. The current study involves the numerical investigation of two-phase flow behaviour inside an effervescent atomizer using a 2-D axi-symmetric computational domain. Both mixture and VOF multiphase approaches with URANS (standard, RNG, and realizable k-ε) turbulence models have been adopted in this study. The effect of turbulence models on the two-phase flow evolution in the injector has been studied with a GLR (gas-to-liquid ratio) of 0.08%. The liquid is taken as ethanol, and atomizing gas is nitrogen for the current study.

Keywords: effervescent atomization, CFD, VOF, mixture model, 2-D axi-symmetric, two-phase flow, k-ε turbulence models.

Proceedings of the 15th International Green Energy Conference
IGEC2023-161
July 10-13, 2023, Glasgow, UK

LIFE CYCLE GREENHOUSE GAS EMISSIONS OF HYDROGEN SUPPLIED CHAINS VIA OFFSHORE WIND FARMS UTILIZING COMPRESSED GASEOUS HYDROGEN, LIQUEFIED HYDROGEN AND AMMONIA: A CASE STUDY OF CHINA

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ABSTRACT

The development of promising offshore wind farms contributes to the cleanliness of the power system, and hydrogen (H_2) is a potential energy carrier to address the challenges of delivering power from long-distance offshore wind farms. In this work, a life cycle evaluation (LCA) model for green hydrogen production from offshore wind farms is developed. The greenhouse gas emissions (GHG) and fossil energy consumption of compressed hydrogen (G-H_2), liquefied hydrogen (L-H_2) and liquid ammonia (L-NH_3) as energy carriers are compared, and the sensitivity of GHG to wind farm load factor and transport distance is analysed. The results show that the G-H_2 route has the lowest GHG emissions of 633.2 (gCO_2eq/kg H_2) and fossil energy consumption of 7.25 MJ/kg. In contrast, the L-NH_3 route possesses the highest GHG emissions of 732.6 (gCO_2eq/kg H_2) and fossil energy consumption of 8.134 MJ/kg H_2. In addition, the sensitivity coefficients of GHG emissions to transportation distance and annual load factor of offshore wind farms are investigated, and the sensitivity of the annual load factor reached between 0.9 and 1.4, following the order of L-H_2 > L-NH_3 > G-H_2. In addition, the sensitivity coefficient of transportation distance is only reflected in G-H_2 and reaches a remarkable value of 0.4 at 500 km. The results indicate that the G-H_2 route has the lowest greenhouse gas emissions and fossil energy consumption at distances of less than 70 km offshore and that beyond 70 km, L-H_2 is the preferred alternative. This work provides a comprehensive life cycle perspective to facilitate the selection of energy carriers for offshore hydrogen production.

Keywords: Green hydrogen, Life cycle Assessment; Greenhouse gas emission, Offshore wind farm

Proceedings of the 15th International Green Energy Conference
IGEC2023-162
July 10-13, 2023, Glasgow, UK

SIMULATION VALIDATION OF MOMENT BALACNING METHOD FOR DRAG-DOMINANT TIDAL TURBINES

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ABSTRACT
Drag-dominated turbines play a key role in the application of urban windfarm and multi-flow direction tidal arrays because of their low cut-in speed and omnidirectional characteristics. A performance analysis study of Pinwheel and Savonius tidal turbines has been carried out using Computational Fluid Dynamics (CFD) software to define the optimal power coefficient (C_p) and Tip-Speed-Ratios (*TSR*). The classic Disk Actuator model assumes a fixed virtual disc with or without porous holes perpendicular to the inflow direction. This is unsuitable for drag-dominant turbine because of the rotating virtual disc of the rotor plate of a vertical-axis turbine, the unaccounted bypass flow interaction on the downstream flow boundary for a horizontal-axis turbine, and parasitic force acting on the rotor/support walls for both. Therefore, a more applicable model is required for the tidal turbine realm. The focus of this study is to propose a novel method to find the optimal *TSR* of a drag-dominant turbine with a cost-effective and user-friendly Moment Balancing algorithm.

The CFD models were inspired and scaled from experimental findings in the literature review. Both models were made comparable using a parametric study to equalize the blockage area at 12%. After careful analysis of different solver settings, steady k-epsilon model was selected, and grid independence tests were conducted. V-shaped *TSR* matrix was developed with varying turbine rotational speeds and fluid inlet velocity, unlike previous works simulated at a fixed velocity. For Pinwheel and Savonius, the *TSR* range for simulations is 0.64-5.0 and 0.3-1.0 respectively. Thrust Moment (Acting) is calculated when the turbine is stationary, but the fluid motion exerts load and rotates it. Idle Moment (Resisting) is calculated when the turbine is rotating at a given speed and the water is stationary hence, a load is exerted on the turbine. Linear regression analysis was performed and coefficients for thrust and idle moment were calculated, thus, formulating an equation for the net moment of Pinwheel and Savonius. It is found that the power coefficient is maximum or zero when idle and thrust moment offset each other at the neutral point. The optimal *TSR* are found for Pinwheel at 2.37 and Savonius at 0.63 with 15.6% and 11.1% error rate respectively for experimental validation.

Based on the findings, thrust and idle moment have a positive and negative quadratic relationship respectively with the inlet velocity. A hill-shaped curve is observed between power coefficient and *TSR*. The optimal *TSR* for Pinwheel is higher than Savonius, thereby a higher rotational and lower inlet speed should be adjusted accordingly and vice versa. The proposed algorithm is expected to improve and simplify an engineer's understanding of the turbine's optimal *TSR* by adjusting the rotor speed to suit the inlet flow case. The computational cost is greatly reduced through replacing net moment simulations by combining thrust and idle moment simulations. Upon commercial launch of the algorithm, the tidal energy development will become robust and more affordable.

Keywords: Drag-Dominant Tidal Turbine, Performance Optimization, Savonius, Pinwheel, Steady-State

Proceedings of the 15th International Green Energy Conference
IGEC2023-164
July 10-13, 2023, Glasgow, UK

CFD ANALYSIS OF COMBUSTION OF GASOLINE, HYDROGEN AND HCNG BELNDS IN INTERNAL COMBUSTION ENGINE

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ABSTRACT

Despite the rise of renewables and EVs, IC engines are very prevalent in applications requiring a reliable, compact, remote and scalable power source. As a result, improving engine performance and addressing environmental concerns associated with NOx and soot emissions becomes important. The current study explores viability of cleaner and faster burning fuels like H_2 and CNG to replace Diesel fuel and HFOs to achieve lower emissions. CFD simulations using CONVERGE software with detailed chemical kinetics are used to model engine combustion and predict heat release rate and pressure rise for a canonical geometry in spark ignited mode. In the first part of the study, gasoline fuel combustion is simulated to validate the CFD tool with theoretical predictions and good agreement has been observed. In the second part of the project, simulations for the same engine geometry were performed with the fuel being pure CH_4, 50/50 CH_4/H_2 by volume and pure H_2. Due to high-flame speed and extremely low 'minimum ignition energy requirement' of H_2, combustion duration is low and pressure rise is extremely steep. Consequently, for H_2 case the piston ends up working against the hot gases, while for a similar operating condition, peak pressure is considerably low for pure methane. The engine with the HCNG blend as the fuel can achieve higher cycle work than either of the two cases by the fuels compensating for shortcomings of the individual fuels: H_2 and CH_4. The amount of NOx produced was predicted to undergo a non-linear increment with hydrogen enrichment. Therefore, higher engine power can be achieved in the 50/50 mixture with less than half of the NOx produced for pure hydrogen.

Keywords: Combustion, Hydrogen, HCNG, Computational Fluid Dynamics, Internal combustion engine.

Proceedings of the 15th International Green Energy Conference
IGEC2023-165
July 10-13, 2023, Glasgow, UK

DEGRADATION CHARACTERISTICS OF PROTON EXCHANGE MEMBRANE FUEL CELL WITH DIFFERENT CATHODE LOADING

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ABSTRACT
Substantial progress has been achieved in decreasing cathode platinum loading in proton exchange membrane fuel cells (PEMFCs); nevertheless, the degradation characteristics of PEMFCs with low platinum loading are not clear. In this paper, the degradation characteristics of PEMFCs with different platinum loading (0.15 mg cm-2 and 0.35 mg cm-2) are investigated experimentally under a simulated automotive startup-shutdown condition. Polarization curve, electrochemical impedance spectroscopy (EIS), cyclic voltammetry and oxygen transport resistance measurements are applied to characterize the degradation behavior of PEMFC. The experimental results show that the membrane electrode assembly (MEA) with low Pt loading has a severe degradation of cell performance and electrochemical surface area (ECSA) compared to that with high Pt loading. Apart from that, it was found that oxygen transfer resistance and mass transfer losses increase significantly after accelerated stress tests, especially for MEA with low Pt loading.

Keywords: PEMFC, degradation, low platinum loading, carbon corrosion.

Proceedings of the 15th International Green Energy Conference
IGEC2023-167
July 10-13, 2023, Glasgow, UK

HIGH-PERFORMANCE H_2O_2 PAPER FUEL CELL BENEFITED FROM DUAL-ELECTROLYTE AND A SANDWICHED HYDROGEL

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ABSTRACT

Microfluidic fuel cells (MFCs) have been developed on cellulose papers to eliminate the auxiliary pumping systems, and hydrogen peroxide (H_2O_2) is an appealing fuel because it is non-flammable, non-toxic, and eco-friendly for producing only water. Although H_2O_2 can serve as both fuel and oxidant to bypass the typical issue of fuel crossover in MFCs, the electrochemical performance of reported H_2O_2 MFCs have been lowered due to the mixed potentials, which are caused by simultaneous oxidation and reduction at the same electrode. To improve the H_2O_2 MFC performance, an innovative architecture of two parallel paper channels sandwiching a low-cost hydrogel has been designed, and the alkaline anolyte and acidic catholyte have been optimized independently to achieve high performance. Compared to the literature, the open-circuit voltage of the H_2O_2 paper fuel cell has been elevated from ~ 0.6 V to 1 V and the peak power density has been promoted from ~ 1 mW cm^{-2} to 10.2 mW cm^{-2}. This fuel cell also shows great durability and instant re-activation upon refueling. More importantly, in-depth reaction mechanisms at each electrode in the dual-electrolyte have been studied. It was first revealed that free radicals were generated from H_2O_2 in alkaline media, which not only facilitates the H_2O_2 oxidation at the anode but also helps to maintain a large voltage difference between the electrodes. This hydrogel-sandwiched dual-electrolyte MFC design opens up possibilities for practical applications of direct H_2O_2 MFCs, and the mechanistic study provides a theoretical backbone for the future development of H_2O_2 fuel cells.

Keywords: Microfluidic fuel cells, paper-based fuel cells, H_2O_2 fuel cells, dual-electrolyte, hydrogel.

Proceedings of the 15th International Green Energy Conference
IGEC2023-168
July 10-13, 2023, Glasgow, UK

PREDICTION OF TRANSPORT PROPERTIES OF METHANOL-OCTANE BLENDS AT DIFFERENT TEMPERATURES AND PRESSURES USING MOLECULAR DYNAMICS SIMULATION

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ABSTRACT
Methanol-blended gasoline has gained momentum as an alternative fuel for direct injection spark ignition engines. In modern gasoline direct injection (GDI) injectors, the fuels are generally injected into combustion chamber at high injection temperature and pressure, but accurate estimation of the blended fuel properties at these conditions remains a challenge. To overcome the challenge, molecular dynamics simulation, which has the potential to find the properties at engine-relevant conditions can be used. In this study, the molecular dynamics (MD) simulation is performed to predict the transport properties of methanol-octane fuel blends (M15: 15% Methanol & 85% Octane and M85: 85% Methanol & 15% Octane) such as density, viscosity, and diffusion coefficient at different temperatures (303 to 363 K) and pressures (1 to 200 bar). The MD simulation results for neat methanol, n-octane, and methanol + octane binary mixture was validated with the NIST and experimental data available in the literature and found a good agreement with density (absolute error: < 1%) and viscosity (absolute error: < 5%). The MD simulation results for both M15 and M85 blend show that density and viscosity decrease with temperature and increase with pressure, while diffusivity increases with temperature and decreases with pressure. These molecular fuel properties at wide range of pressure and temperature could be useful in analyzing fuel spray, ignition, and combustion characteristics of spark ignition (SI) engines.

Keywords: Methanol-octane blends (M15 and M85), MD simulation, density, viscosity, diffusivity, pressure, temperature

Proceedings of the 15th International Green Energy Conference
IGEC2023-171
July 10-13, 2023, Glasgow, UK

EXPERIMENTAL INVESTIGATION OF A DIESEL ENGINE RUN ON SIMULATED GASEOUS FUELS UNDER VARYING COMPRESSION RATIO

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ABSTRACT

This research work attempts to explore the combined effect of engine load and compression ratio (CR) on the performance, combustion, and emission characteristics of a 3.5 kW diesel engine utilizing simulated biogas (SBG), simulated producer gas (SPG), and SPG-SBG mixture under dual fuel (DF) mode. The compositions of the gaseous fuels are prepared based on the volumetric percentage of the individual gas components and are inducted into the engine cylinder using a novel venturi-type air-gas mixer. For the preparation of SBG, methane (CH_4) and carbon dioxide (CO_2) are mixed at a 70:30 ratio. Similarly, hydrogen (H_2) and carbon monoxide (CO) are also mixed at a 70:30 ratio for the preparation of SPG. Again, H_2 and CO at a 50:50 ratio are mixed with a 70:30 ratio of CH4 and CO_2 to simulate the SPG-SBG mixture. Engine experiments are executed at five different loads, viz. 20%, 40%, 60%, 80%, and 100%, and four different CRs, viz. 16, 17, 17.5, and 18, at a standard injection timing (IT) of 23° BTDC. Maximum brake thermal efficiency (BTE) and liquid fuel replacement (LFR) are obtained at 100% load and CR of 18. At this operating condition, SBG, SPG, and SPG-SBG mixture showed a BTE of 20.66%, 20.94%, and 22.11% respectively, and LFR of 89.76%, 81.44%, and 84.36% respectively. The combustion data indicated a decrement in ignition delay (ID) with an increase in CR. It has also been observed that SBG, SPG, and SPG-SBG mixture showed an average decrease of 10.51%, 9.93%, and 11.16%, respectively, of unburned carbon monoxide (CO) emission when the CR is raised from 16 to 18. Similarly, an average unburned hydrocarbon (HC) emission reduction is obtained to be 16.13%, 13.01%, and 20.07% for SBG, SPG, and SPG-SBG mixture, respectively.

Keywords: Diesel engine, dual fuel combustion, compression ratio, simulated biogas, simulate producer gas

Proceedings of the 15th International Green Energy Conference
IGEC2023-174
July 10-13, 2023, Glasgow, UK

TWO-PHASE FLOW IN THE GAS DIFFUSION LAYER WITH DIFFERENT PERFORATION OF PROTON EXCHANGE MEMBRANE FUEL CELL

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ABSTRACT
Proton exchange membrane fuel cell (PEMFC) has drawn the world's attention for its advanced features of zero-emission, high-power density and low noise. However, water management significantly influences the performance of proton exchange membrane fuel cells (PEMFC). Gas diffusion layer (GDL) is an important pathway for water transport in the PEMFC. The presence of excessive liquid water in the cathode GDL will cause "water flooding" and block the reactant transport to catalyst sites. Therefore, it is critical to improve water management in the GDL to enhance cell performance. Specially, perforated GDL is an effective way to improve the water transport process. In this study, the volume of fluid (VOF) method is used to numerically simulate the transport process of liquid water in perforated GDL with different hydrophilicity distributions. The GDL geometry is reconstructed based on the stochastic parameter method. With our numerical method, the GDLs with cylindrical and conical perforations are compared to understand the water transport process. Additionally, the effects of perforation shapes and fiber hydrophilicity gradient distributions on the water transfer process also been discussed. The results show that the GDL with conical perforation (bottom surface close to the inlet), liquid water tends to diffuse along the though-plane direction. The GDL with cylinder perforation are most effective to transporting fluid water. The water saturation in GDLs with gradient wettability is higher than that in GDLs without gradient wettability.
Keywords: PEMFC, Gas diffusion layer, Perforation, Gradient hydrophilicity distributions, Volume of fluid.

