

BRAMBLE ENERGY

POWERING NET ZERO

**1D Modelling of Fuel Cell System
for USV using GT-SUITE**

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Project Aim

“The demonstration of SEA-KIT's X-Class Uncrewed Surface Vessel powered by a new and novel hydrogen fuel cell engineered by Bramble Energy. The demonstration will showcase a successful diesel to hydrogen conversion of SEAKIT's proven USV”



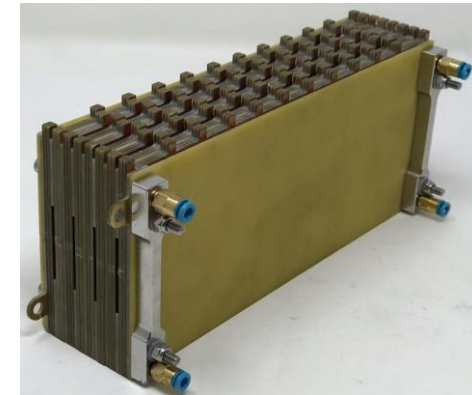
Introduction

- Bramble energy's Printed Circuit Board Fuel Cell **PCBFC™** is a **patent protected**, revolutionary design leveraging existing manufacturing routes from the PCB industry to offer a cost-effective, scalable hydrogen fuel cell solution
- This **simplifies design approach** & reduces BOM compared to conventional fuel cells, reducing cost and weight of the PCBFC
- Due to its inherited advantages, PCBFC™ can be used on the Aviation, Marine, Stationary and range extender applications
- **Maritime transport** is one of the key sector where hydrogen fuel cell can help to **reduce carbon emissions by electrification** as battery power electrification has many limitations.

- Bramble energy is developing a **10kW (net power) fuel cell system** to be used in Sea-Kit's USV.
- This presentation describes the **usage of GT-SUITE** in **Bramble energy** to support the development of the fuel cell system for the project



Liquid Cooled

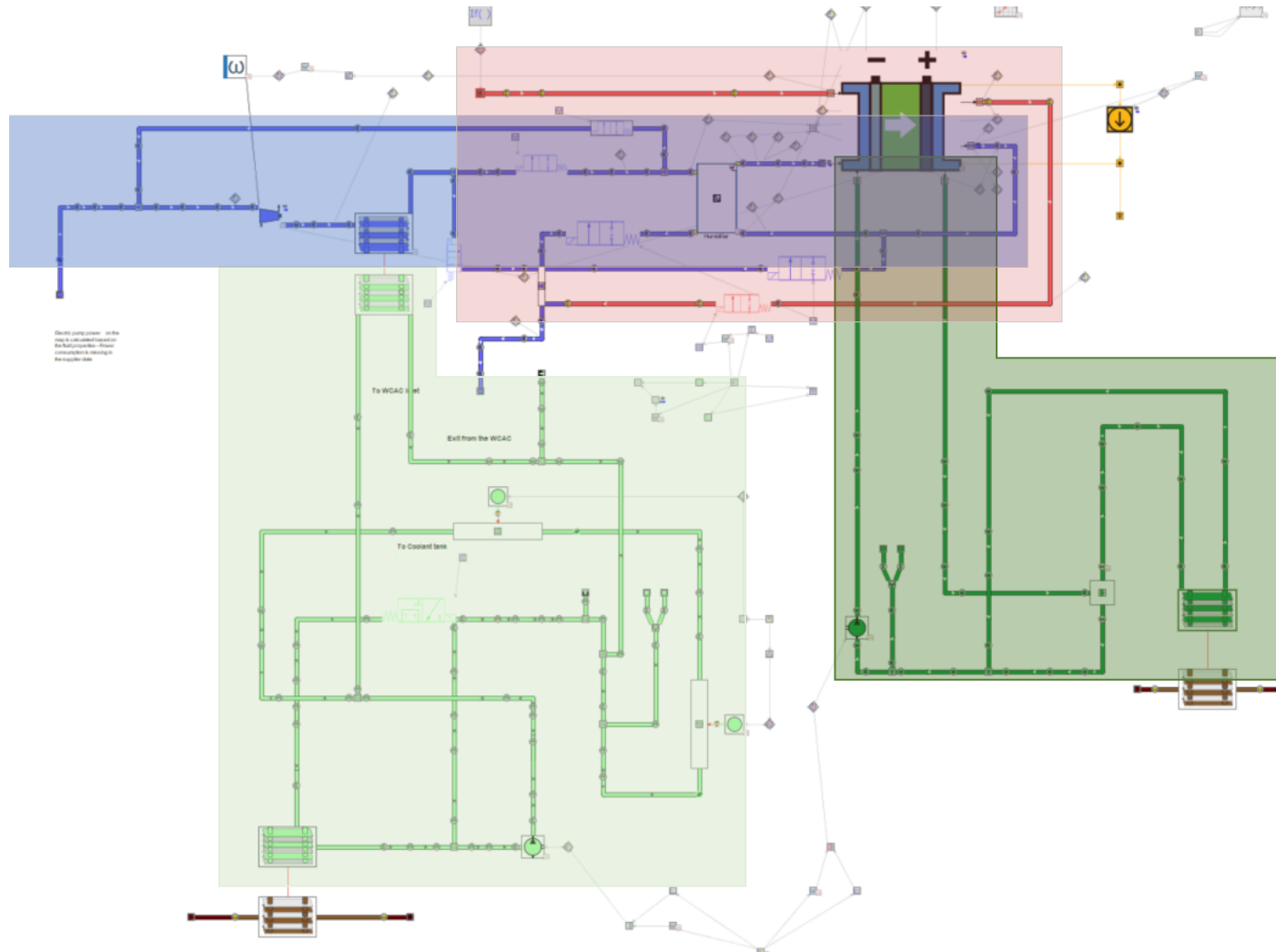


Air Cooled



1D FC System Modelling - Overview

- 1D model of the PCBFCC system was modelled as shown below
 - Model is **capable of steady state and transient analysis**



