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# Modelling of PEM Fuel Cell using MATLAB Simulink

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***Abstract:** In this project, we present a detailed modelling approach for a Proton Exchange Membrane (PEM) fuel cell using MATLAB Simulink. The paper provides a comprehensive analysis of the PEM fuel cell system, including the electrochemical reactions that occur within the fuel cell, the thermodynamics of the system, and the transport processes of the reactants and products. The model is based on a multi-phase approach and incorporates several sub-models for each component of the fuel cell system. The resulting model is validated using experimental data from literature, and the results show excellent agreement with the experimental data. The model is further used to investigate the effects of various parameters, such as gas flow rate, and cell voltage, on the fuel cell's efficiency. . The research's conclusions give important new information about the operation and optimisation of PEM fuel cells, and the suggested model can be utilised to build and improve PEM fuel cell systems.*
***Keywords:** Modelling.*

## I. INTRODUCTION

The paper titled "Modelling of PEM Fuel Cell using MATLAB Simulink" aims to present a comprehensive analysis of the performance of a Proton Exchange Membrane (PEM) fuel cell through computer simulations. Fuel cells are an alternative source of energy that have the potential to replace traditional fossil fuels due to their high efficiency, low emissions, and minimal environmental impact. PEM fuel cells are particularly attractive due to their ability to operate at low temperatures and high-power densities. This utilizes MATLAB Simulink, a powerful software tool for simulating dynamic systems, to model the various components of a PEM fuel cell system including the reactant and the electrochemical reactions, and the heat and mass transfer processes. The simulation model is validated through comparison with experimental data from literature.

## II. BASICS OF PEM FUEL CELL

Generally, a Proton Exchange Membrane (PEM) fuel cell is a type of electrochemical device that generates electricity by converting the chemical energy of a fuel, such as hydrogen, into electrical energy through an electrochemical reaction. PEM fuel cells are attractive due to their high efficiency, low emissions, and potential for use in a variety of applications including stationary power generation, transportation, and portable electronic devices.

The basic structure of a PEM fuel cell includes an anode, a cathode, and a proton exchange membrane. Hydrogen fuel is fed into the anode, where it is split into positively charged protons and negatively charged electrons. The electrons flow through an external circuit, generating electricity, while the protons travel to the cathode via the proton exchange membrane. Water is produced as a by-product of the reaction between oxygen and protons and electrons in the cathode. The electrochemical reaction in a PEM fuel cell is facilitated by a catalyst, typically platinum, that is coated onto the surface of the electrodes. The catalyst speeds up the reaction without being consumed in the process, making it a key component in the fuel cell.

To maintain the optimal operating conditions for the fuel cell, it is necessary to control the temperature, pressure, and humidity of the reactant gases. Water management is also important as excess water can block the flow of reactant gases and reduce the efficiency of the fuel cell.

In summary, a PEM fuel cell operates by converting the chemical energy of hydrogen fuel into electrical energy through an electrochemical reaction. The fuel cell consists of an anode, a cathode, a proton exchange membrane, and a catalyst. Control of temperature, pressure, humidity, and water management are critical for optimal fuel cell performance.

## III. WORKING PRINICIPLE OF PEM FUEL CELL

An ion conductive electrolyte (Na-fion) is present between catalytic porous electrodes in a PEM fuel cell. The PEM fuel cell's redox reaction is described below:

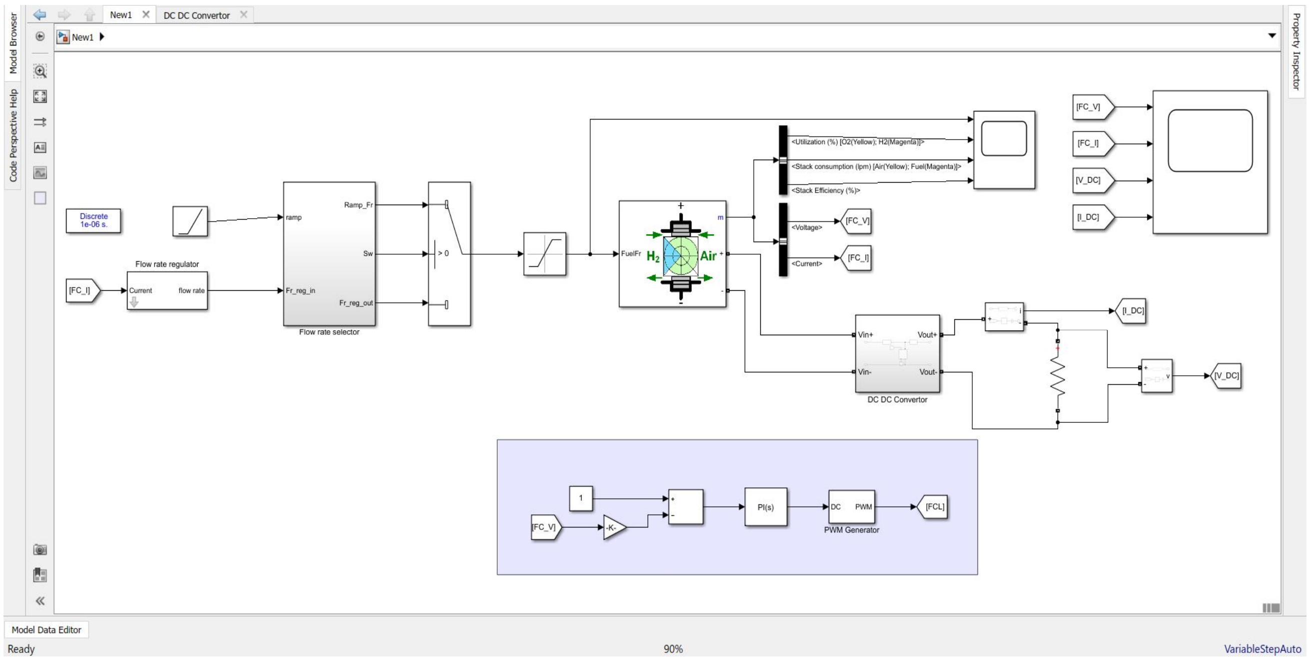
Anode Reaction: $H2 \sim 2H+ \quad + 2e-$

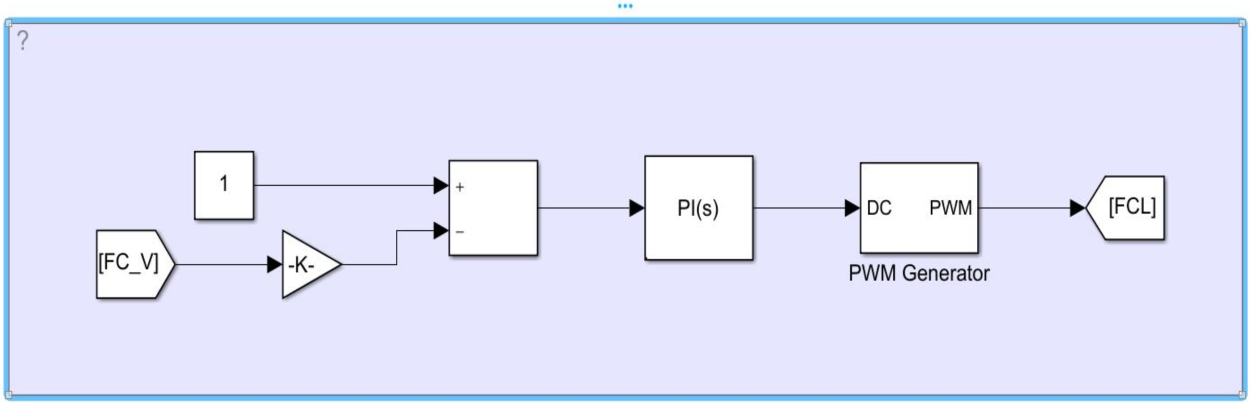
Cathode Reaction: 2H +2e +1/2O2 ~ H2O

Overall reaction: H2 + 1/2O2 ~ H2O

Any technology can be developed and improved with the use of modelling. In order to increase fuel cell technology efficiency and control costs, fuel cell modelling is crucial. The fuel cell model needs to have a few qualities, such as the ability to address fuel cell-specific issues, increase efficiency, and be reliable and accurate. Any fuel cell model must take into account a few crucial elements that have an impact on performance like the pressure, temperature, humidity, fuel and oxidant mix, flow rate, and number of cells in the stack.