Proceedings of the 15th International Green Energy Conference
IGEC2023-175
July 10-13, 2023, Glasgow, UK

Customized Assessment and Adoption of Carbon Dioxide Hydrate Refrigeration System Technology: Research Framework

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Abstract

Cooling and refrigeration technologies are integral to modern society, but their energy consumption and greenhouse gas emissions pose significant environmental challenges. In the UK, cooling and refrigeration currently consume up to 14% of electricity and account for around 10% of direct and indirect greenhouse gas emissions. Furthermore, cooling energy generation in the summer drives peak electric demand, which hinders the integration of renewable energy sources. To address these challenges, this paper explores CO2 refrigeration technologies and the newly proposed CO2 hydrate refrigeration system. First, we aim to provide an in-depth review on current UK rules and regulations, business models and financing mechanisms. To provide a more accurate depiction of the future energy and emissions markets in the UK, we propose several scenarios that account for the uncertainties and risks associated with decision-making. Using Multiple Criteria Analysis (MCA), here SBM-MAXIMIN-DEA, we develop a model for identifying the best business models under different scenarios. SBM-MAXIMIN-DEA integrates both the relative importance (weights) of the criteria and takes into account undesirable outputs, such as emissions. Notably, this approach overcomes the common issue of infeasibility that arises when introducing weights into the model. Recognizing the importance of incorporating stakeholder preferences into the decision-making process, we develop a weighting scheme on the chosen criteria across economic, social, environmental dimensions to be integrated into our model. By including this weighting scheme, our decision-making model can provide a more accurate and tailored assessment of the different scenarios and business models under consideration. This approach ultimately helps ensure that the final decision reflects the preferences and interests of all relevant stakeholders, including policymakers, investors, and industry representatives. Our finding including a comprehensive analysis of the challenges facing newly introduced CO2 hydrate refrigeration system in the UK and provides a framework for transitioning towards more sustainable natural refrigerant-based refrigeration technologies.

Keywords: Cooling, Refrigeration, two-stage CHB-VCRS, DEA.

Proceedings of the 15th International Green Energy Conference
IGEC2023-176
July 10-13, 2023, Glasgow, UK

A MULTI-INDEX EVALUATION METHOD OF SUPERCRITICAL CARBON DIOXIDE BRAYTON CYCLE FOR NUCLEAR POWER PLANTS DESIGN

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ABSTRACT

The supercritical carbon dioxide Brayton cycle (S-CO_2BC) is considered as an ideal energy conversion system for fourth generation nuclear power plants due to its simple layout, compact structure and high cycle efficiency. In this paper, mathematical models of four different cycle layouts are developed, and the advantages and disadvantages of simple recuperation cycle (SR), recompression cycle (RC), re-heating cycle (RH), and intercooling cycle (IC) are compared from the viewpoint of thermal and economic performance. A parametric analysis of the SCO_2BC with the Gas-cooled Fast Reactor (GFR), the Sodium-cooled Fast Reactor (SFR), the Lead-cooled Fast Reactor (LFR) and the Molten Salt Reactor (MSR) as heat sources was carried out to investigate the influence of four key parameters on its thermo-economic performance. The G1+TOPSIS multi-indicator comprehensive evaluation method was used to compare four reactors and four cycle layouts combinations. The evaluation results of different schemes based on security, thermodynamics, thermo-economic and compactness and the final score of all indicators are given. The results show that for a Generation IV reactor with the same design thermal power, the higher the exit temperature of the core the better the thermodynamic performance of the cycle. From a techno-economic point of view the efficiency of the turbine and compressor is not necessarily that the higher, the better, but the system can obtain higher profits when the efficiency of the turbine is around 0.85. The thermodynamics and thermo-economic ranking of the systems is the same for the different reactors, GFR > MSR > LFR > SFR, and the ranking of the different cycle layouts is RC > SR > IC > RH, IC > SR > RC > RH. Among them, GFR+RC has the highest thermal efficiency and exergy efficiency of the assembly room with 47.4% and 56.48% respectively. GFR+IC has the lowest the Specific Cost (SC) and the Internal Rate of Return (IRR) of 1861.3$/W and 24.8%, respectively. The re-heating cycle (RH) has poorer figures than the other cycle layouts, but it requires the lowest initial investment cost, where GFR+RH is only 1.33$e^9$$. The intercooled Cycle (IC) has the lowest the Levelized Cost Of Electricity (LCOE), where GFR+IC is only 0.0134$/(KW·h). The simple recuperation cycle (SR) has the best system compactness, with the rest of the cycle layouts being equally compact. Considering all the indicators of the four tiers, the final reactors ranking is MSR>LFR>SFR>GFR and the cycle layouts is RC>SR>IC>RH. For Generation IV nuclear power technology, MSR+RC should be given priority, while GFR+SR and GFR+RH should be considered with caution.

Keywords: Supercritical CO_2 Brayton cycle, Techno-economic comparison, Thermodynamic analysis, multi-index evaluation method.

Proceedings of the 15th International Green Energy Conference
IGEC2023-177
July 10-13, 2023, Glasgow, UK

Analysis of the impact of propanol-gasoline blended fuel on engine performance and emissions by response surface methodology

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Abstract

In recent times, alcoholic fuels have emerged as potential power source of energy for modern vehicles. Many researchers have investigated their impact on engine’s emissions and performance characteristics using methanol, ethanol, etc. But, here propanol is used over which quiate a little research work has been carried out so far. The use of alcoholic fuels is also the need of the hour to cater to the current era's energy needs and counter the increasing pollution levels because they produce lesser emissions and greater efficiency as compared to fossil fuels. Researchers have used various blended fuels like methanol-gasoline blended fuels and ethanol-gasoline blended fuels, but there is little work done on Propanol-gasoline fuel blends. This study examines and compares the experimental results and their analysis using the response surface methodology (RSM) technique for investigating the outcomes and discharge of 4 strokes, single-cylinder spark ignition engine using propanol-gasoline mixtures of 0%, 3%, 6%, 9%, 12%, 15%, and 18% of propanol. The study utilized seven different fuel fractions at engine speeds between 1700 and 3800 rpm and fixed loads of 10 and 20 psi. As a result, the propanol at 18% proportion in the mixed fuel combination improved performance metrics and kept exhaust emissions under control. The optimum blended fuel worked best with an engine load of 10.0004 psi and an engine speed of 2326.71 rpm. RSM based optimization analysis revealed a composite durability value of 0.60 with 1.75 kW brake power, 7.10 Nm torque, 0.56 g/kWh BSFC, 20.06% BTE, 2.81 ppm CO, 126.64 ppm HC, 9.43 ppm CO_2, and 869.65 ppm. Also, overall desirability is highest for BSFC (0.84), least for BTE (0.29), others being torque (0.66), brake power (0.39), CO (0.77), $C0_2$ (0.78), HC (0.64), NO_x (0.66), and overall desirability being 0.60. This study will cast a positive impact on both the public and the engineering community. This study benefits both the general public and the engineering community. In terms of the engineering community, it also encourages more researchers to work on alcoholic fuels and the use of alcoholic fuels. On the other side, using alcoholic fuel, primarily propanol mixed gasoline reduces emissions and increases efficiency, which are the two most critical concerns of the public.

Keywords: Response surface methodology; alcoholic fuel; 4-stroke engine; emissions; propanol-gasoline fuel

Proceedings of the 15th International Green Energy Conference
IGEC2023-178
July 10-13, 2023, Glasgow, UK

EXPERIMENTAL STUDIES ON LAB SCALE PROTOTYPE OF SLAG BLENDED CALCIUM ALUMINATE CEMENT CONCRETE MODULE FOR HIGH TEMPERATURE THERMAL ENERGY STORAGE APPLICATION

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ABSTRACT

Thermal energy storage (TES) systems play an essential role in the dispatchability of solar thermal power. Concrete based sensible heat storage (SHS) is a matured and cost-effective technology compared to the latent heat and thermochemical heat storage techniques. However, the thermal stability of the concrete is a major concern for applications over 250 ℃. Calcium aluminate cement (CAC) is widely used in concrete for refractory applications. Incorporating industrial waste materials like ground granulated blast furnace slag (GGBS)) in CAC concrete enhances the long-term cyclic performance and cut down the material and operational costs of TES systems. A GGBS blended CAC concrete (CACC)TES module of dimensions: 1.2 (L) *0.24 (W)*0.24 (H) has been fabricated. The module consists of a shell and tube type heat exchanger of square cross section wherein, the concrete is filled in the shell side and a total of 9 tubes placed equidistantly conveying the heat transfer fluid (HTF). A test facility to study the thermal performance of concrete up to 600 ℃ has been developed with air as an HTF. The charging time and charging power are the critical parameters that determine the storage/discharge performance of TES systems. These parameters depend on the SHS material, heat exchanger design, and operating parameters. Concrete as a storage material and shell and tube type heat exchangers have been tested for suitability in TES applications operating over 450 ℃ and proven to yield the best storage/discharge performance in previous studies. However, there is no study on the thermal performance of the lab scale porotype of slag bended CAC concrete TES module. In this study, the effect of the operating parameters on the storage performance of CACC TES module has been experimentally investigated in the temperature range of 523 K-583 K. The storage/discharge time and the storage/discharge power of the module are evaluated at three different HTF flow velocities- 4.5 m/s, 6 m/s and 7.5 m/s. The charging time was reduced by 36.1 % and 61.7 % for the HTF velocities 6 m/s and 7.5 m/s, respectively, compared to the HTF velocity of 4.5 m/s. Similarly, the discharging time was reduced by 43.9 % and 48.4 % for the HTF velocities 6 m/s and 7.5 m/s, respectively. The average storage and discharge power at HTF velocity of 7.5 m/s were 1.34 kW and 1.5 kW, respectively. This investigation would facilitate the use of concrete based TES system for high temperature applications.

Keywords: Sensible heat storage, Concrete, Calcium aluminate cement, Ground granulated blast furnace slag, Charging, Discharging, Thermal performance

Proceedings of the 15th International Green Energy Conference
IGEC2023-179
July 10-13, 2023, Glasgow, UK

FINITE TIME EXERGY ECONOMIC ANALYSIS OF THERMOACOUSTIC ENGINE CONSIDERING IRREVERSIBILITY FACTORS

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ABSTRACT
By analyzing the thermodynamic cycle of thermoacoustic engine system, it is known that there must be a critical point where the heat absorption rate of gas working medium is zero. The wave equation of working medium, internal energy change equation of working medium, ideal gas state equation and energy conservation equation are solved simultaneously, and the exergy economic analysis method is introduced. The results show that in order to optimize the performance and profit margin of thermoacoustic engine, it is necessary to control the pressure drive ratio, and there is a pressure drive range that makes both of them optimal.

Keywords: exergy economic analysis, thermoacoustic engine，irreversibility factors

ACKNOWLEDGEMENT
The research work of this paper is supported by the China Scholarship Council (202008420030) and the Scientific Research Foundation of Wuhan Institute of Technology (K201919).

Proceedings of the 15th International Green Energy Conference
IGEC2023-180
July 10-13, 2023, Glasgow, UK

MODELING AND APPLICATION OF FULLY COUPLED MECHANICAL-ELECTRICAL MODELS FOR OFFSHORE WIND TURBINES: A COMPREHENSIVE REVIEW

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ABSTRACT

As the cost increasing fallen into a competitive level, wind energy has been considered to be one of the ideal renewable energy sources for achieving global emission reduction targets. Its capacity potential also made it the main driving force for the overall growth of renewable energy. Over the past few years, significant efforts have been undertaken by various international working groups, including the International Electrotechnical Commission (IEC) and the Western Electricity Coordination Committee (WECC), to develop common dynamic wind turbine models for use in power systems stability analysis. The modeling of offshore wind turbines (OWT) dynamics has typically involved simplifying or reducing the complexity of the system, often neglecting the mechanical responses that can have an impact on electrical analysis of power output performance characteristics. This paper presents a comprehensive review of progress and breakthroughs made in the fields of wind energy conversion system (WECS) modeling and the programming achievements of the OWT dynamics research cooperation project represented by OC3(Passon *et al.*, 2007). These studies have led to the development of a series of fully-coupled mechanical-electrical OWT models, with the latest releases demonstrating improved integration and inheritance of the latest achievements in aero-hydro-servo-elastic (AHSE) modeling and WECS modeling. The paper also analyzes the main challenges and potential adjustments required when progressing from staking OWT to floating offshore wind turbines (FOWT). Finally, the paper provides a detailed description and comparison of simulation software, design schemes, and analysis methods that can be used in the coupling simulation platform, making the results relevant for grid operators, software developers, wind farm owners, and researchers interested in their industrial practices and academic research in integrating increasing wind energy into power systems.

Keywords: Coupled mechanical-electrical modeling, Aero-hydro-servo-elastic modeling, Wind energy conversion system modeling, Wind energy integration.

Proceedings of the 15th International Green Energy Conference
IGEC2023-181
July 10-13, 2023, Glasgow, UK

A PHOTOCATALYSIS SYSTEM SPLITS MOISTURE FOR HYDROGEN PRODUCTION USING 2D $ZNIN_2S_4$ NANOSHEETS HYDROGEL

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ABSTRACT
Hydrogen is a crucial component in the production and advancement of clean energy sources. One such sustainable approach for producing hydrogen is through photocatalytic water-splitting, which is considered a green method. This study focuses on the integration of hygroscopic hydrogels with photocatalytic technology, enabling the environmentally spontaneous collection of water for hydrogen production. A novel hybrid 2D $ZnIn_2S_4$ nanosheets polyacrylamide (PAM) hydrogel composite photocatalyst by the radical polymerization. 2D $ZnIn_2S_4$ has been used as an outstanding photocatalyst for moisture splitting, while the hydrogel was used as the supporting substrate, suspended environment and moisture collector. The H_2 evolution rates of hybrid 2DZISPAM hydrogel reached 4.088 mmol/h/g, which was 5.31 times and 1.6 times higher than that of the ZISPAM (0.717 mmol/h/g) and 2DZIS (2.561 mmol/g/h), respectively, much higher than bulk $ZnIn_2S_4$ (0.555 mmol/g/h). Additionally, the hybrid 2DZISPAM hydrogel remained well stability even after three cycles of running for 30 hours, with no significant decrease in H_2 evolution observed during long time irradiation. The hydrogel matrix keeps the free diffusion of smaller molecules and prevents $ZnIn_2S_4$ nanosheets photocatalyst aggregation. Thus, more surface active sites of $ZnIn_2S_4$ can expose compare with bulk Zn2In2S4. In the hybrid material, the combination of hydrogel and 2D $ZnIn_2S_4$ provides a prospect for H_2 evolution through moisture splitting.
Keywords: Photocatalytic; $ZnIn_2S_4$; Hydrogel; Moisture; Hydrogen

Proceedings of the 15th International Green Energy Conference
IGEC2023-182
July 10-13, 2023, Glasgow, UK

EFFECT OF SUBSTRATE MIXING RATIO ON ANAEROBIC CO-DIGESTION OF CATTLE DUNG AND VEGETABLE WASTE WITH AND WITHOUT ADDITION OF BIOCHAR

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ABSTRACT
The present study investigated the effect of various substrate mixing ratios of cattle dung (CD) and vegetable waste (VW) on biogas yield, both with and without biochar addition. Two sets of batch-type anaerobic biochemical methane potential experiments were conducted at different percentages of CD: VW mixing ratio viz. 70:30, 50:50 and 30:70% on a mass basis simultaneously in triplicate, maintaining substrates/water ratio 1: 1 using the 1000 ml glass reagent bottles with a working volume of 700 ml for the retention time of 45 days. The set-I experiment comprised a mixer of CD and VW only, whereas set-II comprised CD and VW with the addition of 15 g/l biochar. The biochar was prepared from the water hyacinth using a pyrolyser at a pyrolysis temperature of 550 °C. The set-II digesters with CD: VW mixing ratios of 70:30, 50:50 and 30:70% were obtained to be 28.52, 17.91 and 18.29% higher volume of methane yield than the digesters with respective mixing ratios for set-I. The higher methane generation rate was observed for set-II as the biochar can provide an adequate surface area for colonisation of the microbial flora, which was detected in the analysis of its morphology and pore surface. Improvement in pH value was also observed with the addition of biochar due to the alkaline nature of biochar. Comparing cumulative methane yield, the digester with CD and VW mixing ratio of 70:30% was detected to be the best for all sets of experiments. The maximum specific cumulative methane yields for these digesters without and with biochar addition were 132.57 mlCH_4/gVS and 183.07 mlCH_4/gVS, respectively. A kinetic study was also carried out for all sets of experiments using a modified Gompertz model. The correlation coefficient (R^2) value was above 0.9, indicating that the modified Gompertz model and experimental data agreed reasonably well. The present study introduces a sustainable waste management method that can be applied to rural areas for clean energy generation.

