Simulation on Phosphoric Acid Fuel Cell with Organic Rankine Cycle using Aspen Plus

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I ABSTRACT

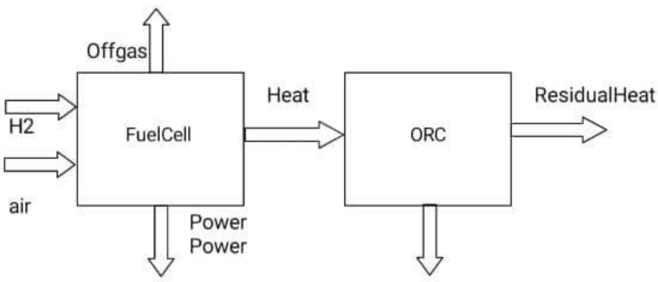
The production of energy by pure and efficient way without any harm to environment is the main issue of the today's struggling generation, so scientist and researchers' team are working on fuel cells. The PAFC's convert the simple chemical energy to electrical energy, and they are much efficient producers of these type of energy, without any harm to environment and it is a clean and pure form of electricity. These fuel cells have the potential to provide electricity commercially. The reactants of the PAFC's are natural gases such as hydrogen, biogas/syngas (methane) and air. The product of the cell is electricity, and the side product is steam, which is condensed, and we get further in form of water. Phosphoric Acid fuel cell has three components of operation (Cathode, Anode, Ceramic material/monolithic material). The combination of these components leads to number of unique characteristics of the cell such as stack design, flexibility of cell, manufacturing process. The author is interested to make efficient fuel cell to replace traditional thermal power generation units. The project discusses PAFC's characteristics and features that will be backbone of rising technologies. This paper includes Preparation of fuel cell and study on structure of cell.

Keywords: Phosphoric Acid Fuel Cell, Chemical Energy, Electrical Energy, Electrolysis.

II INTRODUCTION

Fuel cells have emerged as promising clean energy technologies due to their high efficiency and low environmental impact. Among various types of fuel cells, phosphoric acid fuel cells (PAFCs) stand out for their stability, reliability, and commercial viability. PAFCs operate at moderate temperatures (typically around 150- 200°C) and use phosphoric acid as an electrolyte, enabling their application in stationary power generation. The integration of computational simulations has played a pivotal role in unraveling the complexities inherent in PAFCs, offering a comprehensive understanding of their behavior, optimizing designs, and paving the way for advancements in their performance. This project endeavors to delve into the realm of PAFCs through simulation-based investigations. By leveraging computational tools, our aim is to create a nuanced model that encapsulates the intricate interplay of electrochemical, thermal, and fluid dynamics phenomena within a PAFC. This simulation project seeks not only to comprehend the fundamental mechanisms governing PAFC operation but also to explore avenues for enhancing their efficiency, durability, and overall performance. The simulation and modeling of PAFC systems play a crucial role in understanding their behavior, optimizing performance, and aiding in the design of efficient fuel cell systems. Aspen Plus, a widely used process simulation software, offers a robust platform for modeling chemical processes, including fuel cell systems. In this project, the utilization of Aspen Plus for simulating PAFCs provides an opportunity to analyze and optimize the operational parameters and performance of these cells

II METHODOLOGY



Fig; Block Flow Diagram of PAFC

Fuel cell system produces power and heat. Heat can be converted to power, improving performance of system. Our objective of this process is producing 300 KW Energy via Phosphoric Acid Fuel Cell (PAFC) and Organic Ranking Cycle (ORC) are modeled ORC is method for generation of additional power.

The Experimental setup of a Phosphoric Acid Fuel Cell (PAFC) typically involves several key components. These cells operate at higher temperatures compared to other fuel cell types, and here are some general aspects of their experimental setup:

• Electrodes and Catalysts: - PAFCs have porous electrodes (anode and cathode) coated with catalysts, often platinum, to facilitate the Fuel Cell ORC 12 electrochemical reactions.

• Phosphoric Acid Electrolyte: - Phosphoric acid serves as the electrolyte in PAFCs. It is usually immobilized in a solid matrix to enhance stability.

• Temperature Control: - PAFCs operate at relatively high temperatures (typically around 150-200 degrees Celsius). The experimental setup includes a temperature control system to maintain optimal operating conditions.

• Gas Flow System: - A system for controlled flow of reactant gases (hydrogen at the anode and oxygen or air at the cathode) is essential. This involves flow controllers, pressure regulators, and gas humidification to optimize performance.

• Current Collectors: - The electrodes are connected to current collectors that allow the extraction of electrical energy produced during the electrochemical reactions.

