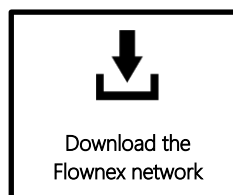




# Design of Low Temperature Proton Exchange Membrane Fuel Cell System Components

This case study focused on accurately modeling the cathode-side airflow of a PEM fuel cell, with particular attention to maintaining proper membrane humidity. Insufficient water removal leads to flooding, which blocks gas transport pathways, while excessive removal causes membrane dehydration, both resulting in reduced performance.



HYDROGEN

# HYDROGEN

## CHALLENGE:

PEMFC, also known as polymer electrolyte membrane fuel cells, are mainly developed for portable fuel cell applications, transport applications as well as stationary fuel cell applications. The challenge in this case study was to accurately model the cathode-side air flow of the fuel cell. One of the key elements for optimum performance is to maintain proper humidity of the PEM fuel cells. When water is removed at a lower rate than the supplied water, water flooding will occur hindering the transport of reactant gases by blocking the pores in the gas diffusion layers and catalyst. Membrane dehydration takes place when the removal rate of water is higher than the generated water, consequently resulting in performance degradation.

## BENEFITS:

Flownex contains components to replicate the processes observed within a proton exchange membrane fuel cell. The cathode air-side system, such as the compressor, heat exchanger, humidification membrane and fuel cell, can be modelled with standard components. Using scripting, the water vapor transfer rate in the humidifier could be specified using data obtained from literature. By including the data for the vapor transfer rate of different flow configurations within the humidifier, the performance can be compared quickly and efficiently. This makes Flownex very useful in determining the optimal flow configurations of the humidifier.

## SOLUTION:

The Flownex model was used to model the cathode-side air flow. The compressor power and cooling needed for the air-side was determined. The humidifier at the inlet of the fuel cell was modelled by importing the water vapor transfer rates from literature. The chemical reaction in the fuel cell was not modelled and consequently the heat generation was also excluded. The pressure loss and increase in relative humidity in the fuel cell was determined, allowing for the calculation of the outlet temperature.



## INTRODUCTION

Hydrogen fuel cells are seen as a zero emissions solution when batteries are not feasible, such as in heavy-duty vehicles, locomotives, and maritime vessels. A variety of countries are extensively researching and deploying hydrogen fuel cells in several applications. Countries like Germany, France and Norway are heavily invested in the use of hydrogen-based fuel cells as a means of reaching zero emissions.

A dynamic simulation tool such as Flownex SE can be effectively utilized to assist companies to design and optimize their hydrogen fuel cells. In this case study a Flownex model is created of the cathode-side air flow of the proton-exchange membrane hydrogen fuel cell (PEMFC) system. The diagram of the PEMFC is given in Figure 1.

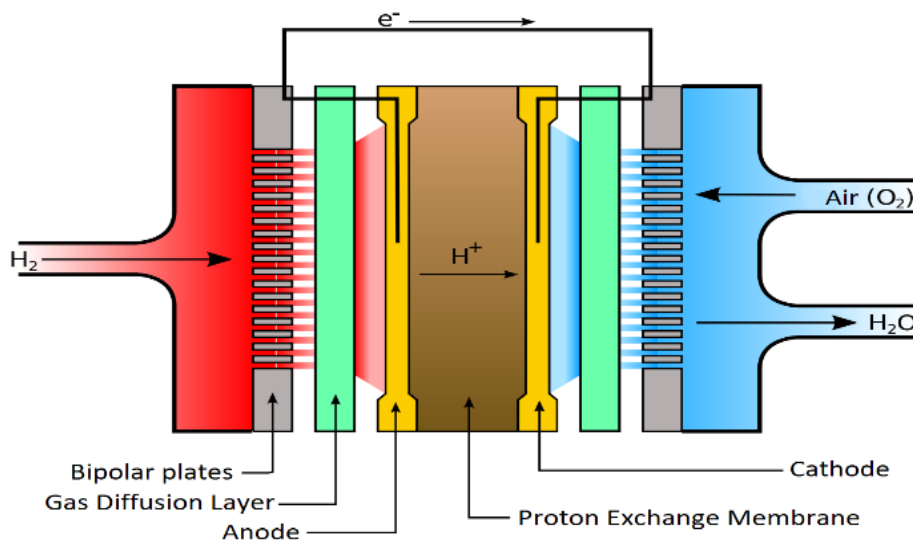


Figure 1: Proton Exchange Membrane Fuel Cell  
(<https://de.wikipedia.org/wiki/Polymerelektrolytbrennstoffzelle>).

## METEDODOLOGY

As hydrogen molecules arrive at the anode side, it oxidises by releasing two protons and two electrons. The positively charged hydrogen (protons) diffuses through the membrane and the electrons flow through a separate copper wire. The electrons and protons meet up with the oxygen at the cathode side where they react and form water.

At the cathode side, a psychrometric boundary condition was used to define the humid air sucked in at ambient conditions. The humid air is then compressed and due to the temperature rise from compression, a heat sink is needed to cool the air to  $75^\circ\text{C}$ . As the temperature increased from ambient conditions, the relative humidity decreased and needed to be increased to 30% by means of a moisturized membrane. The pressure drop within the membrane was implemented using a user specified pressure drop component by defining the pressure drop as a function of flow rate. The water vapor transfer rate as a function of volumetric flow in the membrane from the wet-side to the dry-side was defined from data in literature. At the membrane, the water vapor



condenses and diffuses from the wet side to the dry side. A steam/water trap component was used to extract the condensate from the wet side's mass flow and introduce it into the dry side's flow. Figure 2 shows the membrane humidifier.