Cathode

Anode

High – Temperature Coolant loop

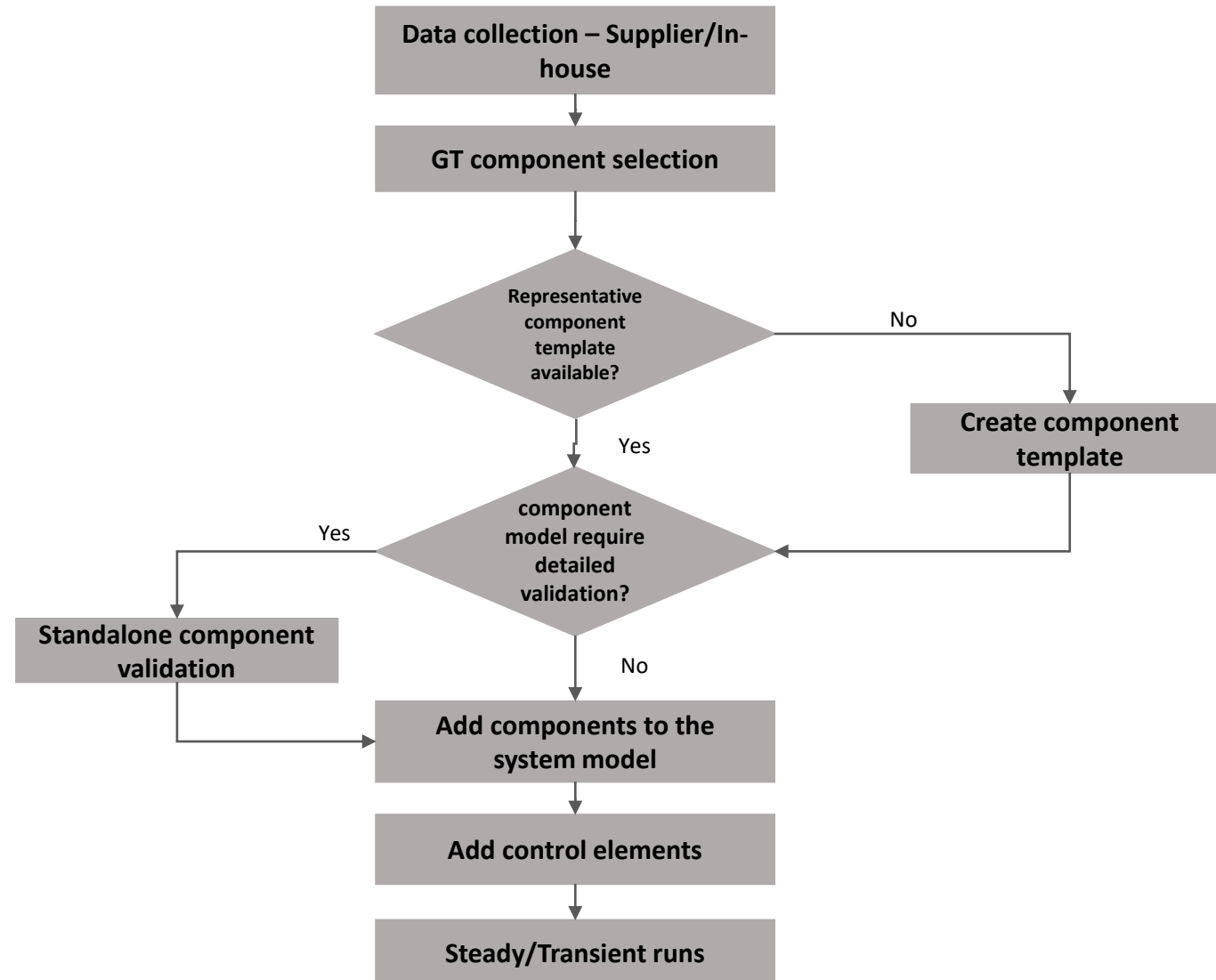
Low – Temperature coolant loop



1D FC System Modelling

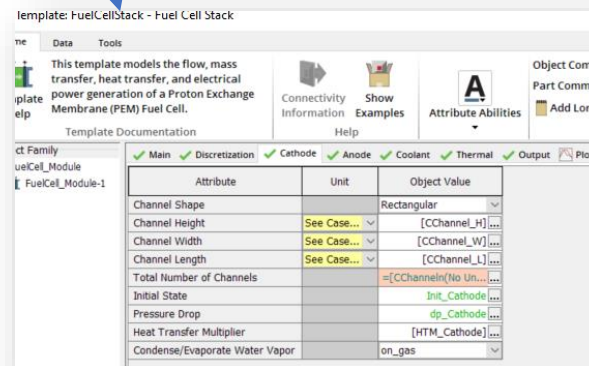
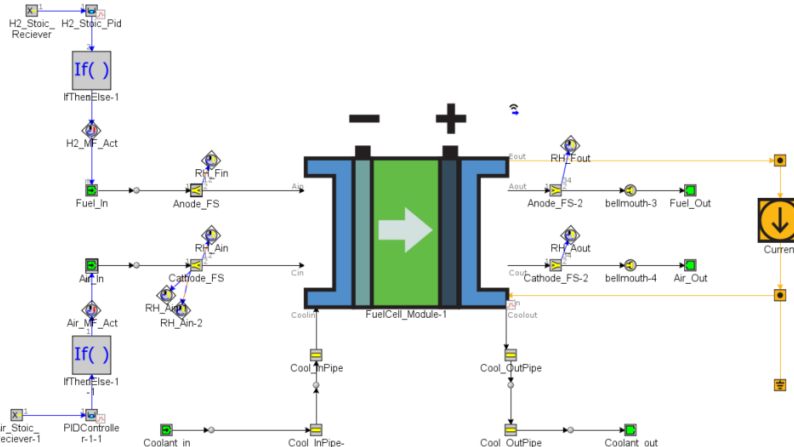
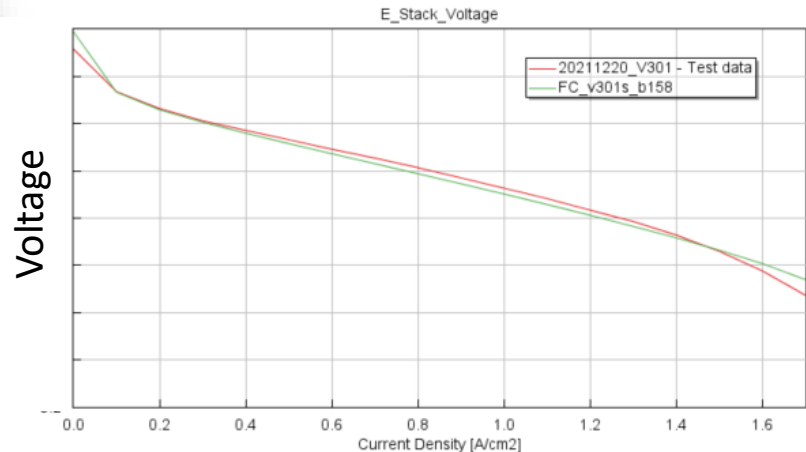
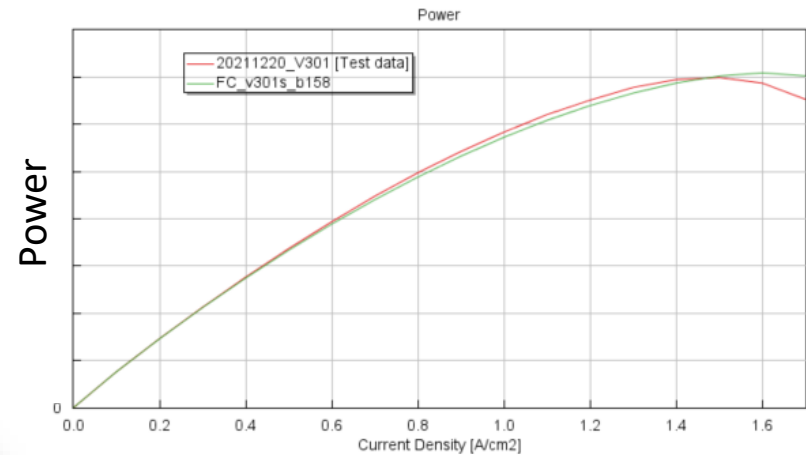
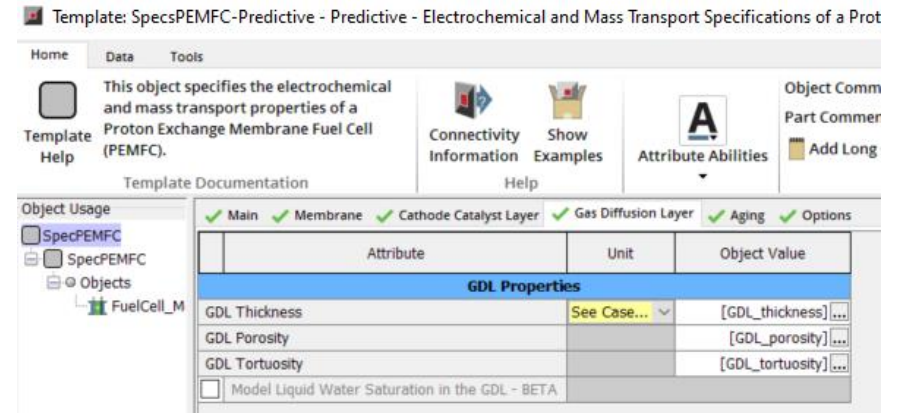
Process Flow

- Below flow diagram shows the **system model process flow**



1D FC System Modelling - Fuel Cell Module Validation

- Fuel cell module element in GT-SUITE was adapted to represent PCBFCC by modifying **material properties** and **thermal parameters** accordingly