Keywords: Substrate mixing ratio, biogas, biochar, kinetics study.

Proceedings of the 15th International Green Energy Conference
IGEC2023-184
July 10-13, 2023, Glasgow, UK

A THERMODYNAMIC ANALYSIS OF INTEGRATED SUPERCRITICAL WATER GASIFICATION & SUPERCRITICAL CO_2 BRAYTON CYCLE: A NOVEL APPROACH FOR POWER GENERATION FROM REAL-WORLD WET BIOMASS

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ABSTRACT
Supercritical water gasification (SCWG) is a promising waste treatment technique capable of producing sustainable H_2-rich syngas from high-moisture organic wastes by taking advantage of the unique properties of water above its critical point (373ºC and 22.1 MPa). Given that processing times are fast and intensive feedstock pre-drying is not required, SCWG offers significant advantages over other biomass treatment methods such as anaerobic digestion and conventional gasification. Despite its promise, several hurdles currently prevent the full-scale commercialization of SCWG; most significantly is the high energy demand required to sustain supercritical conditions. The comparatively lower critical point of CO_2 (31.1ºC and 7.38 MPa) makes it an attractive supercritical fluid for industry, and consequently it sees much usage in a wide range of applications, fulfilling roles as an extractant, solvent, reagent, and many more. Supercritical CO_2 (sCO_2) would be produced in both a large volume and high purity as a by-product post-combustion of the gasification derived syngas. This work explores the use of sCO_2 power cycles in SCWG, which previous literature have demonstrated to be highly efficient methods of generating power from the oxy-combustion of syngas. Preliminary results from the thermodynamic simulations produced in Aspen Plus suggest that further optimization of pre-existing Brayton cycles is needed to achieve thermal efficiencies in SCWG that are comparable to coal-fed gasification processes. Additionally, the results indicate that the process efficiency is highly dependent on feedstock moisture content and type, with no clear correlation between the heating value of the biomass and the plant efficiency.

Keywords: SCWG, sCO_2, Brayton cycle, thermodynamic model

Proceedings of the 15th International Green Energy Conference
IGEC2023-185
July 10-13, 2023, Glasgow, UK

OPTIMIZING AIR-CONDITIONER TARGET TEMPERATURE AND FAN MODE FOR ENERGY CONSERVATION BASED ON LONG-SHORT TERM MEMORY AND PARTICLE SWARM OPTIMIZATION

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ABSTRACT
A data analytics model for a cooling management system is proposed to find the optimal adjustment of target temperatures and air-conditioner fan mode to maximize energy efficiency while maintaining residents' comfort. The ambient scenarios and usage of air conditioner data can be collected from sensors and Internet of Things (IoT) devices installed in an occupied home. Long-short-term memory (LSTM) algorithms have been developed to predict the power consumption of the air conditioner and the indoor temperature and humidity from ambient scenario data and adjustment data of target temperatures and air-conditioner fan mode. A particle swarm optimization (PSO) algorithm has been developed to be capable of selecting the target temperatures and the air-conditioner fan mode that are most appropriate for energy savings while controlling comfort for the occupants by using a predicted mean vote (PMV) as a criterion. The implementation results indicate that the proposed data analytics model can effectively predict the power consumption of the air conditioner and the indoor ambient conditions and succeed in finding the best adjustment case for the air conditioner in any different ambient scenarios, thereby increasing the potential for home energy savings.

Keywords: Cooling management system, Energy conservation, Long-short-term memory, Particle swarm optimization, Predicted mean vote.

Proceedings of the 15th International Green Energy Conference
IGEC2023-186
July 10-13, 2023, Glasgow, UK

THEORETICAL ANALYSIS OF PLASMA GASIFICATION FOR WASTE TREATMENT IN INDIA

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ABSTRACT
Waste accumulation on land and water bodies is a global concern impeding the sustenance of human and marine lives. As per Central Pollution Control Board (CPCB) 2021 report, in 2019-20 FY approx. 9 million tonnes of hazardous waste, approx. 3.5 million and approx.1 million tonnes of E-waste was generated. The same report indicates approx. 5 million tonnes of hazardous waste, approx. 1.5 million and approx. 0.2 million tonnes of E-waste were recycled. It is imperative the share of non-recycled waste every year is not negligible by any means. Several incineration and gasification units exist in India. However, plasma based gasification centres are still not common in India and globally this technology has proven to be a potential solution to handle the menace of waste accumulation. The high-temperature (1000-5000 K) environment of thermal plasma is assumed to be breaking down complex waste molecules into much simpler forms which is substantiated by emission (NO_x, HC, PM, dioxins, furans) levels in producer gas much lower than the regulated environmental norms. A theoretical study has been carried out addressing multiple aspects of the plasma-based waste gasification, such as composition of product gases post-gasification, dominant plasma characteristics and estimation of waste depletion rate in thermal plasma environment. Such a study can provide the foundation of an analysis tool which can help planning and establishment of several plasma-based waste treatment plants across the country.

Keywords: plastic waste, thermal plasma, gasification, producer gas

Proceedings of the 15th International Green Energy Conference
IGEC2023-187
July 10-13, 2023, Glasgow, UK

ESTIMATION OF LATENT HEAT AND VAPOR PRESSURE OF ETHANOL-GASOLINE BLENDS USING MACINE LEARNING AND THERMODYNAMIC RELATIONS

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ABSTRACT
Latent heat of vaporization (LH_{vap}) is a crucial property in internal combustion engines (ICEs). It affects the cylinder temperature, ignition delay, NO_x emission and other phenomenon in ICEs. With the increase in global warming, use of alternative fuels in ICEs such as gasoline-ethanol blends, gasoline-methanol blends have become evident. Another important use of LH_{vap} values is encountered while performing the spray combustion analysis of blended fuels using Computational Fluid Dynamics (CFD). There are largely three ways by which LH_{vap} values of blended fuels could be estimated – experimental, molecular dynamics simulation and thermodynamic modeling. Experimental method is time-consuming, costly and all possible engine chamber conditions are not tractable through experimentation. The second is by using Molecular Dynamics (MD) simulations. This method could give accurate values, but it is a time & resource consuming process. The third is by determining the values through machine learning algorithms and already available property database. Here, the advantage is reduction in turnaround time. This paper investigates the use of various Machine Learning (ML) techniques to predict the latent heat of vaporization (LH_{vap}) for blended fuels. The algorithms used were Linear Regression (LR), Polynomial Regression (PR), Support Vector Machine (SVM), K Nearest Neighbors (KNN), Decision Tree (DT), and Random Forest (RF). The features used were Temperature, Blend Ratio, Molecular weight, Carbon (wt.%), Hydrogen (wt. %), Oxygen (wt. %). For training the algorithms, data was collected from several published research papers with LH_{vap} values of gasoline-alcohol fuel blends and various diesel blends. The model was initially trained with data pertaining to gasoline-alcohol blends only, which showed that LR performed better than other algorithms in predicting both $LH_{vap,}$ with a coefficient of determination (R^2 score) of 90% and Mean Absolute Percentage Error (MAPE) of 6.2%. This behavior was attributed to the linearity in the data, as most of the data points were of gasoline-alcohol blends with different blend ratios and temperatures. However, when more datapoints were included such as various oxygenated blends of diesel, it was found that RF performed much better than other algorithms, with an R^2 score of 95.7% and MAPE of 6.8%. Furthermore, additional features were considered such as vol. % of paraffins, aromatics, olefins, iso-paraffins, cyclo-paraffins, napthenes along with original features. The results showed that predictions improved with adding these features as the R^2 score improved for all algorithms. It could be summarized that with availability of more data, the performance of RF algorithm could further improve. Thermodynamic relations have been attempted to correlate predictions of latent heat of vaporization with vapor pressure data of the blends.

Keywords: machine learning, ethanol-gasoline blends, latent heat of vaporization, vapor pressure

Proceedings of the 15th International Green Energy Conference
IGEC2023-188
July 10-13, 2023, Glasgow, UK

EXPERIMENTAL ANALYSIS AND NUMERICAL OPTIMIZATION OF THE STRATIFICATION EFFICIENCY IN A COMMERCIAL STRATIFIED THERMAL STORAGE

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ABSTRACT
The ever increasing demand for renewables in the energy system has drawn attention to technologies capable of minimizing the effect of renewables' intermittency and shave-off the generation-demand imbalance of the system. Energy storage can help to level peaks in energy demand, thus reducing wastage due to excess capacity during off-peak demand periods. Among the storage media, thermal energy storages (TES) have a large variety of applications, ranging from solar energy utilization and power peaking to industrial waste heat storage.

In this study, data collected from an operating commercial stratified tank are used to validate a 2-D axisymmetric CFD model. Temperature profiles at various heights are collected throughout one month with a one-minute refresh rate. The model replicating the tank is generated in COMSOL Multiphysics® and validated by emulating the registered charging phases of the real storage, thus comparing the temperature layers before and after the charging occurs. The model is then employed to optimize the stratification efficiency of the tank, by varying the logics applied to pinpoint optimal values of both inlet water temperature and velocity.

The study aims to minimize the MIX number, a parameter often utilized in literature to identify the ability of the storage to generate and preserve optimal temperature stratification. Said dimensionless number is evaluated by accounting for the momentum of energy of the different temperature layers found in the water tank. Therefore, a discretization of the thermal storage in five sub-volumes, each of them characterized by the presence of an installed thermocouple, was defined. Finally, the experimental MIX number has been evaluated for the aforementioned temperature profiles.
Keywords: Solar Energy, Stratified Thermal Energy Storage, Stratification, Efficiency.

Proceedings of the 15th International Green Energy Conference
IGEC2023-189
July 10-13, 2023, Glasgow, UK

HIGH-VACUUM FLAT PLATE COLLECTORS' DYNAMIC ANALYSIS FOR DRY SATURATED STEAM PRODUCTION THROUGH A FLASH VESSEL AND KETTLE REBOILER COMPARISON

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ABSTRACT
Steam is a key energy vector in the industrial sector and each application requires steam at a specific pressure and temperature. In this paper the production of low pressure dry saturated steam for industrial use through high-vacuum flat plate solar collectors (HVFPCs) will be discussed. This technology can be used to produce steam from solar energy, hybridizing it to existing fossil powered steam generators to obtain significant energy savings and avoid CO_2 emissions.
In recent years, various studies have been conducted to evaluate the efficiency of these collectors. A recent study was carried out in 2020 by a Chinese study group [1] on MT-Power panels v4 SK produced by TVP Solar company. This study shows high efficiencies (greater than 50%), even when panels are operated at medium-high temperatures. In this work an energy comparison between numerical results of different plant configurations is made, which differ from each other precisely in the type of dry saturated steam production device. These devices are necessary as it is not possible to produce steam directly inside the collectors.

Two possible steam generation methods were analysed: direct steam production, using a Flash vessel, and indirect steam production, using a Kettle reboiler. Flash vessel produces steam through flash-type expansion of the solar plant pressurized water while Kettle reboiler is similar to a traditional steam generator, but its primary fluid is the hot fluid coming from the solar field.Two different case studies will be also analysed, elaborated with the data from two different TVP Solar fields, one located in Avellino (Italy), to produce steam at 130°C, and another one located in Qurayyah (Saudi Arabia), to produce steam at 150°C. Both the plant solutions presented are to be considered as test plants, thus not accounting for the variations in the consumer's demand. The steam produced is dispersed into the surroundings instead.

Dynamic simulations were carried out using the 0-D Trnsys® software, which allows to do an hourly analysis for the evaluation of the plant operating parameters, with variable weather conditions, introduced through the Meteonorm® database. The various configurations were simulated changing step-by-step the steam generation device and considering or not the presence of an intermediate heat exchanger (HE) separating the solar field from the steam production device. However, the use of an intermediate HE involves the increase of the solar field temperature (entailing a reduction of the solar collector's efficiency) by about 5°C.

Finally, each configuration was simulated by imposing a ΔT on the solar field of both 10°C and 20°C, which are the temperature gradient of the steam generation devices (direct and indirect). Dynamic results show that flash vessel configurations are generally the most efficient, with the same operating parameters, compared to the configurations with Kettle reboiler. Furthermore, with the same plant configuration, the one with smaller ΔT (10°C) leads to the best results, due to the higher HVFPCs' efficiency at lower temperatures.

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Keywords: *EFPC, dry saturated steam, solar field, Trnsys.*

MODELING AND PERFORMANCE ANALYSIS OF HIGH VACUUM FLAT PLATE HYBRID PHOTOVOLTAIC-THERMAL COLLECTORS

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ABSTRACT
We propose a novel layout of a high-vacuum flat plane hybrid PV-T device (HV PV-T) that synthetizes the capacity of cutting down the convective losses, due to high vacuum encapsulation, and the ability to maintain a non-negligible electrical efficiency at elevated temperatures, characteristic of PV cells adopted in space applications. This layout is suited to solar-to-thermal energy conversion and can efficiently match the thermal loads of industrial processes up to 150°C, i.e., boiling and pasteurizing. The presented PV-T system consists of three main components: glass cover, which keeps, together with the metallic vessel, the device under high vacuum ($p < 0.1$ Pa), and the actual PV-T Device. The PV-T device has four main layers: a Transparent Conductive Oxide (TCO), a Perovskite-based PV cell, a Solar Absorber (SA) and a copper substrate and it is welded on a copper tube where the heat transfer fluid can circulate. The PV cell is placed above the SA in a way that all the solar energy that has been absorbed by the PV cell but non converted into electricity will be conducted to the SA, contributing to the production of useful thermal energy. We investigate, through a 1-D numerical model developed in MATLAB, the performances of the proposed PV-T device, which are still mined by radiative losses. These latter depend on the operating temperature of the absorption layer (T_{op}) and on the emittance of the TCO (ε_{TCO}), therefore the performance analysis has been carried out varying these two parameters in the ranges (25÷175) °C and (0.05÷0.45) respectively. The annual thermal and electrical productions (kWh/m^2year) of our PV-T device have been evaluated considering hourly meteorological data of distinct locations: Amsterdam (Netherlands), Naples (Italy), and Doha (Qatar). A comparison with the performances of commercial High-Vacuum Flat Plate Solar-Thermal (HVFP ST) and PV collectors is also proposed. Results indicate that, at an operating temperature of 100°C, providing emittance values lower than 0.21, the annual thermal productions are higher than 503 (Amsterdam), 941 (Naples), and 1278 (Doha) kWh/m^2year , still preserving the annual electrical output at 158 (Amsterdam), 234 (Naples), and 288 (Doha) kWh/m^2year. An economic analysis, contextualized in the climate of Naples, reveals promising results: considering an annual thermal demand of 26 GWh, the margin cost for the development of the proposed HV PV-T device to reach the same Simple Pay-Back time of the HVFP ST solution is 248 $€/m^2$. In this case, the HV PV-T solution achieves an annual CO_2 emission saving 58% higher than the one assured by the HVFP ST solution.