## IV. MODEL WITH MATLAB SIMULINK



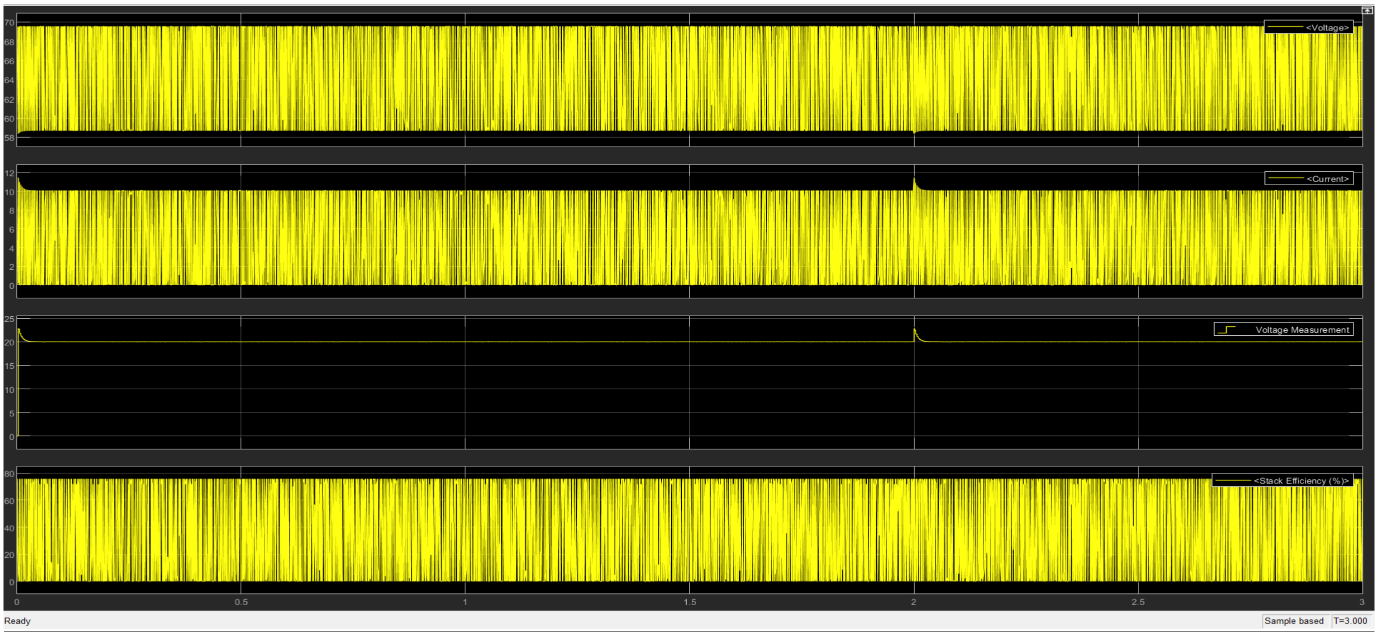




## V. SIMPLIFIED MODEL

The model that is functioning under standard pressure and temperature settings is the simplified model. Based on its amount of detail, this model is referred to as a simple model. Only current and voltage signals are present in a reduced form. Flow rate, fuel utilisation, and stack efficiency are among the other signals that are set to zero. The complete model incorporates temperature, pressure, fuel and oxidant flow rates, and the composition of the fuel and oxidants. By varying the aforementioned factors under the signal variation pan in Simulink, the following changes are seen:

*1)* Current
*2)* Voltage
*3)* Stack Efficiency

## VI. RESULT




## VII. FUTURE SCOPE

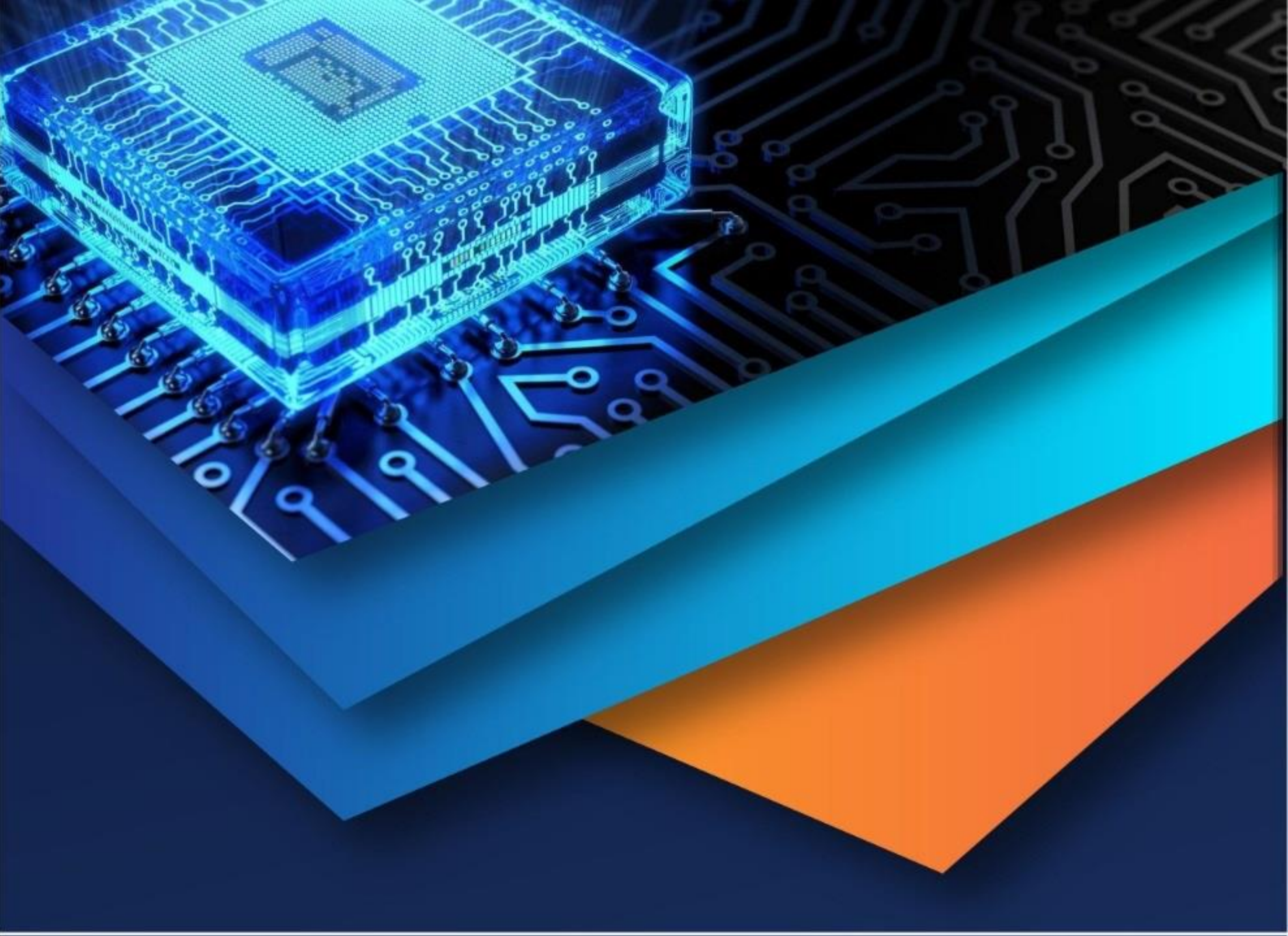
The future of PEM fuel cell technology is promising due to its high efficiency, low emissions, and potential for use in a wide range of applications. Some of the potential future applications of PEM fuel cells are:

1) *Transportation:* PEM fuel cells have the potential to replace internal combustion engines in vehicles, providing a cleaner and more efficient mode of transportation. They can be used in passenger cars, buses, trucks, and even trains
2) *Portable electronic devices:* PEM fuel cells can be used to power portable electronic devices such as laptops, smartphones, and tablets, providing longer-lasting, environmentally-friendly power sources.
3) *Backup power generation:* PEM fuel cells can be used as backup power sources for buildings and homes, providing reliable and clean energy during power outages.
4) *Combined heat and power (CHP) systems:* PEM fuel cells can be integrated with CHP systems to provide both electricity and heat for buildings, improving energy efficiency and reducing emissions.
5) *Distributed power generation:* PEM fuel cells can be used for distributed power generation, providing clean and reliable energy to remote or off-grid areas.

The future of PEM fuel cell technology also involves ongoing research and development efforts to improve the performance and reduce the cost of the technology. This includes the development of new catalysts, membranes, and materials, as well as improvements in system design and control. Furthermore, advances in hydrogen production and storage technology will also play a key role in the future of PEM fuel cell technology.

## VIII. CONCLUSION

In summary, this work has provided a thorough examination of a Proton Exchange Membrane (PEM) fuel cell's performance through computer simulations using MATLAB Simulink. The simulation model developed in this study has successfully captured the complex dynamics of the fuel cell system. The simulation results were validated against experimental data from literature, demonstrating the accuracy of the model. Additionally, the sensitivity analysis performed in this study has provided insights into the optimal operating conditions for PEM fuel cells, including the effects of temperature, pressure, and humidity on fuel cell performance. This study contributes to the understanding and development of PEM fuel cell technology by providing a valuable tool for modelling and analysing fuel cell systems. The results of this study can aid in the design and optimization of fuel cell systems for various applications, including transportation, portable electronic devices, and stationary power generation.

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