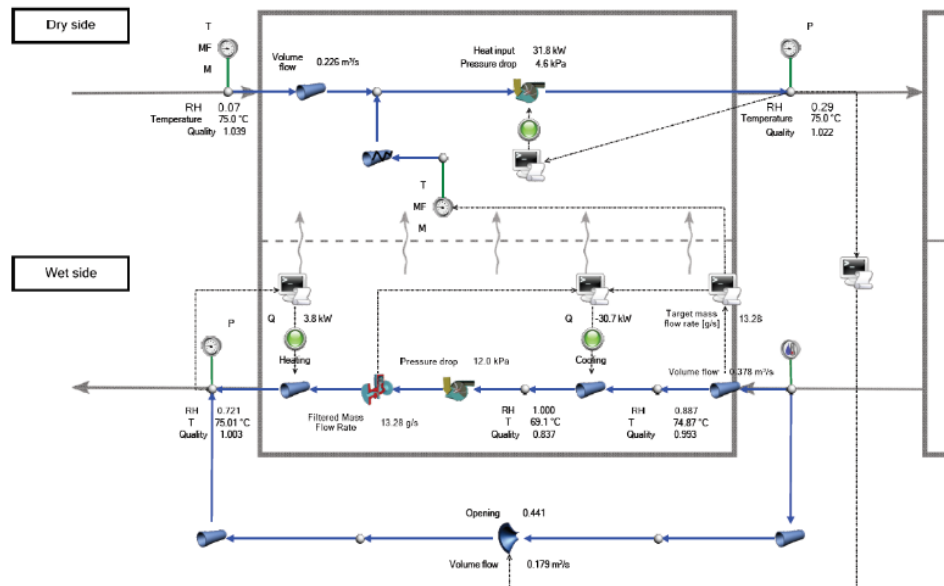


Figure 2: Membrane Humidifier network

The fuel cell stack was developed using a compound component to realise the outlet properties of the stack after the chemical reaction has taken place. This is seen in Figure 3.

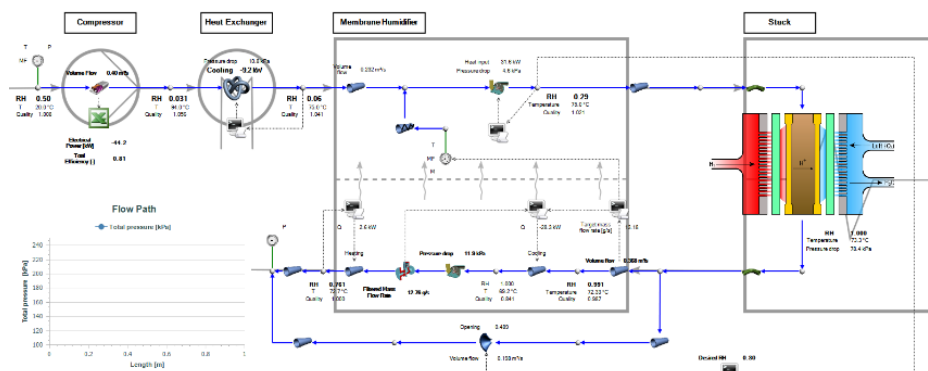
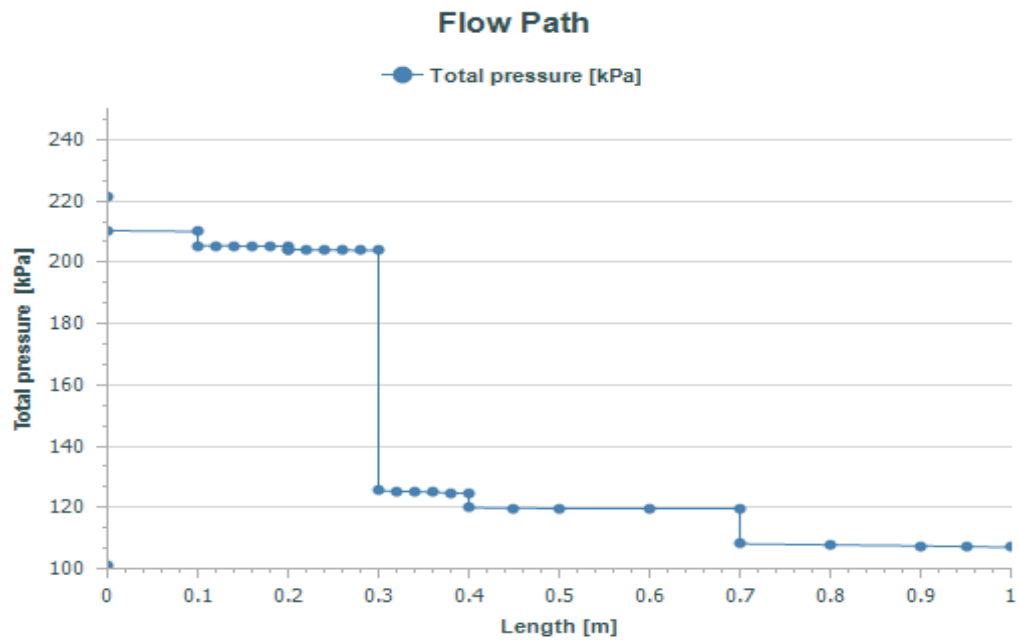


Figure 3: Full model of cathode-side air flow

## RESULTS AND CONCLUSION

By using the network constructed in Flownex, the air flow pressure throughout the flow path could be plotted. This can be seen in Figure 4. This allows for quick evaluation of the fuel cell's design and any errors that may have occurred.





*Figure 4: Total pressure evolution along the air flow path*

By using Flownex, the cathode-side air flow was modelled. The biggest challenge was to model the membrane humidifier and controlling the flow to realise the correct temperature and humidity at the inlet.