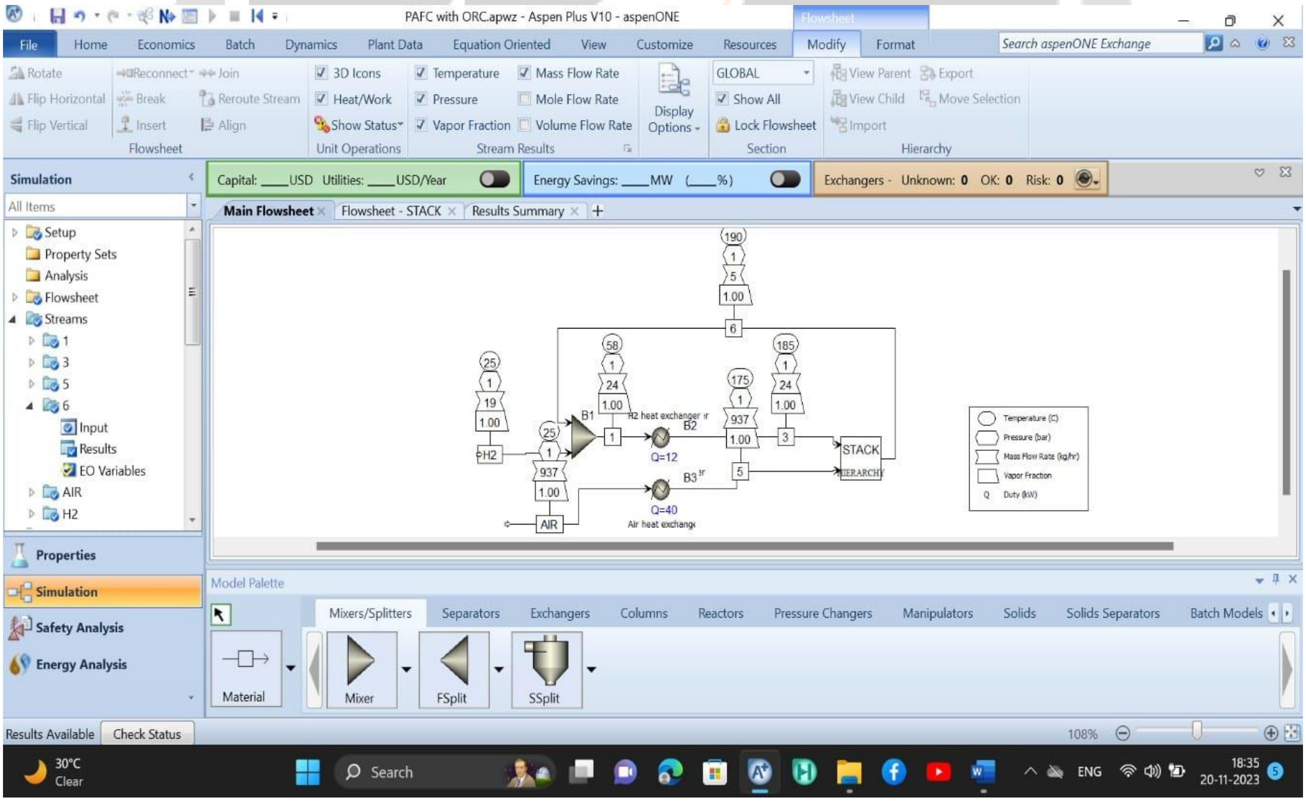
• Load or External Circuit: - The experimental setup includes an external electrical load to measure the current and voltage characteristics of the fuel cell.

• Monitoring and Measurement Equipment: - Instruments like voltmeters, ammeters, and data acquisition systems are used to monitor and record the performance of the PAFC.

• Safety Measures: - Safety features, such as pressure relief systems and temperature sensors, are incorporated to ensure safe operation.