- Standalone **PEMFC predictive model** was used to validate the test data –
 - Single cell test data** was used for initial correlation
 - Validated single cell module was **converted to stack** and used in the system model
- Pressure drop and heat transfer** for all channels (anode, cathode and coolant) were **validated** – further investigation with more data availability
- Model showed a **good correlation to test data**, multiple test cases were run to confirm the validity of correlation

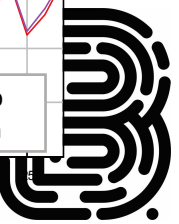
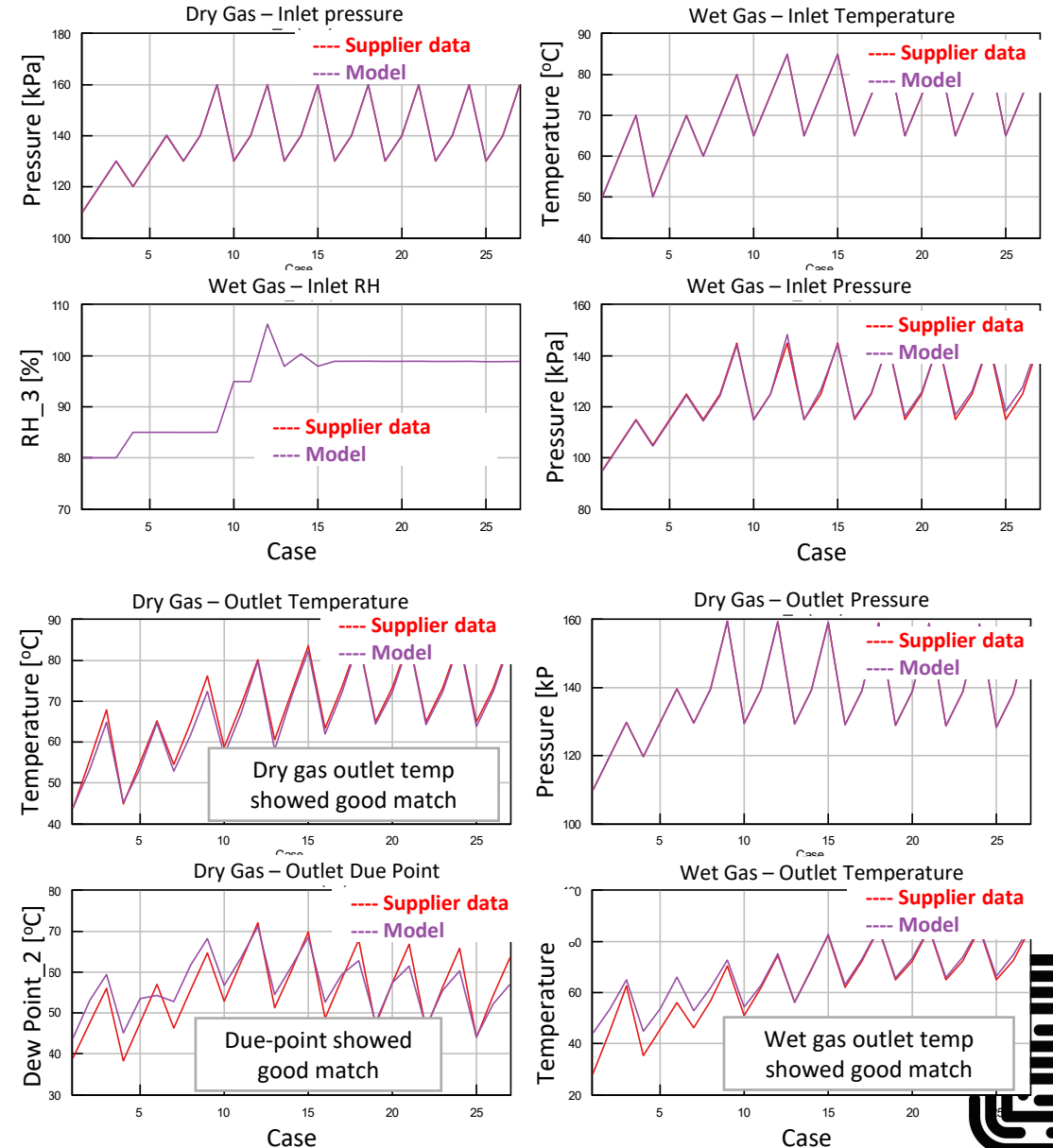