Keywords: Hybrid, PV-T, Cogeneration, Solar energy, Thermal efficiency, Electrical efficiency, Exergetic efficiency, High vacuum.

Proceedings of the 15th International Green Energy Conference
IGEC2023-192
July 10-13, 2023, Glasgow, UK

PERFORMANCE ANALYSIS OF HIGH-VACUUM INSULATION FOR MID-TEMPERATURE HEAT DELIVERY PIPES

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ABSTRACT
Thermal insulation is crucial for systems where heat delivery is required. This work focuses on fluid transportation applications in the temperature range of 100÷200 °C where high-performance insulating materials play a key role in the overall efficiency. Generally, thermal insulation can be obtained with low thermal conductivity materials (λ expressed in W m^{-1} K^{-1}) such as rockwool, fiberglass, polyurethane, polystyrene [1], and aerogel [2] where the lowest value achieved is 17 mW m^{-1} K^{-1}. Better insulation performance can be reached by adopting high-vacuum technology ($p<1E-4$ mbar), as demonstrated by high-vacuum flat plate solar collectors [3], in which thermal radiation is the main loss mechanism and the role of conduction of the material is minimized. In this work, an innovative technical solution to mid-temperature heat delivery is presented and compared to traditional insulators. The authors built an evacuated short pipe under high vacuum, coated by aluminium foil and a vacuum vessel as the outer tube. To quantitatively define the performance of a high vacuum thermal insulator along the radial direction, an equivalent thermal conductivity is adopted: λ_{eq} (W m^{-1} K^{-1}) which depends also on the insulation system geometry. Higher the operating temperature, the more impactful the heat losses. Different techniques are known in literature [4] to ensure correct temperature gauging, which is critical because inaccurate temperature measurements could underestimate the insulator's performance. For a similar application, Berge et al. [5] and Chen [6] adopted different techniques reaching, as the lowest value, λ=12 mW m^{-1} K^{-1}. In this work compensation technique is adopted, aiming to minimize the difference between central and lateral temperatures. Experiments for the highest tested temperature led to an equivalent thermal conductivity λ equal to 3.5 mW m^{-1} K^{-1}, about 3 times lower than the best solution found in the literature. A comparison between experimental results and an analytical model will highlight that our reached performances are even better than expected with a full contact hypothesis, approaching a no-contact behaviour as a radiant barrier.

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Keywords: Thermal Insulation, High Vacuum, Low Thermal Conductivity.

Proceedings of the 15th International Green Energy Conference
IGEC2023-193
July 10-13, 2023, Glasgow, UK

THE ROLE OF HYDROGEN IN DECARBONISING THE STEEL INDUSTRY: UPSTREAM AND DOWNSTREAM IN THE UK AND ONTARIO

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ABSTRACT

Currently the iron and steel industries are a significant contributor to global carbon emissions due to their reliance on fossil fuel powered processes. Use of technologies exploiting hydrogen as a fuel have gained prominence as a potential route to decarbonise the sector. This research offers a hitherto under-explored understanding of the enablers and barriers to industry adoption of hydrogen technologies, using the context of the steel industry in the UK and Ontario, Canada as case studies. Through thematic analysis of semi-structured interviews with key businesses and stakeholders across the steel network, we build a causal map which explicates the decision-making underpinning adoption of hydrogen technologies in the processing and production of steel. The outcomes will inform priorities for technological development and policy to support decarbonisation of steel manufacturing, a problem of international importance.

Understanding the interdependency between decisions, uncertainties and goals are essential for informing effective strategy development in such a socio-technical problem. Causal mapping provides a means to visually represent the cause-effect relationship between relevant factors within a system. We explore issues with goals such as carbon emissions and ‘net-zero’, uncertainties related to carbon taxes, government policy, and hydrogen colour classification, as well as hydrogen embrittlement, costs and technology replacement in relationship to hydrogen adoption. The corresponding policy-facing causal map interprets this understanding into a decision-making tool to assist the journey to net-zero. We adopt an inductive reasoning approach by firstly analysing data gathered from the UK industry, developing a concurring hypothesis and testing this on the Canadian industry. Our paper presents the preliminary data and findings, and argues that the three main barriers to hydrogen technology adoption in the UK steel industry are: (1) Cost; (2) Supply; (3) Knowledge.

This project is in collaboration with the National Manufacturing Institute Scotland (NMIS). NMIS have formed a conglomerate of industrial partners from the UK forging industry and furnace companies to develop hydrogen powered furnace technology.

Keywords: hydrogen furnace, steel, barriers, enablers, sustainable transition, net-zero

Proceedings of the 15th International Green Energy Conference
IGEC2023-195
July 10-13, 2023, Glasgow, UK

SUSTAINABLE REDOX FLOW BATTERY OPERATION: FINITE-TIME EXERGY ANALYSIS

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The redox flow battery (RFB) is predicted to play a critical role in forming more productive and resilient renewables industries due to recent technological advancements, their adaptability, modularity, and reductions in capital and running costs[1]. The RFB is an energy storage device which benefits from having energy transfer physically separated from energy storage, meaning that they can be designed for a wide range of possible power/ capacity combinations and can be scaled to accommodate alterations to design specification once implemented on account of their modularity[1]. With their upcoming widespread implementation, it is important to understand how to optimise their operation and performance, particularly when integrated into a renewable energy system with variable supply and demand.

Exergy analysis is an essential tool to assess sustainability and performance which focuses on the exergy differences between system state points with the intention of highlighting regions of excessive exergy destruction within a process. If the exergy analysis scope is extended to include and optimise time- or rate-dependent phenomena (e.g. mass transfer rates, load/demand profiles, reaction kinetics, input supply rates, storage dissipation rates, etc.), the additional detail can be used to further reduce internal exergy destruction and increase resource efficiency. These concepts are derived from the principles of finite-time thermodynamics[2], which, though there have been direct and indirect examples of applications to improve sustainable engineering practice[2],[3], could be implemented more extensively. Knowledge of a system's internal rate-dependent exergy destruction combined with dynamic modelling techniques allows engineers to better design systems for minimal exergy destruction.

In this work, the principles of finite-time thermodynamics are applied to analyse the effects of fluctuations in power output, power demand, fuel flow rates, and state of charge on exergy destruction rates in vanadium RFBs using experimentally validated dynamic models from the literature. This is then used to provide insight on the optimal range of operating parameters for any given RBF system based on charge/discharge exergy destruction.

This study is used as an illustrative example of how a detailed analysis of the rate dependent exergy destruction in processes can provide perspective and further insights to achieve sustainable engineering.

This form of analysis can be applied to systems containing processes which operate over finite time-spans or contains physical rate constraints, including separation processes, reaction engineering, circular economy modelling, agriculture, and power systems.

Keywords: exergy analysis, finite-time thermodynamics, redox flow battery, rate optimisation

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Proceedings of the 15th International Green Energy Conference
IGEC2023-196
July 10-13, 2023, Glasgow, UK

INVESTIGATION OF ENERGY EFFICIENCY ROAD MAP OF INDUSTRIAL FACILITY

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ABSTRACT

Industrial facilities are dynamic businesses that consume more than one energy in their production processes. This study developed an energy efficiency roadmap, which should be followed by energy management in an industrial enterprise with textile production, and the business process was evaluated. The energy efficiency assessment of the enterprise is a key indicator for corporate management strategies and is a process that must be managed. Indeed, energy efficiency analyses were primarily evaluated with the GAP analysis, handled according to a framework, and the energy efficiency study was evaluated. In this context, a consumption analysis has been made for the last three years and a road map has been created for the target productivity potential based on consumption. According to the efficiency histogram developed accordingly, a target of 29.08% was determined for energy efficiency. The sustainable efficiency flow of the enterprise was evaluated along with a four-year action period, and the actions that needed to be developed were evaluated.

Keywords: Industry, Energy management, Energy efficiency, Road map, Sustainability.

Proceedings of the 15th International Green Energy Conference
IGEC2023-197
July 10-13, 2023, Glasgow, UK

ASSESSMENT OF DIFFICULTY OF GREEN TRANSITION OF AIRPORTS BASED ON ENTROPY MANAGEMENT

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ABSTRACT

Airports, an important center of action for the aviation sector, can be seen as a key structural model for combating global climate change. The framework of energy management should be considered entropy management and sustainability, especially for these structural systems, which are multi-source for fossil resource consumption and have a mobile campus with all its elements. This study discussed the environmental indicators taken as a basis for an exemplary airport and the difficulties in front of the green transformation in the institutional structure. The study evaluated the effects of the indicators developed for control tools and the classical approaches. In this respect, it is seen that exergy destruction in airports has potential effects on green transformation as an environmental problem. The exergy approach can be used as a model to evaluate energy efficiency potential. In this context, it will be possible to define the potential for changing tools in energy consumption and to shape a target for decision processes. A target evaluation to be defined with the green transition for squares with a savings potential of up to 70% will make a significant contribution to road maps. At the end of the study, some suggestions are also presented for this purpose

Keywords: Airports, Green transition, Exergy, Entropy, Sustainability.

Proceedings of the 15th International Green Energy Conference
IGEC2023-199
July 10-13, 2023, Glasgow, UK

THE TITLE: DESIGN AND ANALYSIS OF HYDROGEN FUEL CELL PROPULSION SYSTEMS FOR AEROSPACE APPLICATIONS

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ABSTRACT
Emissions from airplanes at high altitudes have several times higher adverse impact on the environment and climate change than emissions at ground levels. Therefore, it is imperative to develop zero emission propulsion systems for airplanes in order to meet emission reduction targets. Proton exchange membrane fuel cell (PEMFC) is considered to be one of the most important technologies for providing emissions-free electricity for aircraft propulsion systems. It can offer competitive advantages regarding high energy efficiency, zero emissions, low noise, cruise range, and diverse fuel sources. However, as a new power and propulsion system, there are technical challenges associated with the design and optimization of fuel cell propulsion systems to meet the specific requirements of aerospace industry in terms of capacity, cost, and performance. In this study, the objective is to develop designs of aerospace electric propulsion system, including hydrogen and air supply, PEMFC stack, water management, and thermal management, and then carry out analysis for the performance of such designs by using MATLAB/Simulink to explore the sensitivity of the system performance to design options as well as design and operation parameters.

Keywords: Electric propulsion, PEM fuel cell, hydrogen storage, and supply, air supply, thermal management, system performance

Proceedings of the 15th International Green Energy Conference
IGEC2023-200
July 10-13, 2023, Glasgow, UK

THE TITLE: HYDROGEN PRODUCTION FROM FOSSIL FUELS INTEGRATED WITH CARBON CAPTURE, UTILIZATION, AND STORAGE (CCUS)

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ABSTRACT
Production of hydrogen, one of the most promising alternative clean fuels, through catalytic conversion from fossil fuel is the most technically and economically feasible. Catalytic conversion of natural gas into hydrogen and carbon is thermodynamically favorable under atmospheric conditions. However, using noble metals as a catalyst is costly for hydrogen production, thus mandating non-noble metal-based catalysts such as Ni, Co, and Cu-based alloys. This study provides a comprehensive review of the various hydrogen production methods from fossil fuels through pyrolysis, partial oxidation, auto thermal, and steam reforming, emphasizing the catalytic production of hydrogen via steam reforming of methane. The multicomponent catalysts composed of several non-noble materials have been summarized. Among the Ni, Co, and Cu-based catalysts investigated in the literature, Ni/Al_2O_3 catalyst is the most economical and performs best because it suppresses the coke formation on the catalyst. To avoid carbon emission, this method of hydrogen production from methane is integrated with carbon capture, utilization, and storage (CCUS). Carbon capture is accomplished by absorption, adsorption, and membrane separation processes. The remaining challenges, prospects, and future R&D directions are described.

Keywords: Hydrogen production, catalytic conversion, oil and gas cracking, steam reforming, carbon capture, utilization, and storage (CCUS).

Proceedings of the 15th International Green Energy Conference
IGEC2023-201
July 10-13, 2023, Glasgow, UK

RENEWABLE ENERGY PERSPECTIVES: BRAZILIAN CASE STUDY ON GREEN HYDROGEN PRODUCTION

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ABSTRACT
Due to increased pressure to control polluting emissions, it is necessary to study and evaluate the exploitation of more efficient and sustainable resources for energy distribution and storage. In accordance with international carbon emission agreements, the use of fossil fuels is reduced. Therefore, the use of clean energy resources is encouraged. Hydrogen, an abundant element whose complete combustion is clean, is pointed out as a global bet of renewable energy matrix for the future, and can be obtained from different raw materials, such as water, bioethanol, and microalgae. The objective of the study is to evaluate the current scenario of renewable energy production in Brazil, focusing on the production of green hydrogen. The work is developed from the analysis of the data obtained through the reading and collection of information in scientific articles and technical reports of funding agencies, to have a better view of the problem and have clarity in the results and discussions. It was investigated from articles in the literature subjects such as hydrogen sources, production, storage, and transport. The current Brazilian energy matrix is evaluated. This study focuses on analyzing the prospects of green hydrogen production, with emphasis on electrolysis. In this sense, the current situation of renewable energy production in Brazil will be evaluated, with a focus on hydroelectricity, wind, and solar energy. Brazil has a robust energy matrix, and 48% of its energy supply is derived from renewable resources. In Brazil, several technical and economic studies and projects aimed at the production of green hydrogen are being developed. In addition, the country has a prominent position to become an exporter of low carbon hydrogen, because its territory presents excellent and favorable climatic conditions for the generation of electricity through wind, water, and solar sources. In the Brazilian electricity matrix, the water source is the main resource, representing about 57% of the domestic supply. Then there is the use of biomass (8.2%), wind (10.6%) and solar (2.47%).

Keywords: Hydrogen, Renewable energy, Alternative fuels.

Proceedings of the 15th International Green Energy Conference
IGEC2023-202
July 10-13, 2023, Glasgow, UK

DEVELOPMENT OF NON-SPHERICAL PLATINUM CATALYST WITH FUNCTIONALIZED CARBON SUPPORTS FOR PROTON EXCHANGE MEMBRANE FUEL CELLS

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ABSTRACT

Proton exchange membrane fuel cells (PEMFCs) are anticipated to play an important role in decarbonizing the global energy system. Before they can be deployed in large scale, PEMFCs must be made more economical by improving the performance of platinum (Pt) catalyst. Studies have identified non-spherical Pt nanoparticles and functionalized carbon supports as promising ways to address this challenge. However, to realize the full benefits of these strategies, the catalyst synthesis procedures must be successfully scaled up and it must be designed to perform well in full-cell tests. In this study, a surfactant-free one-pot method is developed to synthesize non-spherical Pt nanoparticles on Ketjen Black carbon, which is either non-functionalized (Pt/KB), treated with oxidizing acids (Pt/KB-O), or nitrogen-doped (Pt/KB-N). The catalysts are synthesized in both small and large batches to determine the effect of scaling up the synthesis procedure. Physical tests confirm that both functionalization methods affect the carbon's surface chemistry and microstructure, in turn affecting the properties of the supported Pt catalysts. When the synthesis is scaled up, Pt/KB-O and Pt/KB-N are dispersed more evenly on the carbon and retain their morphology better compared to Pt/KB, demonstrating the benefits of oxygen- and nitrogen-containing surface groups. In electrochemical tests, Pt/KB-O achieves only similar or slightly lower oxygen reduction reaction (ORR) activity as Pt/KB, and Pt/KB-N achieves similar or slightly higher ORR activity. These results show that functionalizing the carbon support does not always improve the catalyst's performance, which may depend specifically on each catalyst's morphology and poisoning from the ionomer. All three catalysts have similar durability when cycled between 0.5-1.0 V for Pt degradation, but Pt/KB-O is the most durable when cycled between 1.0-1.5 V for carbon corrosion. Unexpectedly, all three catalysts achieve higher ORR activity when synthesized in large scale, with this result attributed to unintentionally formed anisotropic Pt structures (e.g., nanorods). These results will help inform the implementation of shape-controlled Pt catalysts and functionalized carbon supports in large scale.