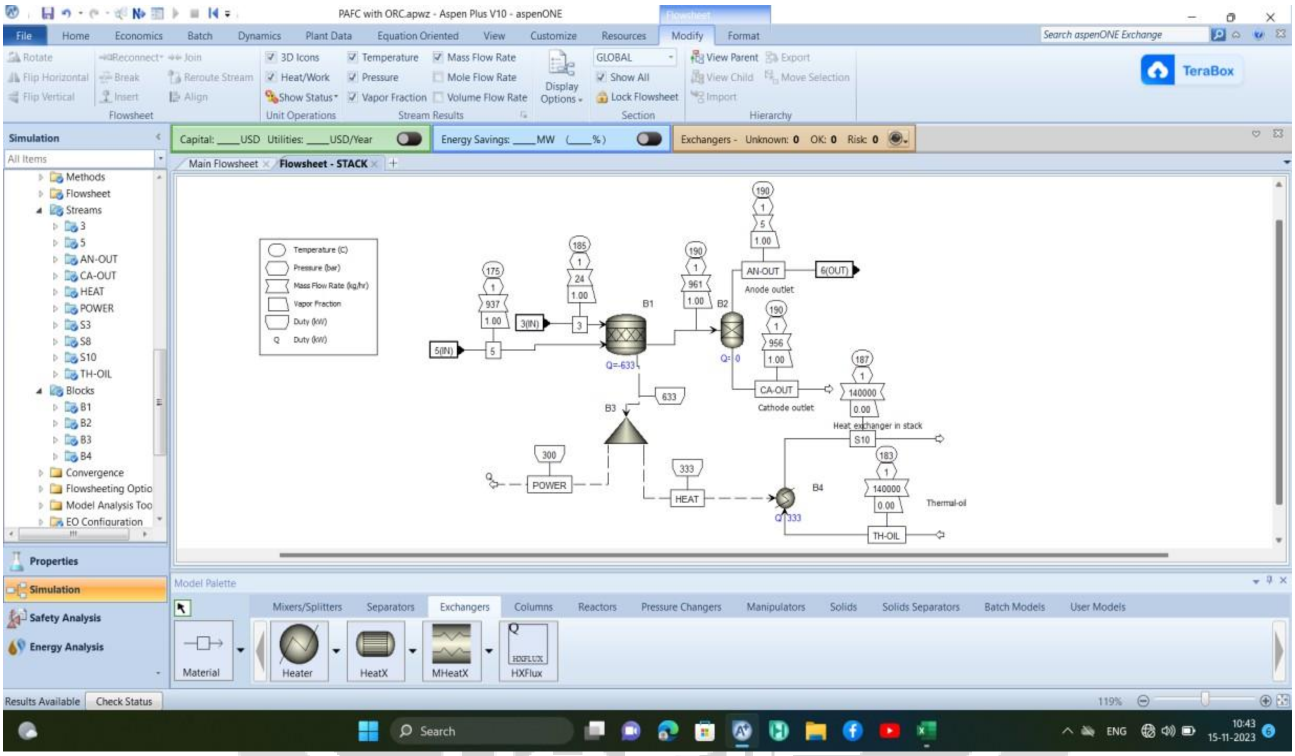
• Experimental Controls: - Parameters like gas flow rates, temperature, and humidity are carefully controlled to study their impact on the fuel cell's performance.

III SIMULATION AND ANALYSIS



Fig; Main Flowsheet

1. Development of PAFC Model: - Initiate the configuration of a comprehensive Phosphoric Acid Fuel Cell (PAFC) model within the Aspen Plus environment. Define the constituent elements, encompassing electrodes, catalysts, and the phosphoric acid electrolyte.
2. Electrochemical Reaction Kinetics: - Articulate the kinetics governing electrochemical reactions transpiring at the anode and cathode. Specify the intricacies of hydrogen oxidation and oxygen reduction reactions.
3. Incorporation of Electrolyte Characteristics: - Integrate the properties of the phosphoric acid electrolyte, encompassing concentration and conductivity, within the model framework.
4. Temperature Regulation System: - Implement a robust temperature control system to sustain optimal operational temperatures for the PAFC,150- 210 © recognizing its dependency on controlled thermal conditions.
5. Management of Gas Flow and Pressure: - Establish a controlled gas flow regime, encompassing hydrogen at the anode and oxygen at the cathode, with due consideration for flow rates and pressures to ensure requisite stoichiometry.