1D FC System Modelling - Humidifier Validation

- A custom humidifier model was created for **cross-flow flat sheet humidifier** opposed to the tube and shell type available in the GT-SUITE component template

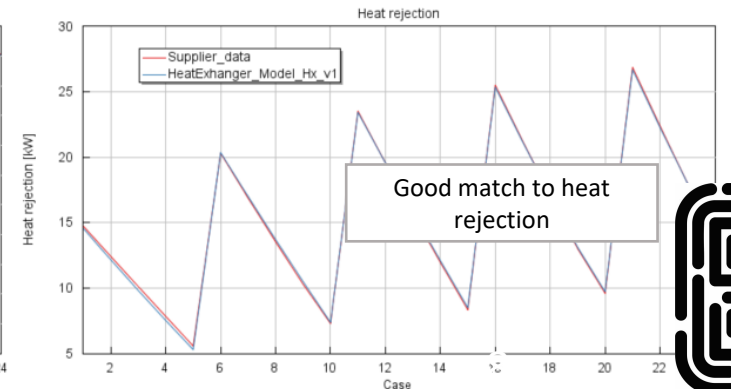
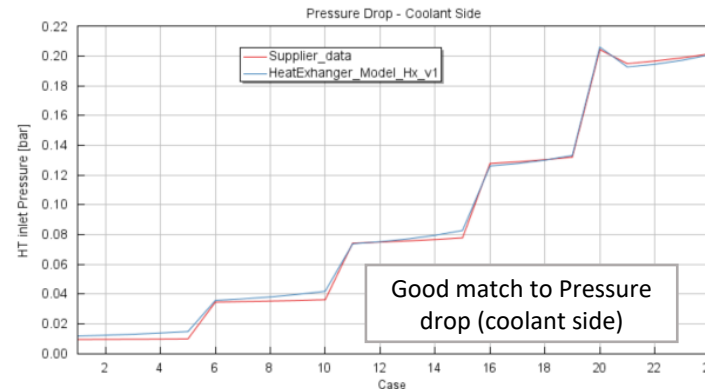
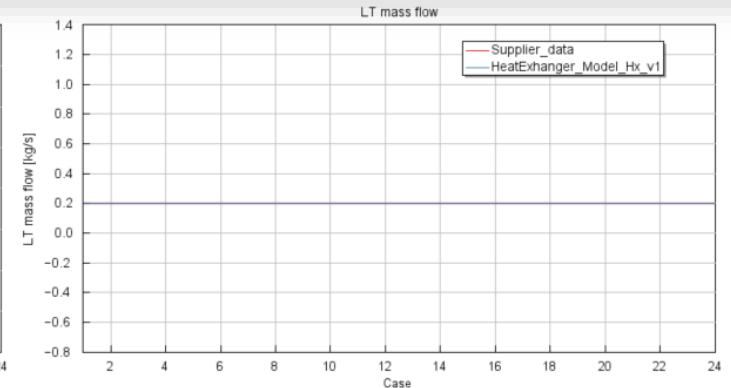
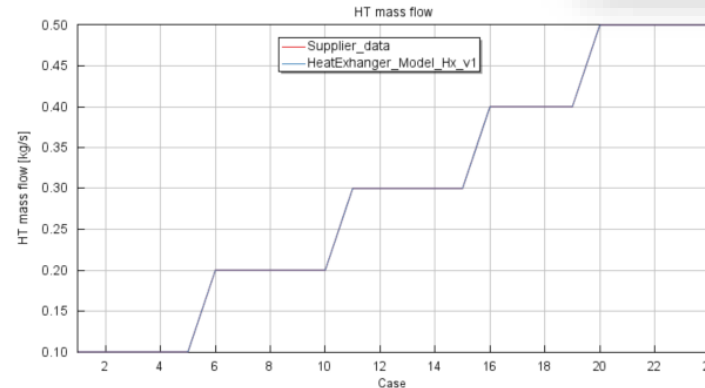
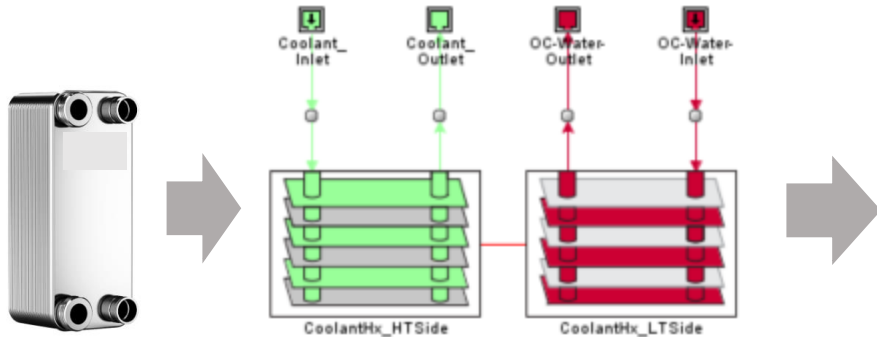
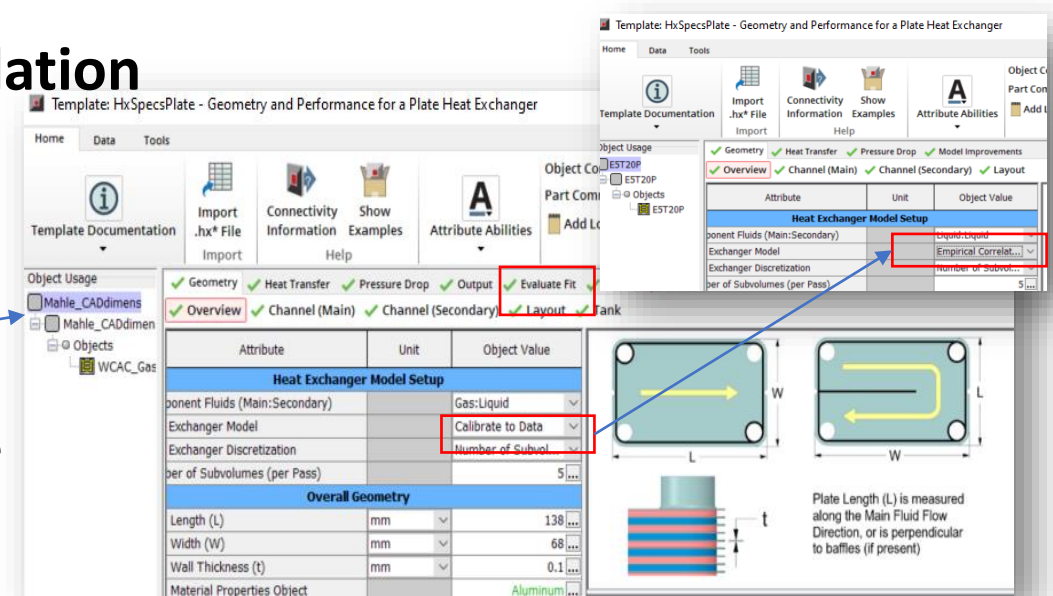