Keywords: PEMFC, Pt/C catalyst, shape control, carbon support, functionalization, ORR activity, scale-up.

Proceedings of the 15th International Green Energy Conference
IGEC2023-203
July 10-13, 2023, Glasgow, UK

A REVIEW OF BIPOLAR PLATE AND FLOW FIELD DESIGNS FOR PROTON EXCHANGE MEMBRANE FUEL CELLS

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ABSTRACT
Proton exchange membrane (PEM) fuel cell technology is maturing with early commercial adoption for the hard-to-decarbonize sector of industry, including heavy-duty ground transport and aviation applications. For these mobile applications, it is essential to have a lightweight compact fuel cell power and propulsion system, mandating high power density fuel cell stacks. Bipolar plates are key components in PEM fuel cell stacks, and they fulfill important functions and requirements to allow fuel cell stacks to achieve high power density, high efficiency, low cost and long lifetime in practical applications. Existing bipolar plates contribute up to 80% by weight and volume and 40% by cost of PEM fuel cell stacks. Therefore, in this presentation the evolution and innovation for the bipolar plate and flow field on the bipolar plate is reviewed comprehensively. The focus is on the fundamentals to the latest developments and state of the art knowledge and technology for practical applications. First, the functions and requirements of bipolar plates are stated, then flow field designs as the major structural features fulfilling one of the key functions for reactant gas distribution to proper membrane electrode assembly (MEA) surfaces are described, fundamental designs and principal design improvement features are presented, their incorporation leading to the state-of-the-art designs is illustrated. Proper selection of materials is presented in the category of graphite, carbon composites and metals, as well as their pros and cons. Manufacturing methods utilizing the unique properties of the selected materials are provided that are practiced in industry. The presentation will end with a discussion of comparison of the various bipolar plates used in practice today. The combinations of proper materials, flow field designs and methods of manufacturing developed for the bipolar plates allow the achievement of commercial targets, especially for zero-emission propulsion systems for aviation applications.

Keywords: PEM Fuel cell; Bipolar plate; Flow field design; Materials and manufacturing

Proceedings of the 15th International Green Energy Conference
IGEC2023-204
July 10-13, 2023, Glasgow, UK

INVESTIGATION ON HEAT GENERATION IN FAST CHARGING OF LITHIUM BATTERIES: EFFECT OF CHARGING RATE AND BATTERY COMPONENT THICKNESS

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ABSTRACT
The heat generation and temperature distribution of lithium-ion batteries during fast charging directly affect the performance and safety of the battery system. A deep understanding of the heat generation mechanism during the charging process of lithium-ion batteries is essential, but it has been missing from the literature. In this paper, a three-dimensional electrochemical-thermal coupling model of pouch lithium-ion batteries is developed, and the model is verified by the experimental results on temperature distribution, current and voltage profiles. We further study the effects of charging rate, active material coating thickness, and current collector thickness (each at three levels) on heat generation and temperature distribution. The results show that the temperature of the lithium-ion battery increases, and the temperature uniformity worsens with the increase of charging rate. The percent of charged capacity and heat generation in the constant current phase are lower as the charging rate increases from 0.5 to 2.5 C (charged capacity from 97.2% to 86.1%, and heat generation from 99.4% to 93.4%). The electrodes account for the majority of total heat generation (87.5% with 2.5 C charging rate), and the percentage decreases as the charging rate increases. The negative electrode heat generation is slightly greater than the positive electrode heat generation. Reversible heat is the dominant heat source at low charging rate, and it decreases as the charging rate increases.
The effects of battery component thicknesses on thermal behavior under fast charging are significant. The overall battery temperature increases by 11.5 K as the positive electrode thickness increases from 40 to 70 μm , due to the increase of the ohmic resistance and polarization resistance in the electrode. The increased ohmic resistance in the current collector and the separator also contributes to the elevated temperature. The reduction of the thickness of the current collector by 33% doubled the heat generation of current collectors, but hardly changed the overall temperature of the battery.

Keywords: Lithium-ion batteries, heat generation, electrochemical-thermal coupling model, charging rates, current collector thickness

Proceedings of the 15th International Green Energy Conference
IGEC2023-205
July 10-13, 2023, Glasgow, UK

PERFORMANCE PREDICTION OF ANAEROBIC DIGESTION OF PULP AND PAPER SLUDGE COUPLED WITH HYDROTHERMAL PRE-TREATMENT USING MACHINE LEARNING ALGORITHMS

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ABSTRACT
The pulp and paper (P&P) industry is responsible for generating 27% (wt.%) of wastewater sludge annually, as reported by the Environmental Protection Agency (EPA). The current disposal methods for this waste often result in greenhouse gas emissions and/or groundwater contamination, causing environmental and health hazards. As of September 2021, there are about 220 (P&P) mills in Canada alone, producing 1.2 million tonnes of dry sludge per year. Effluents from pulp and paper (P&P) manufacturing mills and primary and secondary sludge from wastewater treatment plants contain large amounts of organics. The high organic load of these waste streams makes it suitable for anaerobic digestion (AD) treatment. However, the first stage of AD, hydrolysis, occurs slowly as converting macromolecules to soluble monomers is typically the rate-limiting step. Thermal Hydrolysis (TH) is a method to accelerate the hydrolysis and the overall AD rate as it breaks large polymer chains into smaller molecules. This would increase organic solubilization, which improves AD performance, including methane production rate and extent. Finding optimum conditions such as temperature, pressure, and residence time to achieve optimum organics solubilization is critical for the effective application of TH. Reviewing the published literature has revealed that the use of AD technology for the P&P industry is limited and insufficient data is available for the AD of solid residues and sludge generated from these facilities to perform a reliable modeling. The closest feedstock to P&P sludge is waste-activated sludge generated in municipal wastewater treatment plants, for which the feasibility of TH coupled with AD has been demonstrated well in the literature. This project aims to model the results of previously published works where an advanced AD process with TH were applied to both waste activated sludge and P&P sludge to determine the optimum conditions along with producing a predictive model that can forecast the result of various scenarios. Three machine learning algorithms, random forest, extreme gradient boosting, and artificial neural networks were evaluated for their feasibility of predicting the performance of TH on the operating parameters collected in published articles on waste-activated sludge and P&P sludge (total of ~760 data points). The accuracy in predicting model outputs, such as methane production and solubilization ratio, is evaluated for each method by calculating the root mean squared error (RMSE) and mean absolute percentage error. The feature importance analysis is performed for both methane yield and solubilization. This study demonstrates the potential of using machine learning algorithms to model AD coupled with TH. The decision-tree models perform better than ANN for this database.
Keywords: Anaerobic Digestion, Thermal Hydrolysis, Machine learning, Modeling.

Proceedings of the 15th International Green Energy Conference
IGEC2023-206
July 10-13, 2023, Glasgow, UK

O_2-ASISTANT RECHARGEABLE ALUMINUM-CO_2 BARRETY

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ABSTRACT (FONT, ARIAL, SIZE 9.5, BOLD)

Metal-CO_2 batteries have been proposed as a novel and clean strategy for energy storage and greenhouse gas utilization. Among them, Aluminum-CO_2 (Al-CO_2) batteries show the potential as a low-cost and sustainable energy storage solution due to the abundance of aluminum and CO_2. Although it displays a high energy density, this technology is still in its early stage and faces many challenges. To be specific, it was reported that aluminum reacts with CO_2 in the cathode to produce aluminum carbonate (Al_2CO_3) and carbon during the discharging process, while aluminum carbonate and carbon are converted back to aluminum and CO_2 during the charging process. However, the Al_2CO_3 is unstable making it difficult to predict, the reaction mechanism is still unclear, and the battery is hard to be rechargeable. Therefore, a rechargeable Al-CO_2 battery has been developed to study the reaction mechanism during charging and discharging processes. Researchers found that the discharge voltage decreased quickly to below zero under a N_2 and Ar gas environment, but when CO_2 was introduced into the battery, the discharge voltage remained stable at around 0.5V with a current density of 100 mA/g catalyst. Additionally, the battery's discharge voltage could increase to 0.75V with the addition of 1% O_2 in CO_2 gas, and the discharge-charge gap was reduced to 0.15V. The O_2-assisted Al-CO_2 battery was able to cycle for more than 50 cycles, and the reaction mechanism was further studied. Overall, this study has achieved a true CO_2 redox reaction on the cathode and offers promising prospects for further development of the Al-CO_2 batteries.

Keywords: Aluminum-CO_2, battery, rechargeable, O_2 assisted.

Proceedings of the 15th International Green Energy Conference
IGEC2023-208
July 10-13, 2023, Glasgow, UK

MEMBRANES OF ZIF-90 IN POLYETHERIMIDE DENSE AND SPONGY MATRICES FOR EFFICIENT HYDROGEN PURIFICATION FROM CO2

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ABSTRACT
Hydrogen is inherently a green fuel which is mainly produced through water splitting (Green hydrogen) or steam reforming of methane (Blue hydrogen). The blue hydrogen production consists of CO_2 as a byproducts. Therefore the purification of hydrogen from impurities like CO_2 and methane is highly needed. In this work report on the fabrication of new membranes made of ZIF-90 nano-particles for H_2 purifications. The ZIF-90 embedded in polyetherimide (PEI) at 10 wt.% resulted in the formation of the dense and spongy ZIF-90/PEI mixed matrix membranes (MMMs). 10 wt.% of ZIF particles were dissolved in DMAC, and the resulting solution was added to a polymer solution. A casting knife was used to spread the mixture evenly on a clean glass plate at a thickness of 200 m and leave the membrane in air for more than 12 hours to get a spongy texture. For dense texture, the membrane was kept in the oven at 120°C. To help the sample stick together. ZIF-90 particles have been synthesized and characterized using powder X-ray diffraction, infrared and nuclear magnetic resonance spectroscopic techniques, which confirmed the production of the pure phase ZIF-90. Particle and morphology analysis has been carried out by field emission-scanning electron microscopy (FESEM) that revealed the narrow dispersity and the cubic morphology of the produced ZIF-90 particles. The resulting membranes have been characterized using FESEM and energy dispersive x-ray spectroscopy, revealing the formation of dense and spongy textures, fine particle-polymer adhesion, and the uniform ZIF-90 particles dispersion in the PEI matrix. The fabricated ZIF-90/PEI MMMs showed an excellent hydrogen purification performance versus O_2, N_2, CO_2 and CH_4 in terms of permeability and selectivity that has been confirmed from the surpass of the latest Robeson upper bound curve for H_2:CO_2 and H_2:CH_4 separations. Finally, this work demonstrates the capacity of the spongy membrane texture, versus dense, to overcome the low permselectivity challenge, which hinders the industrialization of the membrane technology in the hydrogen purification application.

Keywords: Green Fuel, Hydrogen, *Metal-organic frameworks, Membranes, CO_2 separation, H_2 separation, CO_2 mitigation..*

Proceedings of the 15th International Green Energy Conference
IGEC2023-209
July 10-13, 2023, Glasgow, UK

IMPACT OF RENEWABLE, AND NON-RENEWABLE ENERGY CONSUMPTION AND ICT ON ECONOMIC GROWTH AND ENVIRONMENTAL DEGRADATION: EVIDENCE FROM ASIA-PACIFIC ECONOMIC COOPERATION COUNTRIES

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ABSTRACT
The purpose of this is two-fold. First, to investigate the effects of renewable and non-renewable energy consumption and ICT on GDP and carbon emissions. Second, to investigate the existence of Environmental Kuznets curve hypothesis in Asia-Pacific Economic Cooperation countries. This study used panel data of 20 Asia-Pacific Economic Cooperation (APEC) countries over the period 1990-2021. It employed cross-sectional dependence test, unit root test, panel causality test, quantile regression and a series of robustness checks. The results reveal panel empirical evidence that there is short-term bidirectional causal association between GDP, renewable energy consumption and CO2 emissions and between non-renewable energy consumption, GDP. For the long-term causal association, the Granger causality analysis reveals that there is bidirectional causal association between non-renewable energy consumption and CO2 emissions. Moreover, there is evidence of unidirectional causal association from economic growth to CO2 emissions and non-renewable energy consumption and from renewable energy consumption to CO2 emissions. Empirical outcomes also show that there is an inverted U-shaped relationship between GDP and CO2 emissions, which confirms the existence of the Environmental Kuznets curve (EKC) hypothesis. The empirical evidence suggests that (APEC) countries should expand the investment in renewable energy sectors and plan for a viable strategy for development of energy security for sustainable energy growth to defend the environment for future generations.

Keywords: Renewable Energy Consumption, Non-renewable Energy Consumption, Economic Growth, CO2 emissions, Panel cointegration, Energy Policy, APEC Countries.

Proceedings of the 15th International Green Energy Conference
IGEC2023-210
July 10-13, 2023, Glasgow, UK

DYNAMIC RESPONSE CHARACTERISTICS OF S-CO2 BRAYTON CYCLES FOR ENERGY CONVERSION OF GENERATION IV NUCLEAR REACTORS

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ABSTRACT

The S-CO_2 Brayton cycle is considered as a promising power generation system, which is of great significance for achieving power upgrading in broad energy area. In this work, we take the energy conversion system of generation IV nuclear reactors as the research object and carry out the research on the dynamic response characteristics and propose control strategies of S-CO_2 Brayton cycle system.

Firstly, a thermodynamic model of S-CO_2 Brayton cycle system based on high temperature helium gas cooled reactor was constructed, and the cycle parameters were determined according to the heat source from nuclear reactors. The modeling method of the main component models will also be introduced. Secondly, experimental data are used to verify the dynamic model. The relative error between simulation and experiment is less than 1%. Then based on the dynamic model verified, the dynamic response characteristics of the system under varying operating conditions were studied. The study includes the influence of enthalpy of heat source, the rotational speed of turbomachinery and mass flow of cooling water. It is found that the effect of heat source enthalpy on the system is more obvious at the hot end of the cycle than at the cold end and the response speed grows along the cycle path; the effect of turbine rotational speed on the system pressure is greater than that on the temperature and the deviation from the optimal design point will result in the reduction of turbine work; the effect of cooling water mass flow variation on the system is relatively small. And based on these characteristics the control strategy was proposed to provide reference for the design and control of the combination of generation IV nuclear reactor and S-CO_2 Brayton cycle.

Keywords: supercritical CO_2; Brayton cycle; dynamic performance;

Proceedings of the 15th International Green Energy Conference
IGEC2023-213
July 10-13, 2023, Glasgow, UK

STUDY ON DIFFERENT REFRIGERANTS FOR ORGANIC RANKINE CYCLE AND VAPOR COMPRESSION REFRIGERATION CYCLE COMBINED BY SINGLE ROTOR COMPANDER.

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ABSTRACT

It is a global challenge to reduce the emissions of greenhouse gases, which are essentially responsible for climate change. One potential solution is to reduce the use of fossil fuel-based electricity and increase the use of energy harnessed from renewable and sustainable energy sources, many of which are based on low-grade heat sources such as solar energy, geothermal energy, and waste heat. A promising technology for converting heat into usable energy is the organic Rankine cycle (ORC), which can act as a prime mover in electricity production or in running power consuming processes. In this study, the expander of the ORC is acting as a prime mover to drive the compressor of a vapor compression refrigeration (VCR) cycle to generate cooling effects. To transfer power from the ORC to the VCR with minimal power loss, the new single-rotor compander was employed, which has an expander and a compressor mounted on a single shaft in one casing. This study numerically evaluates the thermal performance of the ORC-VCR system using different refrigerants, both from energy and exergy point of views. The refrigerants considered are potentially natural refrigerants such as R600, R600a, R717, R290, R245, R1234fy, and R1234ze(E). The performance indicators considered are heat-to-cooling ratio, exergy efficiency, and overall system performance.