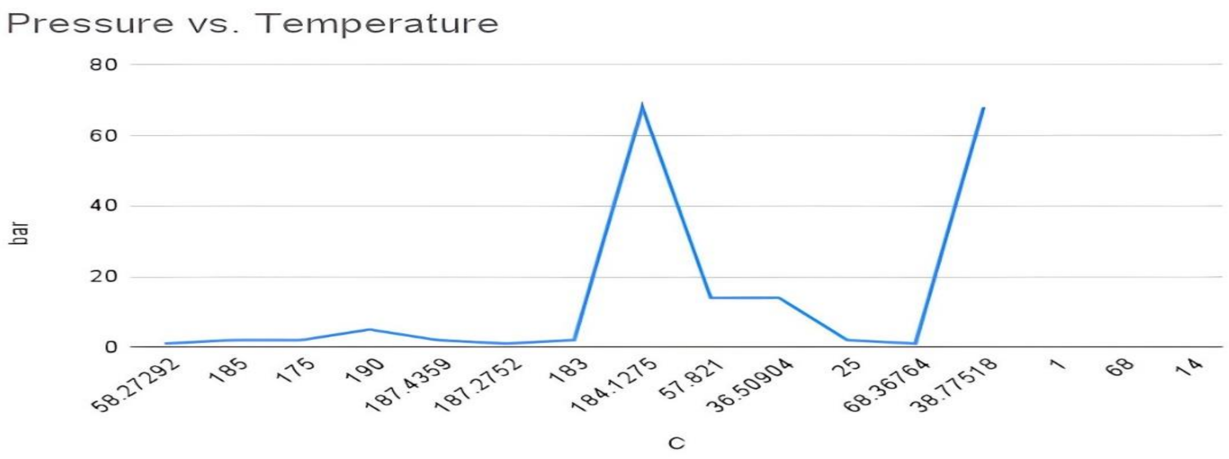
Fig; Stack flowsheet

6. Integration with ORC: - Interconnect the PAFC model with an Organic Rankine Cycle (ORC), specifying essential components including heat exchangers and expanders, thereby facilitating a synergistic energy system.
7. Specification of ORC Working Fluid: - Define the working fluid for the ORC, incorporating pertinent thermodynamic parameters to accurately model its behavior within the overall system.
8. Design of Heat Exchange Mechanism: - Develop heat exchangers to effectuate efficient heat transfer between the PAFC and ORC, ensuring the effective utilization of thermal energy for power generation.
9. Incorporation of ORC Expander: - Include an expander within the ORC system to convert thermal energy into mechanical work, a pivotal mechanism for power generation within the integrated system. 10. Parameter Fine-Tuning: - Methodically adjust key parameters such as temperatures, pressures, and flow rates to optimize the performance metrics of the integrated PAFC-ORC system.
11. Simulation Execution: - Execute the simulation within Aspen Plus and closely monitor pertinent performance indicators, including electrical efficiency and thermal efficiency.

III. RESULTS AND DISCUSSION

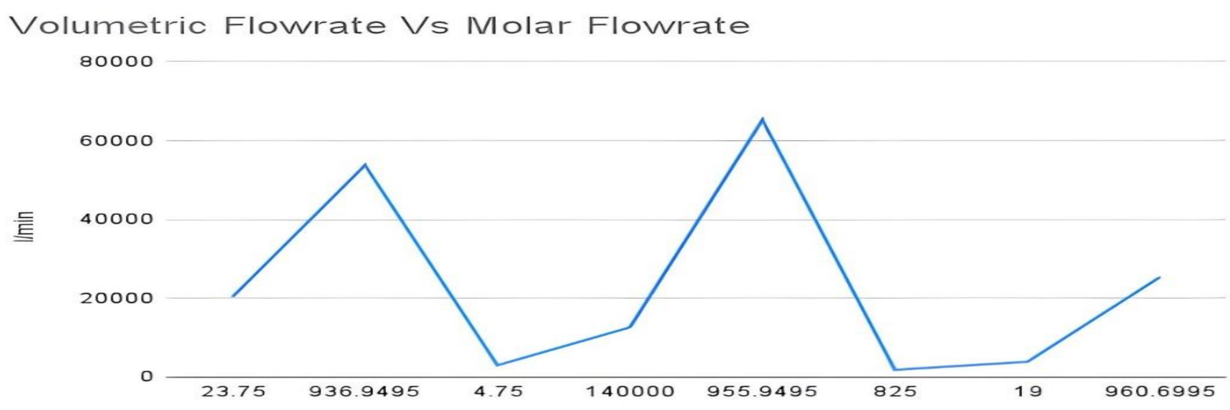
Theoretical Values (Obtained from MS Excel): -

H2 in feed	9.425164196	Kmol/hr	
O2 Utilization	0.7	Validation	
O2 need	6.73226014	Kmol/hr	
Air need	32.49160299	Kmol/hr	
Higher heating value (molar basis) at 0C, reference 0C, for a petroleum mixture	286630	KJ/kmol	
Fuel Cell Efficiency	0.4		
power generation in stack	300.1705348	KW	
New efficiency value (chemical energy to electrical energy)	0.461298488		



Reading Graph No.1

This is the new and obtained parametric difference obtained from the simulation of Aspen Plus version 12 ie: Change in temperature profile Vs Pressure Difference. And, the graph of Volumetric flow rate Vs Molar flowrate is obtained via completion of the simulation.



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IV. CONCLUSION

The purpose of this work is to effectively improve the overall electric efficiency of fuel cells by recovering heat from stack, thermo-economic analysis of PAFC and ORC integration. For practical use, the ORC working fluid selection considered environmental impacts, and fluids of low GWP and ODP were selected. The parametric analysis examines the effect of working fluid capacity and the ORC efficiency under variation of evaporator pressure are performed. Working fluids with large volumetric

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