- Custom created model was run with mass flow rates and pressures at the inlet conditions from test data
 - Pipe friction multiplier, heat and mass transfer multipliers were tuned** to match the humidifier outlet conditions
- Validation showed **good match to the supplier test data in terms of** Heat transfer, pressure-drop and mass transfer (H₂O) (outlet conditions), shown in the plots
- The model was converted to component template model and imported to the system model



1D FC System Modelling - Heat Exchanger Validation

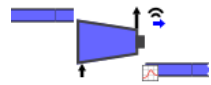
- **Stand alone heat exchanger was validated** against the test data – suitable component template from the component library was selected
- GT-SUITE has '**Evaluate fit**' option that's automatically fits to the selected correlation model
- Further **fine tuning of the correlation parameters** (heat transfer and pressure drop) was carried out to confirm the model validation
- The plot shows the validation results - model showed **good match to heat transfer and pressure drop**
- Similar approach was carried out on WCAC



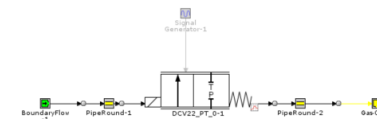
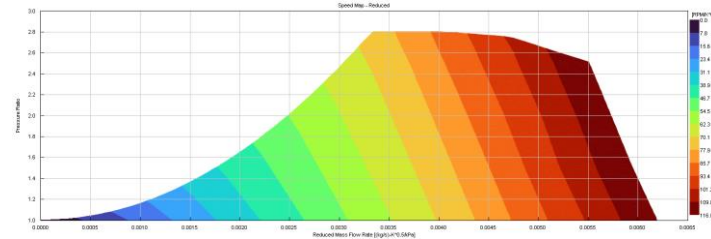
1D FC System Modelling

Compressor, Pumps, Thermostat and Control Valves

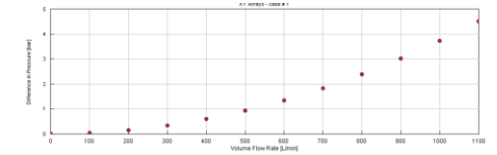
- Map based component such as compressor, thermostat and pump were **modelled and used directly in the system model**
- Some of these elements were run in a standalone model to test its performance, eg – control valves, thermostat etc



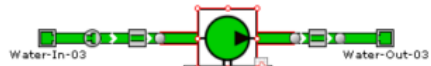
Compressor



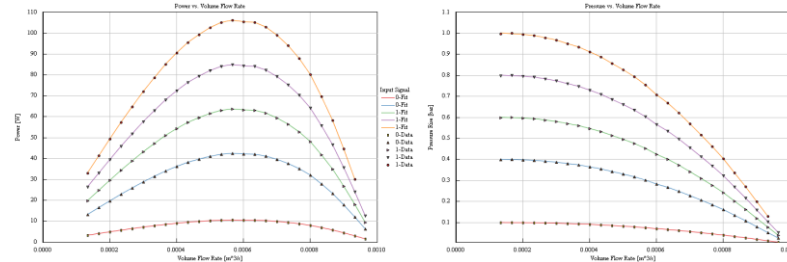
Control Valves



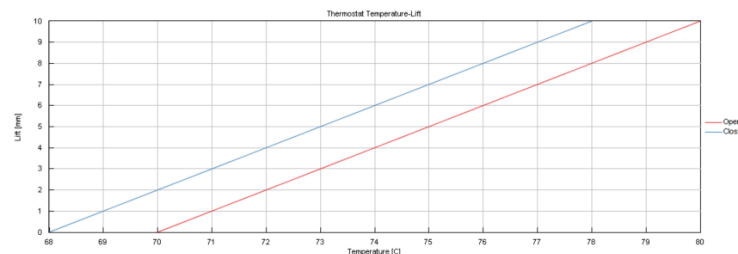
Flow tuned based on simple orifice method