Keywords: ORC-VCR, energy, exergy, natural refrigerants, compander.

Proceedings of the 15th International Green Energy Conference
IGEC2023-214
July 10-13, 2023, Glasgow, UK

DESIGN AND ANALYSIS OF A FINNED HEAT SINK FOR A NOVEL DUAL CONCENTRATED PHOTOVOLTAIC SYSTEM

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ABSTRACT

Concentrated photovoltaic system offers large reduction in mass of the PV cells, high electrical output, reliability and energy security. The rise in temperature due to the waste heat production at the PV cells can induce thermal stresses in the system, exploit the PV cells and develop the micro-cracks in the structure. In order to overcome this issue, different cooling techniques are used to maintain the systems temperature in nominal range. In this study, the finned heat sink is modelled and analyzed thermally for dual concentrated photovoltaic (dCPV). The numerical results are obtained using finite element approach on commercially available software COMSOL Multiphysics 5.5. Two fin orientation are taken into account such as vertical and horizontal orientation. The two fin geometries are investigated for the mass specific power and temperature distribution which determines the viability and economy of the system. The number of fins (n_f) and fin spacing (f_s) are variable parameters. The numerical results show that horizontal fin orientation is more effective because it gives more average temperature drop i.e., 0.29 ^{0}C as compared to vertical fin orientation. The n_f 60 maintains the temperature of the PV cells below 80^{o}C with best mass specific power i.e., 18.05% more than the largest n_f 100. The rectangular fin geometry dissipates the more heat as compared to circular fin geometry at steady state condition. The transient study reveals that system becomes steady after 500 seconds for n_f 10 while for n_f 100, the steady state is achieved after 250 seconds.

Keywords: dCPV system, Passive cooling, Thermal management, Finite element Analysis, Viability, Sustainability

Proceedings of the 15th International Green Energy Conference
IGEC2023-216
July 10-13, 2023, Glasgow, UK

EXPERIMENTAL STUDY ON THE INFLUENCE SOLUTION CONCENTRATION AND NANO-ADDITIVES ON COLD STORAGE PERFORMANCE OF TETRABUTYLAMMONIUM BROMIDE

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ABSTRACT
Tetrabutylammonium bromide (TBAB) is considered as a promising alternative cold energy storage material. It suggested as cool energy storage media for air-conditioning system since their dissociation heats of phase transitions are as large as 200–500 kJ/kg and they form at 278–293 K under atmospheric pressure. In this paper, the cold storage crystallization process of TBAB solution with different concentrations was tested by experiments, and the phase transition temperature and latent heat were measured. Finally, the growth characteristics of TBAB hydrate crystals with different concentrations (10%, 20%, 30%, 40%) were analyzed. Although the pure phase change material of a single substance is durable, it also has the defects of low thermal conductivity and high degree of supercooling. Therefore, researchers usually add various materials to phase change materials to improve the properties of phase change materials and make them have better application value. The nano-additives are added to the phase change material to form a nano-enhanced phase change material, which can improve the thermal conductivity, latent heat, supercooling and nucleation of the phase change material. The original thermal properties of the material can be changed. Therefore, we studied the influence of different nano-additives (Al_2O_3, SiC, TiO_2, ZnO) on phase change materials. The composites with excellent properties were screened by differential scanning calorimeter (DSC). Compared with pure TBAB solution, the phase transition latent heat of the composite phase change materials (PCMs) prepared by adding nanoparticles were significantly increased. This work can provide reference for the future application of nano - enhanced phase change materials.

Keywords: Nano-additives, solution concentration, Phase change materials, Tetrabutylammonium bromide, Cold storage

Proceedings of the 15th International Green Energy Conference
IGEC2023-217
July 10-13, 2023, Glasgow, UK

EFFECT OF ZNSN(OH)$_6$ SCATTERING LAYERS WITH VARIOUS SHAPES ON THE POWER CONVERSION EFFICIENCY OF DYE-SENSITIZED SOLAR CELLS

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ABSTRACT
Dye-sensitized solar cells (DSSCs) have attracted special interest due to their low cost and high efficiency in the group of solar-powered devices. To get high energy conversion efficiency, the first and key step is to fabricate efficiently excellent harvest sunlight system using the dyes attached to TiO_2 scaffold surface. Therefore, it is essential to improve light harvesting within the solar cells to enhance the power conversion efficiency. In this research, we successfully synthesized shape-controlled $ZnSn(OH)_6$ by a 2-step hydrothermal synthetic process. During the synthesis of $ZnSn(OH)_6$ scattering layers with various shapes such as cubic, sphere, and urchin like hollow sphere, a sphere shape was used as a template and formed them based on the Pearson's hard and soft acid and base (HSABs) theory. As a result, a 17% improvement in power conversion efficiency was achieved after introducing the urchin-like hollow sphere $ZnSn(OH)_6$ microstructure scattering layer, which also surpassed the commercial scattering layer, mainly due to increment of the light harvesting efficiency by structural optical property.

Keywords: Dye-sensitized solar cells, Scattering layer, $ZnSn(OH)_6$, Urchin like hollow sphere

Proceedings of the 15th International Green Energy Conference
IGEC2023-218
July 10-13, 2023, Glasgow, UK

Thickness Effect of TiO2 Active Layer on Energy Conversion Efficiency of Dye-sensitized Solar Cells

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ABSTRACT

Recently, many researchers made progress various studies in order to improve the energy conversion efficiency (ECE) of dye-sensitized solar cells (DSSCs). In this paper, a systematic study was carried out to enhance the efficiency of DSSCs with synthesized TiO_2 active layers by changing their thickness. With increasing the thickness of TiO_2 layer up to 18 μm, the ECE was gradually increased as much as 35%, mainly due to improvement of photocurrent density in the DSSCs. This is owing to increase coefficient of light utilization. Consequently, DSSC with 18 μm thick TiO_2 layer exhibits relatively large Jsc value (10.74 mA/cm^2) with an overall ECE of 5.10%. While in the case of 7 μm thick TiO_2 layer, the DSSC shows a very small Jsc value (5.55 mA/cm^2) with 3.77% ECE. This result showed almost 94% increasing of current density, suggesting that an optimum thickness of TiO_2 active layer would be one of important factors influencing the ECE of DSSC.

Keywords: TiO_2 nanoparticle, thickness effect, dye-sensitized solar cell, energy conversion efficiency

Proceedings of the 15th International Green Energy Conference
IGEC2023-221
July 10-13, 2023, Glasgow, UK

LOAD AND LOSS ESTIMATION IN ENERGY DEFICIENT POLYGENERATION UTILITIES

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ABSTRACT
Optimum Load forecasting is an integral part of planning and operation of electric utility. Any positive or negative error at planning stage leads to utility losses. It is hard to reflect impact of all natural, man-made and global effects in models to give the true picture of power demand in future. Electricity demand forecasting techniques may consist of simple trend line extrapolations, statistical regression based techniques, artificial intelligence based neural networks or fuzzy logic based techniques and genetic algorithms, vector support machine and long experience based smart expert systems. All the forecasting methods assume continued supply of various types of fuels and generation development over time to meet the projected targets and goals. Sudden wars, attacks on power and energy lifelines, change in global policies, climate changes and out of blue-sky events such as tsunami in Japan, render even the best predictions useless. If all possible events are considered but they do not happen then the resulting situations affect economic power system operation. Demand forecasting becomes even more difficult in generation deficient utilities. Recent concept of energy generation is trending towards hybridization termed as polygeneration producing various energy vectors simultaneously. Also introducing energy storage as backup and shifting from electronic to molecular is the need of hour. This paper attempts to estimate demand and line losses in generation deficient utilities carrying out demand side management. Random transition from seven to three or two stages tariffs without equating areas under the curves causes unregistered losses to power and gas utilities.

Keywords: Load forecasting, Line losses, Polygeneration, Smart grid

Proceedings of the 15th International Green Energy Conference
IGEC2023-222
July 10-13, 2023, Glasgow, UK

GLOBAL WARMING AND AIR POLLUTION DRIVEN ENERGY TRANSITION IN SOUTH ASIA

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ABSTRACT
Light, heat and electricity are common types of energy. We use food, fuel and electric energies. Sun is the ultimate source of energy, which drives water, wood, wind and wave energies. Sun generates light and heat energy. Solar energy lives in vegetation in the form of hydrocarbon chemical bonds. Fossil fuels are also a form of old times stored solar energies. Anaerobic combustion of plants in subsurface under high temperature and pressure converts buried wood into coal, gas and oil. Burning of coal, gas and oil in power plants and vehicles causes air pollution and climate change due to massive 40GtCO2/y GHG emissions. Global warming is accelerating meltdown of midpole glaciers supplying fresh water to entire Asia. Geopolitics has decelerated efforts slowing down climate change by walking out of Paris Accord. Humankind, since last 200,000 (Nature) to 315,000 (Morocco) years, has been facing global cooling but first time faced the global warming. Global warming is acutely upsetting global food supply chain, transport and ecosystems worldwide. We are already late in starting GHG emission reductions and developing adaptive strategies to cope with global warming, which should no more be delayed to take action. Combustion of coal and GM crops stubble causes air pollution in South Asia. Rice crops stubbles burning in Punjab's increases Air Quality Index (AQI) more than 1000 every year in October and November. Transboundary air pollutions laws similar to water and carbon particles as smog melt glaciers, cause heat waves, choke filters in thermal power plants and deteriorates dielectric strength of high voltage insulators. Scientists and environmentalists propose gradual transition from fossil fuels to renewable energy systems. This paper analyzes air pollution causes and overviews long journey from mire to fire and wave to wire.

Keywords: Air pollution, Climate change, Energy transition, Fossil fuels, Heat waves.

Proceedings of the 15th International Green Energy Conference
IGEC2023-223
July 10-13, 2023, Glasgow, UK

STEAM REFORMING OF SYNGAS WITH BIOCHAR SUPPORTED PEROVSKITE CATALYST FOR HYDROGEN GENERATION

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ABSTRACT
Hydrogen will play a critical role in the future energy systems. Its wide use in power generation and transportation will reduce global greenhouse gas emissions and contribute towards net zero targets. Hydrogen can be sustainably derived from biomass waste streams. However, this hydrogen (H_2) produced from biomass gasification will be in a syngas mixture containing H_2, carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4) and tar. The resulting CH_4 and tar contain a significant amount of hydrogen which can be reformed thermochemically to maximise the hydrogen generation, this can be achieved through catalytic cracking at lower temperatures in the present of the catalyst. Several catalyst types have been reported for syngas steam reforming: noble metal catalysts, nickel-based catalysts, minerals, zeolites, perovskites and biochar. However, these catalysts suffer from deactivation caused by the deposition of carbon (coking) from the polyaromatic hydrocarbons (PAHs) in tar. Therefore, this work developed, synthesized, characterized and tested a novel biochar-supported perovskite catalyst $La_{0.9}Ce_{0.1}Ni_{0.5}Co_{0.5}O_3$ which is tolerant to carbon deposition. The catalyst was tested at the reforming temperatures of 650 - 850ºC, with catalyst loading onto the biochar support of 10 wt%. A mixture of tar (i.e. 68 mol% C_7H_8 and 32 mol% $C_{10}H_8$) and syngas (i.e. molar composition 9.35 % H_2, 11.62 % CO, 20.7 % CO_2, 6.01 % CH_4, 52.32% N_2) was steam reformed over the catalyst and yielded H_2 concentration of up to 30.14%. This yield is significant and shows that the developed catalyst is effective in tar reforming, compared to without using a catalyst, and also considering a maximum of 43.5% H_2 concentration is thermodynamically possible. The molar proportions of the reformed gas species also indicated that the catalyst enables H_2 generation from both the reforming reaction and the water gas shift reaction.

Keywords: hydrogen production, novel perovskite catalyst, catalyst deactivation, catalytic steam reforming.

Proceedings of the 15th International Green Energy Conference
IGEC2023-224
July 10-13, 2023, Glasgow, UK

SUSTAINABLE AVIATION FUEL UTILIZATION EFFECTS ON THERMODYNAMIC, SUSTAINABILITY, ENVIRONMENTAL IMPACT AND COST FORMATION OF A TURBOHAFT ENGINE USED ON HELICOPTER

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ABSTRACT

The gas turbine based turboshaft engines (TSE) are widely used in helicopters nowadays. The goal of this study is to analyze the biofuel utilization as sustainable aviation fuel effects on thermodynamic, sustainability environmental impact and emission cost formation of a TSE used a helicopter. The methyl-oleate ($C_{19}H_{36}O_2$) is selected as a model substance for biodiesel for this study, because it is similar to the C:H:O ratio of the commercial biodiesel. According to results, biofuel utilization effects on thermodynamic, exergy-based environmental and sustainability performances are negligible level. For both jet and biofuel utilization, energy efficiency of TSE is obtained as 25.18% exergy efficiency of TSE is found to be 23.72% for jet fuel and 23.37% for biofuel. The environmental effect factor, ecological effect factor, sustainability index, and sustainable efficiency factor are calculated as 3.216, 4.216, 0.311 and 1.311 for jet fuel whilst they are 3.279, 4.279, 0.305 1.305 for biofuel, respectively. On the other hand, biofuel utilization decreases environmental impact rates form 7699.98 mPts/h to 6365.79 mPts/h while environmental damage cost formation reduces 169.54 $/h to 140.16 $/h. Conversely, the fuel cost rate rises from 412.74 $/h to 657.24 $/h because fuel flow goes up from 445 kg/h to 515.08 kg/h with biofuel utilization.

Keywords: turboshaft engine, exergy, sustainability, environmental impact analysis, environmental damage cost analysis.

Proceedings of the 15th International Green Energy Conference
IGEC2023-225
July 10-13, 2023, Glasgow, UK

REVIEW ON GAS TURBINE AND FUEL CELL HYBRID SYSTEMS

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ABSTRACT

In this study, a comprehensive review of gas turbine and fuel cell hybrid systems has been carried out. It is mentioned that such hybrid systems are very important for the development and popularization of sustainable and environmentally friendly systems. In this review, the characteristics of various gas turbine models (turbojet, turbofan, turboprop, and turboshaft) are mentioned in terms of their advantages, disadvantages, and usage areas, and a classification is made. Regarding fuel cells, which have become an increasingly important topic in the literature in terms of environmentalism and sustainability, different fuel cell types (Proton Exchange Membrane Fuel Cells, Molten Carbonate Fuel Cells, Solid Oxide Fuel Cells, Phosphoric Acid Fuel Cells, Molten Carbonate Fuel Cells, Direct Alcohol Fuel Cells) have been classified according to their advantages and disadvantages. Afterward, the possibilities of hybrid modeling of these fuel cell types with various gas turbine types are compared on the basis of advantages and disadvantages. Within the scope of the study, the hybridization arrangements of gas turbine and fuel cell hybrid systems from the first day to the present day have been classified in detail based on various factors (cycle pressure, reformer type, circulation type), and it is envisaged to determine the most suitable system that will be suitable for the purpose in aviation. In the field of aviation, gas turbine and fuel cell hybrid systems are used as auxiliary power systems in unmanned aerial vehicles or long-range aircraft. In this context, the study focuses on hybrid systems designed for both purposes and discusses the developments to date, hybridization methods, and the latest modeling and simulation techniques.

Keywords: Gas turbine, fuel cell, hybridization, modeling, sustainability, simulation, efficiency

Proceedings of the 15th International Green Energy Conference
IGEC2023-226
July 10-13, 2023, Glasgow, UK

DECISION-MAKING MECHANISM FOR COMPONENT SELECTION AND DESIGN PRIORITIZATION: A CASE STUDY FOR UAS

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ABSTRACT

Unmanned Aircraft Systems (UAS) are used for new purposes thanks to the development of technology. People benefit from these systems in many fields, from agriculture to sports, education to disaster management. Each system should be designed according to its purpose and working environment. UAS comprises many subsystems such as avionics, airframe, antenna and propulsion, and their components. The subsystems' prioritization and the components' selection constitute a multi-stage and dependent decision problem. Solutions to multi-criteria and multi-alternative decision problems require systemic and scientific approaches. Multi-criteria decision-making methods were used for the prioritization of UAS subsystems and the selection of their components. The questions posed by the study were transformed into a multi-echelon decision problem structure. As a result, a new UAS design approach is proposed, and the effects of all the elements that make up the decision problem on the problem and solution are revealed.

Keywords: Decision making, UAS design, unmanned aircraft systems.

Proceedings of the 15th International Green Energy Conference
IGEC2023-227
July 10-13, 2023, Glasgow, UK

EMISSION AND FUEL CONSUMPTION CHARACTERISTICS OF AIRCRAFT PROPULSION SYSTEMS FOR REGIONAL AIRCRAFT

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ABSTRACT

In the global aviation industry, aircraft are divided into wide-body, narrow-body and regional aircraft. There are various types of aircraft in each category. Wide-body aircraft also have the longest flight range, while regional aircraft have the shortest range. Thanks to its small capacity and low flight cost, regional aircraft provide an economical operation opportunity on small and niche routes where the average number of passengers per flight is limited. Most of the regional aircraft in the world consist of turboprop and jet powered regional aircraft. For this reason, regional flights can be carried out by aircraft with two different types of engines. In this study, the amount of fuel and emissions that these engines, which have completely different operating systems, will consume for the same route were investigated. Madrid-Barcelona flight, one of the busiest regional lines in Europe, was used for simulation and calculations. As a result, fuel consumption, greenhouse gas emissions and particulate matter values in all phases of these flights were determined.

Keywords: Regional aircraft, greenhouse gas emissions, turboprop, turbofan.

Proceedings of the 15th International Green Energy Conference
IGEC2023-228
July 10-13, 2023, Glasgow, UK

SOCIAL JUSTICE IN THE GREEN ECONOMY: CARBON TAX AND JET FUEL TAX

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ABSTRACT

Social justice, if it is provided for the society, can cause a number of problems. Especially, in economic areas it is more important than it is thought. In order to provide social justice, taxation is one of the most useful instruments. In addition, public expenditures also can be used. However, these alone are not enough. It is also important what these resources will be used for. In order for people to live longer, resource use should be reflected in parts of the economy that are related to the environment. In other words, the use of economic resources for the green economy and the sustainability of this situation are necessary for the development of humanity. In order to create a green economy, first of all, the events that cause environmental pollution should be dealt with, one of which is the field of civil aviation. Carbon and kerosene used for transportation in civil aviation can seriously harm human health. Undoubtedly, this situation should be prevented. Although this situation can be prevented by some legal regulations, certain taxes must be implemented in order to ensure sustainability. In this study, it has been criticized that carbon and jet fuel taxes are taken in fixed amounts and it is suggested that these taxes be taken in an incremental way as a solution. This is because in this way, a contribution to the green economy can be made in the field of civil aviation and thus sustainability can be achieved.

Keywords: Social justice, civil aviation, carbon tax, kerosene tax, progressive tax.

Proceedings of the 15th International Green Energy Conference
IGEC2023-229
July 10-13, 2023, Glasgow, UK

DEVELOPMENT OF CARBON-BASED CATALYSTS FOR UPGRADING BIOGAS TO LOW CARBON FUELS

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ABSTRACT

As a traditional high value-added energy conversion method, dry reforming of methane (DRM) is of great research importance as it utilises two important greenhouse gases, methane and carbon dioxide, while also producing an important chemical intermediate, industrial syngas. Current catalysts used for dry reforming of methane are mainly noble metal catalysts and nickel catalysts, however, the high cost of noble metal catalysts makes them difficult to use for industrial production. Nickel is an inexpensive and highly active catalyst that is widely used in methane dry reforming reactions. However, high temperature reaction systems tend to lead to rapid deactivation of nickel catalysts due to sintering of the active component and encapsulation of carbon. The development of highly stable nickel catalysts for dry reforming of methane remains an important challenge in this field. The results of existing studies have shown that catalysts of the peroxide structure are resistant to sintering and carbon build-up due to their stable crystal structure. Based on this, we have synthesised a NixCe1-xTiO3 carbon-based catalyst with a peroxide structure, which provides high catalytic activity while maintaining excellent stability. The catalyst characterisation shows that the synthesised catalyst not only has a large specific surface area, but also a high thermal stability, with the catalyst retaining an intact crystalline structure after roasting at 900 °C. The results of these characterisations indicate that the NixCe1-xTiO3 carbon based catalysts are promising for methane dry reforming applications. Aspen simulations show that the optimum hydrogen yield of 34% is achieved at a 1:1 methane to carbon dioxide ratio of 1.2 bar at 800-850 °C. This provides an important reference for the experimental conditions of dry reforming of methane.

Keywords: Methane dry reforming, peroxide structure, carbon-based catalyst, Aspen simulation.

Proceedings of the 15th International Green Energy Conference
IGEC2023-230
July 10-13, 2023, Glasgow, UK

WORKING FLUID PAIR SELECTION OF THERMALLY INTEGRATED PUMPED THERMAL ELECTRICITY STORAGE SYSTEM FOR WASTE HEAT RECOVERY AND ENERGY STORAGE

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ABSTRACT

Global issues such as the energy crisis and carbon emission impulse the development of waste heat recovery and energy storage technologies. In most practical industrial scenarios, the electricity supply and consumption cannot be perfectly matched and effective utilization of waste heat are in urgent need. In this paper, a mathematical model of a thermally integrated pumped thermal electricity storage (TI-PTES) system is established and validated, which could realize the peak load shifting of the power grid and the recovery of low-grade waste heat energy. Multi-objective optimization for screening working fluid pairs with high round-trip efficiency is carried out from 24 fluids of heat pump and 21 fluids of ORC. 3 types of working fluid pair combination strategies are compared and the great improvement of round-trip efficiency by using zeotropic fluids are proved. Among 7 energy storage temperatures covering from 393.15 K to 423.15 K with an increasement interval of 5 K, the highest round-trip efficiency of 101.29% is achieved by adopting the zeotropic fluid pair [90Diethyl ether_10Pentane - 80Butane_20Pentane] at 398.15 K. Furthermore, based on the two-layer multi-objective optimization work flow, the thermo-economic performance of TI-PTES is evaluated under different designing weighting factor groups, which effectively contributes to the screening of working fluids according to designer's trade-off. Finally, through varying energy storage temperatures and designing weighting factors, optimal working fluid pair recommendations including pure fluids and zeotropic ones were proposed to give a recommendation to the fluid selection of TI-PTES.

Keywords: TI-PTES, Waste heat recovery, Working fluid pair selection, Zeotropic fluids, Two-layer multi-objective optimization.

Proceedings of the 15th International Green Energy Conference
IGEC2023-231
July 10-13, 2023, Glasgow, UK

PHASE CHANGE BEHAVIOUR OF SUPERCRITICAL CARBON DIOXIDE (SCO_2) IN TRANSONIC FLOWS

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ABSTRACT

Supercritical carbon dioxide (sCO_2) shows great potential in a range of power applications that include fossil, waste heat, solar, geothermal, nuclear and carbon capture, utilization and storage (CCUS). The separation of sCO_2 is a critical step toward achieving the economic and technical objectives of CCUS. Transonic purification technology, a combination of non-equilibrium condensation and cyclonic separation, can inject new vitality into CCUS technology, which is not only a clean process of sCO_2 processing but also a way to maximum utilize thermal energy. In this study, a numerical model based on the real gas equation of state, nucleation and growth theory was established and validated to evaluate the feasibility of transonic decarbonization and purification in a high-pressure environment. Both the equation of state and the thermodynamic properties of methane and sCO_2 are calculated by the National Institute of Standards and Technology (NIST) REFPROP database. In the co-flow of sCO_2 and carrier gas in a transonic nozzle, the overall condensation law of sCO_2 was found, the mass and heat transfer performance of sCO_2 at the condensation Wilson point was explored, and the carbon condensation amount was further calculated. For the condensation performance of sCO_2, the simulation results show that high pressure will make the properties of sCO_2 in a state of easy condensation, which is conducive to separation. When the pressure is constant, the decrease of inlet temperature or the increase of inlet mole fraction of sCO_2 will lead to an increase in condensation. As for the separation performance of sCO_2 in high pressure, when the mass concentration of heterogeneous droplets at the inlet increases from 0.1 kg/m^3 to 7.5 kg/m^3, the carbon separation amount will increase from 3.33 tons/h to 4.43 tons/h, respectively. Therefore, the high-pressure transonic purification technology can bring obvious development to the CCUS project. Predictably, this technology can play an important role in CCUS technology.

Keywords: Supercritical carbon dioxide, sCO_2, phase change, transonic flow, carbon capture and storage, CO_2 separation, condensation.

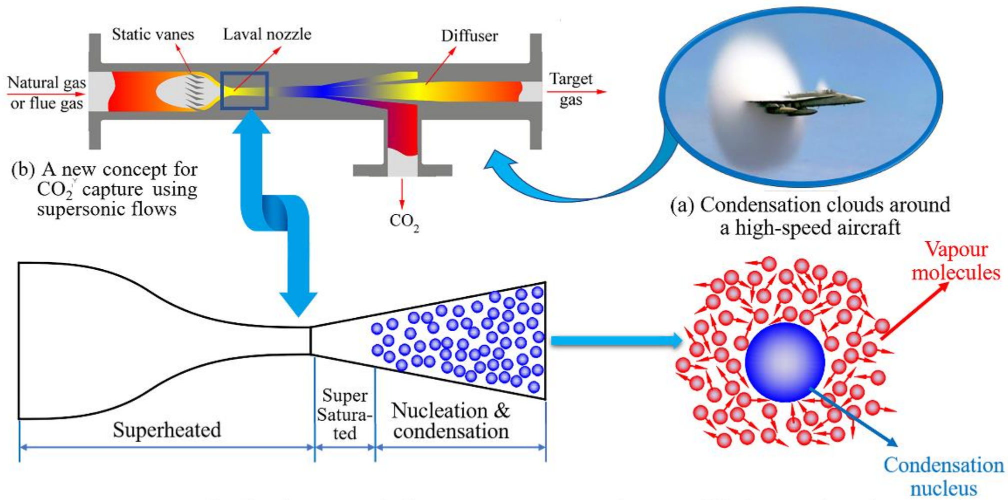

Figure 1 Phase change behaviour of supercritical carbon dioxide (sCO_2) in transonic flows for carbon capture

Proceedings of the 15th International Green Energy Conference
IGEC2023-232
July 10-13, 2023, Glasgow, UK

Analysis of Heat Transfer through Thermal Storage Tank in a Flexible Heat Pump

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ABSTRACT

By utilising a latent heat storage, the flexible heat pump cycle can recover a portion of the sensible heat carried by the hot refrigerant stream leaving the condenser, thereby improving the energy efficiency of heating systems and contributing to the achievement of global emission targets by reducing energy consumption.

The study examines the heat transfer mechanism and temperature variation in a phase change material storage tank during the charging and discharging process of the flexible heat pump. Mathematical modelling and numerical simulations are performed to analyse the impact of various design and operating parameters on the temperature variation and heat rate absorbed and rejected in the storage tank. The simulation results show that there is a temperature differential between the storage medium and refrigerant stream that can affect the system performance in both charging and discharging modes. Specifically, it was discovered that when the outlet temperature of the PCM tank was set at 30°C, the actual temperature within the PCM tank was obtained to be 27.48 °C. The updated COP value revealed an improvement of 15.66%, compared to the previous calculation where the COP improvement was 18.10% in the case of R134a as the refrigerant that indicates a COP decrease of approximately 13.47%.

Keywords: flexible heat pump, heat recovery, heat storage, power saving

Proceedings of the 15th International Green Energy Conference
IGEC2023-233
July 10-13, 2023, Glasgow, UK

Charging performance enhancement for latent thermal energy storage systems: The role of external field-dependent methods

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Abstract

Latent thermal energy storage (LTES) systems presently possess unacceptable charging and discharging performance subjected to the low thermal conductivity of most phase change materials (PCM) and poor heat transfer process. To overcome these challenges, heat transfer enhancement techniques such as using fins and adding highly conductive materials have been widely developed and optimized in recent years. Recently, some novel methods by integrating adjustable external fields including gravity, magnetic field, and electric field have been proposed to enhance the heat transfer performance of LTES, due to their advantages in easily adjusting the field parameters according to the evolution of heat storage process. In view of the great achievements of these traditional and novel heat transfer enhancement methods for LTES, this work briefly summarizes the progress of conventional heat transfer enhancement methods at first. Then the advancement of heat transfer enhancement by integrating adjustable external field effects is emphatically analyzed. Finally, the potential of external fields to improve the heat storage performance of LTES under fluctuating thermal sources is discussed considering the wide existence of fluctuating energy supply and load in real applications. The work is conducted with three main contributions: (1) The latest progress in conventional heat transfer enhancement methods of LTES is concisely concluded for convenient academic tracking; (2) The emerging heat transfer enhancement methods for LTES are comprehensively summarized and analyzed for the first time; (3) The potential of different heat transfer enhancement techniques is demonstrated to overcome the poor heat storage performance under fluctuating thermal sources when considering real applications of LTES.

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The three corresponding authors contribute equally to the preparation of this review article.

Proceedings of the 15th International Green Energy Conference
IGEC2023-235
July 10-13, 2023, Glasgow, UK

MASS TRANSPORT ANALYSIS OF FRACTAL FLOW FIELD PLATE IN PEMFC

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ABSTRACT

Fuel cells (FC) are perspective sources of green energy for industry and domestic use. In the proton exchange membrane (PEM) FC the electric energy is directly converted from hydrogen oxidation reaction at the catalyst layer. The gas fuels H2 and O2 are pumped through a system of channels in the flow-field plate (FFP) and delivered to the PEM through the porous gas diffusion layer (GDL). The FFP occupy ~70% of the volume and ~75% of the mass of a FC stack.

In this study a new fractal type of the FFP (25 cm^2 area) for PEM FC composed by 6 generations (32 outlets) of rectangle channels of 3 mm thickness and 1 mm depth (Fig.1) was constructed in COMSOL Multiphysics 6.1 to investigate the steady-state transport of reactants (Fig.2), and the current density generated in FC including cathode side mass transport phenomena in the flow channels and gas diffusion layers (GDL).The polarization curve (Fig.3) characterizing the cell voltage as a function of the current presents the overall performance of PEMFC.