Electric Pump

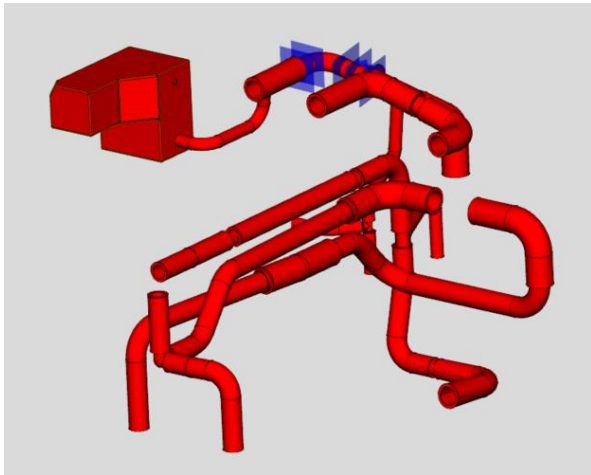


Thermostat

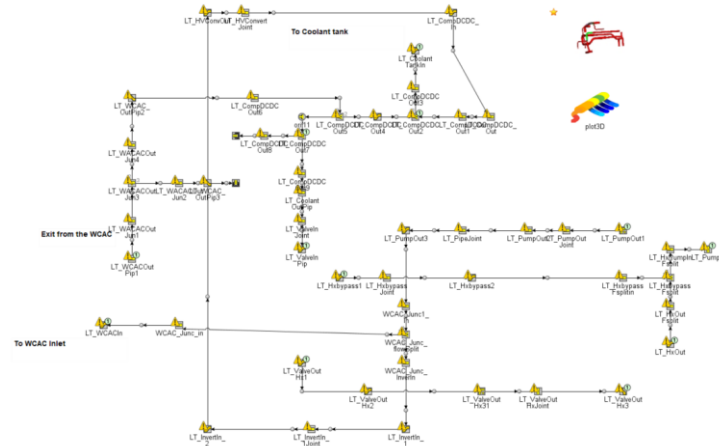


1D FC System Modelling - Conversion of 3D CAD to 1D Flow Elements

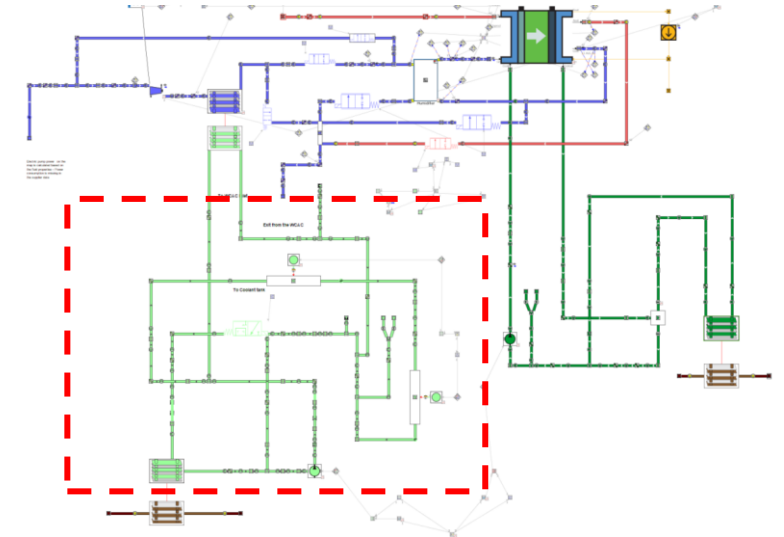
- GT-SUITE's **GEM3D** tool was used for the conversion
- 3D CAD model was imported into GEM3D
 - **3D CAD to 1D elements export** option was utilized to export the CAD to 1D elements
 - This enabled **accurately capture the pressure drop** in the flow path
 - **Complex geometries** such as inlet and exhaust manifolds were **assessed in 3D CFD** for pressure drop characteristics and imposed in the system model



3D CAD Model in GEM3D



Converted 1D flow element
(discretized)



1D Flow elements arranged
in the system model

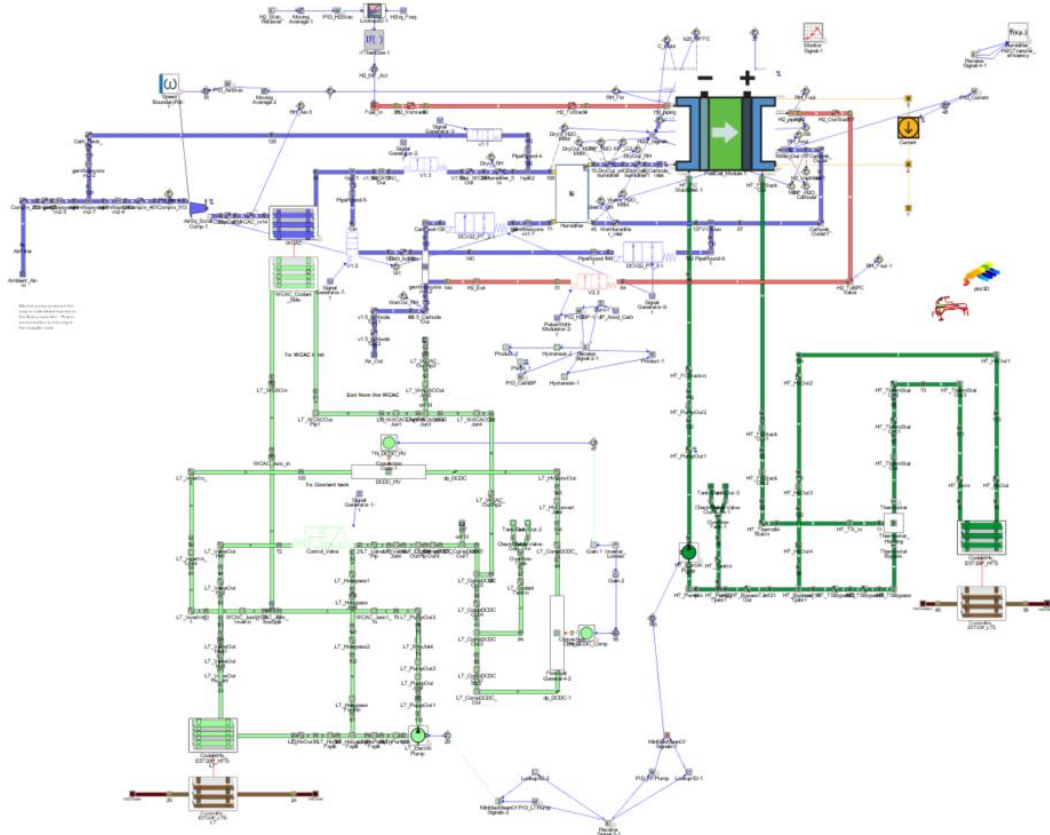


1D FC System Modelling - Current Status

- **Complete flow circuits** were **imported/modelled** including anode, cathode and coolant (HT and LT)
- Whole model was built as **one step at a time**, in-order to identify any potential issues
- **Control strategies on HT and LT coolant pump** were developed **based on the targets**