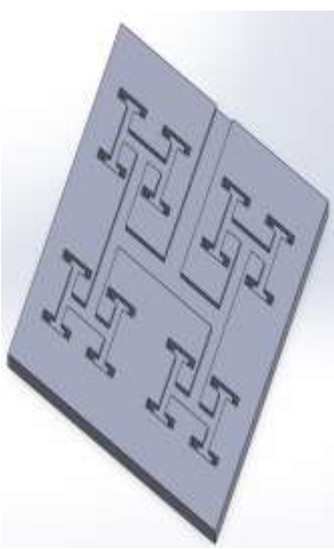

Figure 1. Fractal FFP

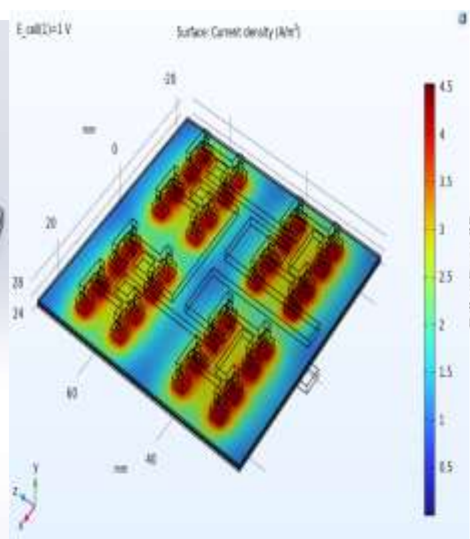

Figure 2. Current density

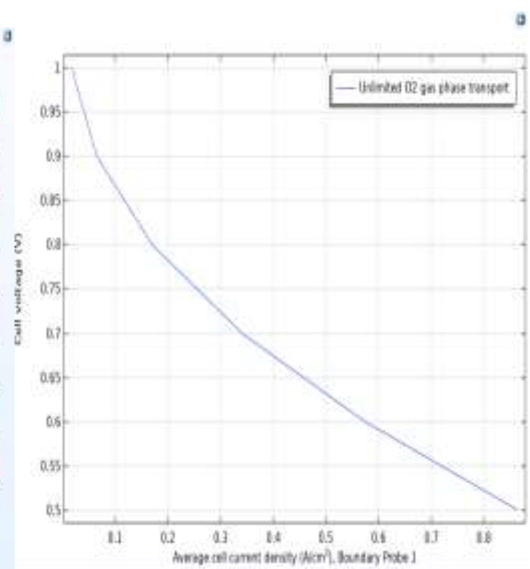

Figure 3. Polarization Curve

Conclusions: Fractal-type FFP performs a uniform distribution of the reactants that promotes higher efficiency (electric current generated at a given flow rate of the fuels) of the FC, low water flooding of the FFP channels, and longer lifespan of the PEM due to more uniform temperature distribution over the membrane.
It was also shown, CFD modeling allows cheap and fast in silico testing of different FFP design for more efficient experimental validation and implementation of the best geometric design and operating conditions for further development of FC and other green technologies.

Keywords: PEM Fuel cells, CFD, Fractal.

Proceedings of the 15th International Green Energy Conference

IGEC2023-236

July 10-13, 2023, Glasgow, UK

Social Impact of Covid-19 Electricity Subsidy on the Lifeline Citizen's Welfare in Ghana: Sharp Regression Discontinuity Design.

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ABSTRACT

To reduce the hardship caused by the COVID-19 pandemic, the President of Ghana announced on 9th April 2020 a nationwide electricity subsidy (ECG, 2020). Several studies have explored COVID-19 policies in different cases. However, studies focusing on a COVID-19 electricity subsidy are scarce. This study explored the causal effect of the COVID-19 electricity subsidy on monthly electricity demand and the lifeline`s social welfare progress during the implementation from April 2020 to March, 2021 using March 2020 electricity bill as a baseline for eligibility of free 100% electricity units.

The study used the Sharp Regression Discontinuity Design approach to look at the statistical comparison between the treated (lifeline)households and the control (non-lifeline) households. Dataset from the Electricity Company of Ghana captured 686,964 monthly electricity consumptions of households in Central Region of Ghana from December 2019 and April 2021. We interviewed 169 habitual lifeline household heads out of the study population who enjoyed the COVID-19 electricity subsidy to explore the impact it had on their social welfare progress during the global health crisis.

The analysis revealed a considerable rise in monthly electricity consumption during the policy implementation. Also, the social welfare progress of the poor households slightly improved during the implementation period. Social welfare areas investigated are job satisfaction, income level, ability to save money, electricity access, trust in the government, cost of living, childcare & healthcare costs, housing costs, provision of food, quality of life, children's reading and education, family connections, physical health and stress level. The implication of the results revealed that the government expenditure on electricity increased significantly during the implementation period.

Keywords: cutoff, electricity subsidy policy, lifeline household, treatment effect.

Proceedings of the 15th International Green Energy Conference
IGEC2023-237

July 10-13, 2023, Glasgow, UK

Advanced Functional Nanomaterials for Clean Energy Applications

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To advance the progress of miniatured devices, numerous promising new advanced functional materials have been systematically investigated in past few years. In this talk, I will discuss various potential electrode materials for energy and sensing devices. This talk provides a broad spectrum of the state-of-the-art research activities that focus on the functional metal-oxide nanostructured (MOXN) systems and their characterizations by diverse and momentous techniques. It commences with the synthetic methods and possible mechanisms that have been employed to form these nanostructures. A wide range of remarkable characteristics will be presented, organized into sections covering a number of nanostructured metal-oxides. Efforts on chemical and biological sensors will be conversed. Additionally. Finally, an overview of challenges, frontiers and opportunities of materials for renewable energy conversion and storage systems will be conversed.

Keywords: 1D nanomaterials, 2D nanomaterials, nanoarchitectures, Nanopatterning, Sensing and Renewable Energy Applications

Proceedings of the 15th International Green Energy Conference
IGEC2023-238
July 10-13, 2023, Glasgow, UK

THERMODYNAMIC ANALYSIS OF METAL HYDRIDE BASED POLYGENERATION SYSTEM FOR HIGH TEMPERATURE ENERGY STORAGE AND COOLING APPLICATION

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ABSTRACT

Energy demands have been increasing due to rapid industrialization and world population. Energy demands are met by conventional fossil fuels, which cause carbon emission. The elevated levels of carbon dioxide in the atmosphere can be reduced by utilizing renewable energy sources such as solar, wind, hydro and geothermal energy. Solar energy is abundant and can be utilized in many applications such as space cooling and heating, electricity generation and cooking. However, the solar energy is not continuous and varies with seasons and in a day. Intermittent nature of solar energy can be managed by adopting thermochemical energy storage system. The thermochemical energy storage system can act as a bridge between energy supply and demand by storing energy during on-sun hours and supplying energy during off-sun hours. Thermochemical energy storage has the advantage of high storage density, stable output temperature, combined cooling and heating, and long-term storage compared to sensible and latent thermal energy storage systems. Metal hydride-based sorption systems have zero emissions as the hydrogen is being used as absorbate, which is environmentally friendly. In the present study, a novel metal hydride based polygeneration system is proposed and thermodynamically analyzed. The proposed system can be able to store the solar energy and recover the stored energy while producing the cooling effect. The system contains a high temperature metal hydride bed (HTMH), low temperature metal hydride bed (LTMH) and a compressor. Both HTMH and LTMH beds are connected by pipeline during energy storage process and hydrogen compressor during energy recovery and cooling process. The proposed system uses magnesium-based metal hydrides such as Mg_2Ni, Mg_2Fe, Mg_2Co and Mg_2Cu as HTMH while mischmetal based hydride, $MmNi_{4.5}Al_{0.5}$, is used as LTMH. Minimum energy storage temperature is estimated by keeping LTMH at ambient temperature and maximum energy recovery temperatures is estimated by running the compressor at different compression ratios. Output parameters such as energy storage efficiency, cooling COP and energy upgradation are considered for the present study. It is observed that energy upgradation increases with increase in compression ratio as absorption of hydrogen at higher pressure increases the heat recovery temperature. Highest energy upgradation of 68°C is obtained when Mg_2Fe is used as HTMH. It is also observed that maximum cooling COP and energy storage efficiency are obtained when the compressor runs at lower compression ratios. Highest cooling COP of 3.41 is obtained at a cooling temperature of 15°C and a compression ratio of 5. Highest energy storage efficiency of 38.1% is obtained when Mg_2Co used as HTMH due to low hysteresis of the hydride.

Keywords: Metal hydrides, hydrogen, absorption, energy storage, cooling.

Proceedings of the 15th International Green Energy Conference
IGEC2023-239
July 10-13, 2023, Glasgow, UK

DEFECTIVE $ZNIN_2S_4$/NIO Z-SCHEME HETEROSTRUCTURE FOR HIGH-PERFORMANCE PHOTOCATALYTIC WATER SPLITTING

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ABSTRACT

Photocatalytic hydrogen evolution reaction (HER) has attracted tremendous attention as a catholicon to the global energy crisis, which converts solar energy into clean hydrogen and oxygen fuel. However, a series of dilemmas lie in bare $ZnIn_2S_4$ photocatalysts, such as limited light-harvesting, poor charge carrier mobility, high bulk recombination and large surface kinetic barrier for water splitting reaction. In this work, the unique two-dimensional (2D) $ZnIn_2S_4$/ oxygen vacancy-rich NiO (Vo-NiO) heterostructured nanosheets to boost photocatalytic hydrogen evolution performance. The obtained 2D $ZnIn_2S_4$/Vo-NiO heterostructure photocatalyst displays a largely enhanced visible-light HER rate of 8.5 mmol g^{-1} h^{-1} and an apparent quantum efficiency approximately 4.42% (λ=420 nm), nearly 9.02 times larger than pristine $ZnIn_2S_4$ photocatalysts. The introduction of Vo-NiO species can efficiently expand light response region to visible light range. Meanwhile, due to the fabrication of Z-scheme heterojunction with highly-matched band alignment at the $ZnIn_2S_4$/Vo-NiO interfaces, the formed internal electric field can facilitate the space separation of charges through accumulating photo-induced holes (h^+) in valence band of NiO and photo-generated electrons (e^-) in conduction band of $ZnIn_2S_4$. Besides, the unique 2D nanosheets with enlarged active surface area and mesoporous merit can provide abundant active sites for photocatalytic water splitting process and offer porous channel for the yielding gases escaping.

Keywords: Heterojunction, photocatalytic, water splitting, hydrogen evolution reaction.

Proceedings of the 15th International Green Energy Conference
IGEC2023-242
July 10-13, 2023, Glasgow, UK

NUMERICAL SIMULATION ON A SHORT PEM WATER ELECTROLYZER STACK BASED ON A THREE-DIMENSIONAL CFD MODEL

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ABSTRACT

Proton exchange membrane water electrolyzer (PEMWE) has been regarded as a promising technical scheme of energy storage by converting the fluctuating electricity from renewable energy sources into hydrogen. In practical application, PEM water electrolyzers are usually connected in series to form a stack to meet the requirement of large-scale hydrogen production, where the inlet and outlet manifolds are thus needed to distribute the reactants and collect the products. However, the uneven distribution of fluid flow that may result from the presence of manifolds leads to inconsistent characteristics of each electrolzyer in the stack, which thus impact the overall performance of the electrolyzer stack. Deep understanding of the detailed physical processes that occur in each electrolyzer and their differences in stack is very important. In this study, a three-dimensional two-phase non-isothermal CFD model for a PEMWE stack with four PEM water electrolyzers is developed to investigate the fluid flow and heat transfer coupled with the electrochemical reactions in each electrolyzer and the stack. The characteristics of each electrolzyer and the differences among them as well as its contribution to the overall performance of the stack are particularly discussed. The model is firstly validated by the experimental polarization curve from our laboratory. Then, the distributions of temperature, liquid/gas saturation, pressure, current density, and water content of ionomer inside each operating PEM water electrolyzer are simulated and compared with each other. The overall performances of the PEMWE stack are predicted under various operating conditions. Finally, the influences of the manifold configurations on fluid flow, heat and mass transfer as well as the performance of the PEMWE stack are discussed. The results show that the distributions of the main physical parameters are different among the four single electrolyzers in the stack. The performance of single electrolyzer decreases gradually from the first unit to the last unit, which is related to the reactant distribution of the manifold. The average temperature of the electrolyzer unit in the middle region is higher than that in the outer region due to the convection heat dissipation of end plates. The uniformity of pressure distribution in the last electrolyzer unit is the best, whereas that in the first unit is the worst. This should be paid attention to in the practical operation since the uniformity may affect the degradation rate of the electrolyzer. This work is helpful for understanding the internal distribution differences in the PEMWE stack and the results can guide the design of PEM water electrolyzer stack.

Keywords: Proton exchange membrane water electrolyzer (PEMWE), Stack, Manifold configuration, Fluid flow, Heat and mass transfer, Hydrogen production.

Proceedings of the 15th International Green Energy Conference
IGEC2023-245
July 10-13, 2023, Glasgow, UK

CHARACTERIZATION OF IONIC CONDUCTIVITY IN ION EXCHANGE MEMBRANES

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ABSTRACT
The ionic conductivity of ion exchange membrane directly affects the performance of fuel cells. In this study, the ionic conductivity of four high-performance ion exchange membranes (including anion and proton exchange membrane) is measured using a two-electrode conductivity cell. The membrane impedances obtained from the linear extrapolation method and the equivalent circuit model are compared, which show that the differences are not significant. The conductivity of all membranes increases linearly with the temperature. Gore 8 membrane shows the best conductivity of 28.7 S m^{-1} at 80 °C, while Alkymer membrane shows the lowest conductivity of 7.3 S m^{-1}. The conductivity of Gore 8 membrane increases by 112%, when the temperature raises from 30°C to 80°C, while the other membranes increase by 55.3%.

Keywords: ion exchange membrane, ionic conductivity, electrochemical impedance spectroscopy, temperature, fuel cell

Proceedings of the 15th International Green Energy Conference
IGEC2023-246
July 10-13, 2023, Glasgow, UK

INSIGHTS INTO OXYGEN TRANSPORT IN PEMFC CATALYST LAYERS USING MOLECULAR DYNAMICS SIMULATIONS

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ABSTRACT
In proton exchange membrane fuel cells (PEMFCs), the oxygen transport resistance of cathode catalyst layers (CLs) will suddenly increase at low Pt loading, resulting in a decrease in electrochemical performance. It is vital for developing low-Pt-loading PEMFCs to understand the oxygen permeation phenomenon in CLs. In this study, a molecular dynamics (MD) simulation system containing an amorphous carbon particle, 6 Pt particles, ionomer film, and oxygen molecules is developed. It also considers the ionomer film covering the Pt/C in the CL, as well as the movement of water molecules and hydrogen ions to further analyze the ionomer film structures and O_2 transport phenomenon. Moreover, the density distribution of the ionomer film and the O_2 permeation flux are computed.

Keywords: proton exchange membrane fuel cells, catalyst layers, oxygen transport, Pt loading, molecular dynamics.

Proceedings of the 15th International Green Energy Conference
IGEC2023-247
July 10-13, 2023, Glasgow, UK

EXPERIMENTAL INVESTIGATION OF THE ORDERED GAS DIFFUSION LAYER PERFORMANCE IN PEMFC UNDER VARIOUS OPERATING CONDITIONS

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ABSTRACT
The Proton Exchange Membrane Fuel Cell (PEMFC) is a highly efficient green electrochemical conversion device using hydrogen energy. The gas diffusion layer (GDL) is the thickest part of membrane electrode in PEMFC. The microstructure of GDL takes an important role for the migrations of gas, liquid, heat and electron. Optimizing the GDL microstructure is crucial to improve the gas-liquid two phase flowing behavior and enhance the PEMFC performance. Therefore, a kind of GDL with ordered pore structure is designed with template method to provide large pore channel for water elimination and normal small pore channel for gas delivery. Then, a comparison between our ordered GDL and commercial GDL has been performed using a PEMFC test platform under different working conditions, including relative humidity and temperature. The results show that the ordered GDL can improve the PEMFC performance under high humidity compared with commercial GDL, which mainly because the large pore channel in ordered GDL can enhance water transfer. The peak power density of fuel cell with ordered GDL is increased by 10.8% compared with commercial GDL at the same high relative humidity. However, with a decrease of relative humidity, the ohmic loss gradually replaces the mass transfer optimization caused by the perforation, and the performance of fuel cell with ordered GDL shows a downward trend. Compared with laser perforation, the current work proposed template method to prepare the ordered GDL, which is low-cost and convenient and provides an alternative concept for batch preparation of ordered GDL.

Keywords: PEMFC, gas diffusion layer, ordered pore structure.