Hardware Specification Development

- The system model was used to identify the rightly sized component such as valves, compressor etc



Cathode

Anode

High – Temperature Coolant loop

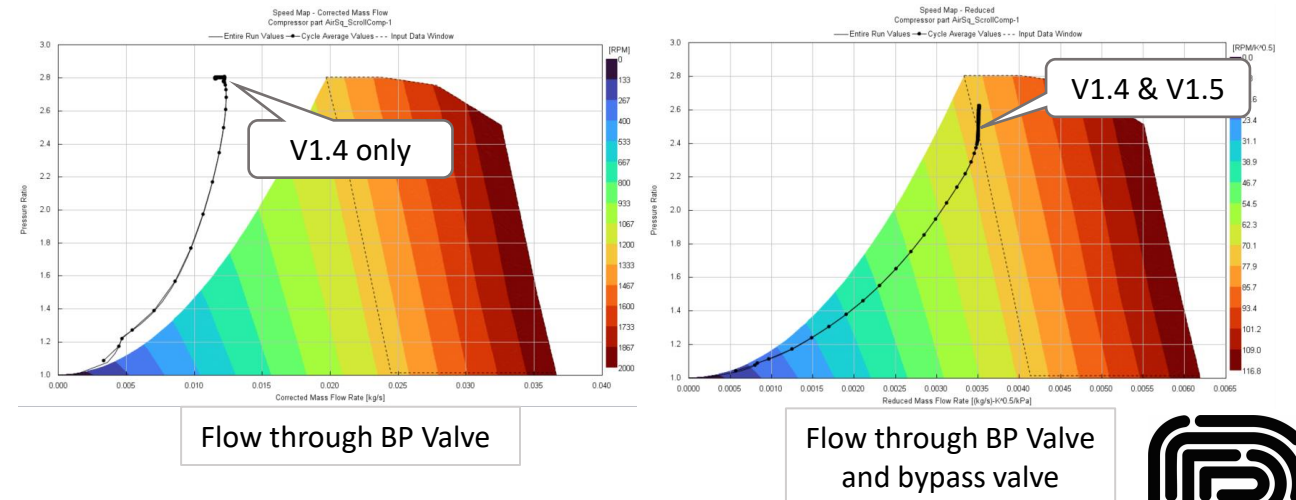
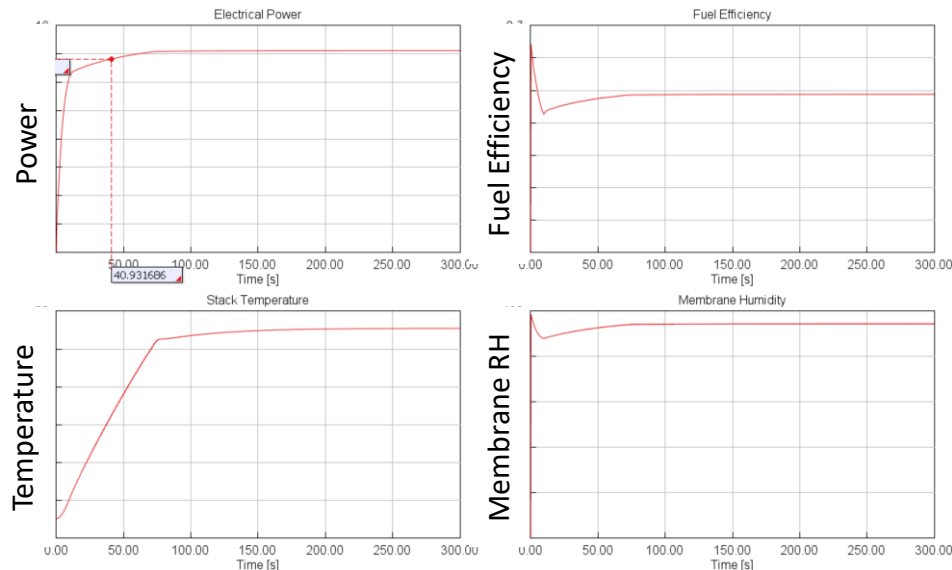
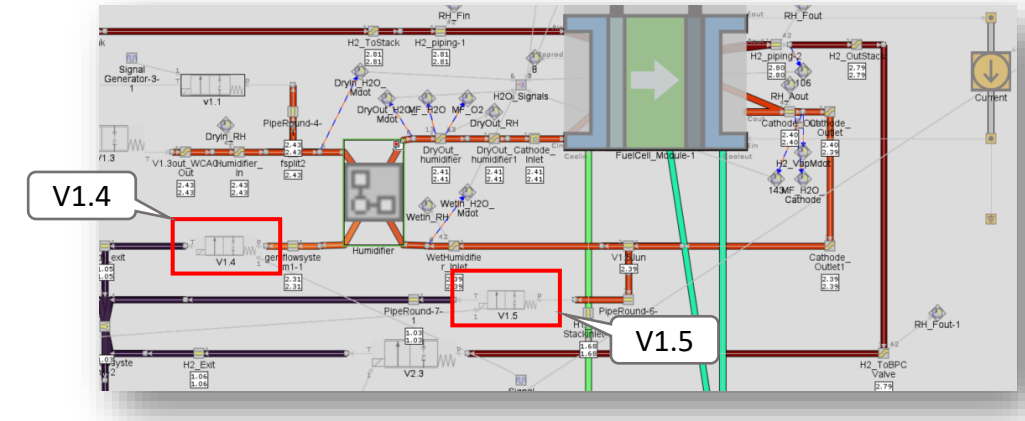
Low –Temperature coolant loop



1D FC System Modelling – Results

Back Pressure Valve Investigation

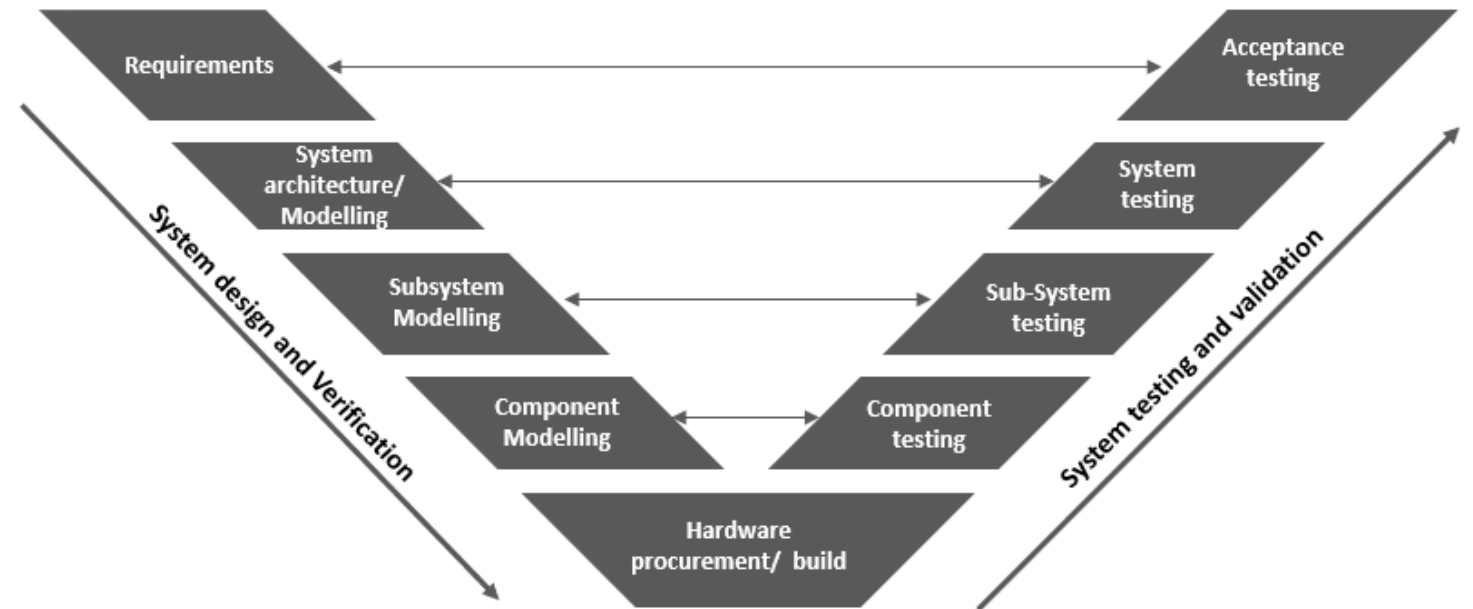
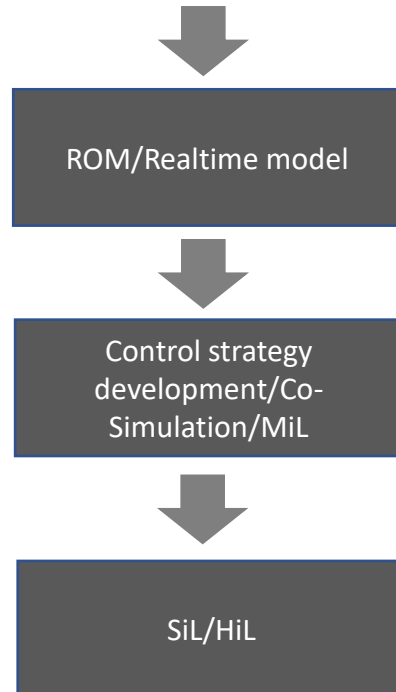
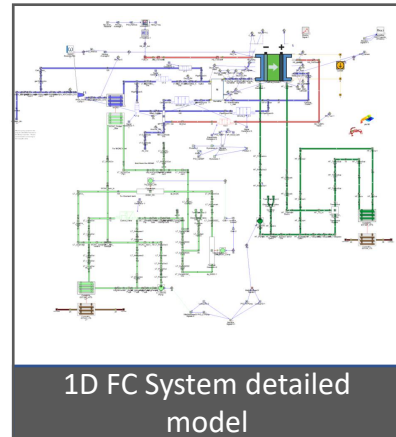
- Initial selection of **Cathode BP valve** was found to be **too restrictive** and that was evident in the compressor plot
- An investigation was carried out by opening the **bypass valve together with the back pressure valve**
 - This helped to reduce the back pressure
 - Below plot shows the result for a full load steady state run of our stacks
 - Investigation was carried out on humidification due to the less mass flow through humidifier to confirm the target performance



1D FC System Modelling - Next Steps

The **baseline model** will serve as an **initial model** for the future projects

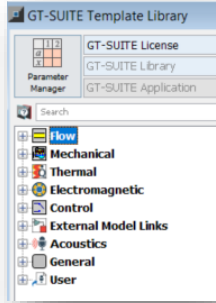
Future planned activities includes:



1D FC System Modelling

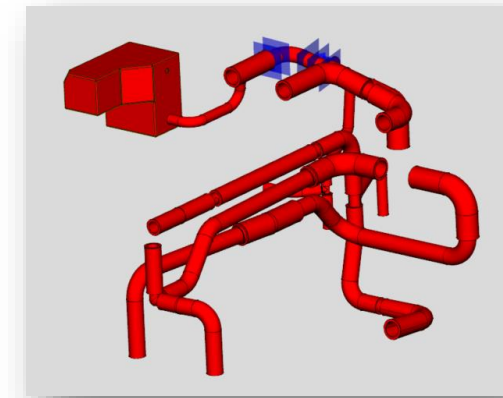
Why GT-SUITE ?

- **Easy to model**
 - Extensive component model library making modelling easy



- **Many options for debugging**
 - Option for detailed report on model run, easy and quick visualization of results in post processing tool
- **Easy to use post processing tool**
 - Visualise the results
 - Post processing – plotting the results
 - Creating reports

- **3D CAD to 1D elements conversion**
 - GEM3D is a very useful tool for converting 3DCAD model to 1D element
 - Improves the accuracy



- **Multi domain system modelling capabilities**
 - Not explored yet
- **Active GT support**
 - Quick and efficient





Q&A
Thank You!





END



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