SYSTEM-LEVEL MODELING OF A FUEL-CELL ROAD VEHICLE FOR COMMON DRIVING CONDITIONS

Hrishikesh Ramesh *Shouvanik Saha* *Ellen Ryckenberg*

TRA105 - Fuel Cell Systems *Project supervisors: David Sedarsky, Lucien Koopmans* *Department: Maritime Science M2*

CHALMERS
UNIVERSITY OF TECHNOLOGY

INTRODUCTION

The use of alternative fuels for road vehicles have become increasingly popular during the recent years. With the world moving towards more sustainable modes of transportation, electric and hybrid vehicles have helped us get closer to this goal. As we look at other options, fuel-cells provide great potential given its high range, zero-emissions and fast refueling compared to recharging a battery. This project will aim towards creating a modelling and exploring real driving cycles of a hybrid PEM fuel cell powered electric vehicle using the simulation tool GT-suite.

BACKGROUND INFORMATION

The most common fuel cell type used today for vehicles is the proton-exchange membrane fuel cell, also called PEMFC. This is a cell made from an electrolyte membrane, with an anode on one side and a cathode on the other. Hydrogen molecules enter through the anode, react with the fuel cell catalyst splitting into protons and electrons. Oxygen enters the cathode and reacts with the hydrogen protons that travel through the membrane. The electrons also travel from the anode to the cathode but in an electrical circuit, and this is where the electricity from the PEMFC comes from. When the protons, electrons, and oxygen molecules all are combined in the cathode they will form water molecules, which is the only emission from this type of fuel cell. (1)

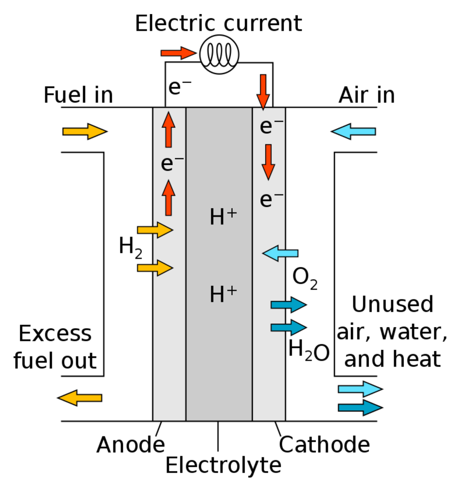
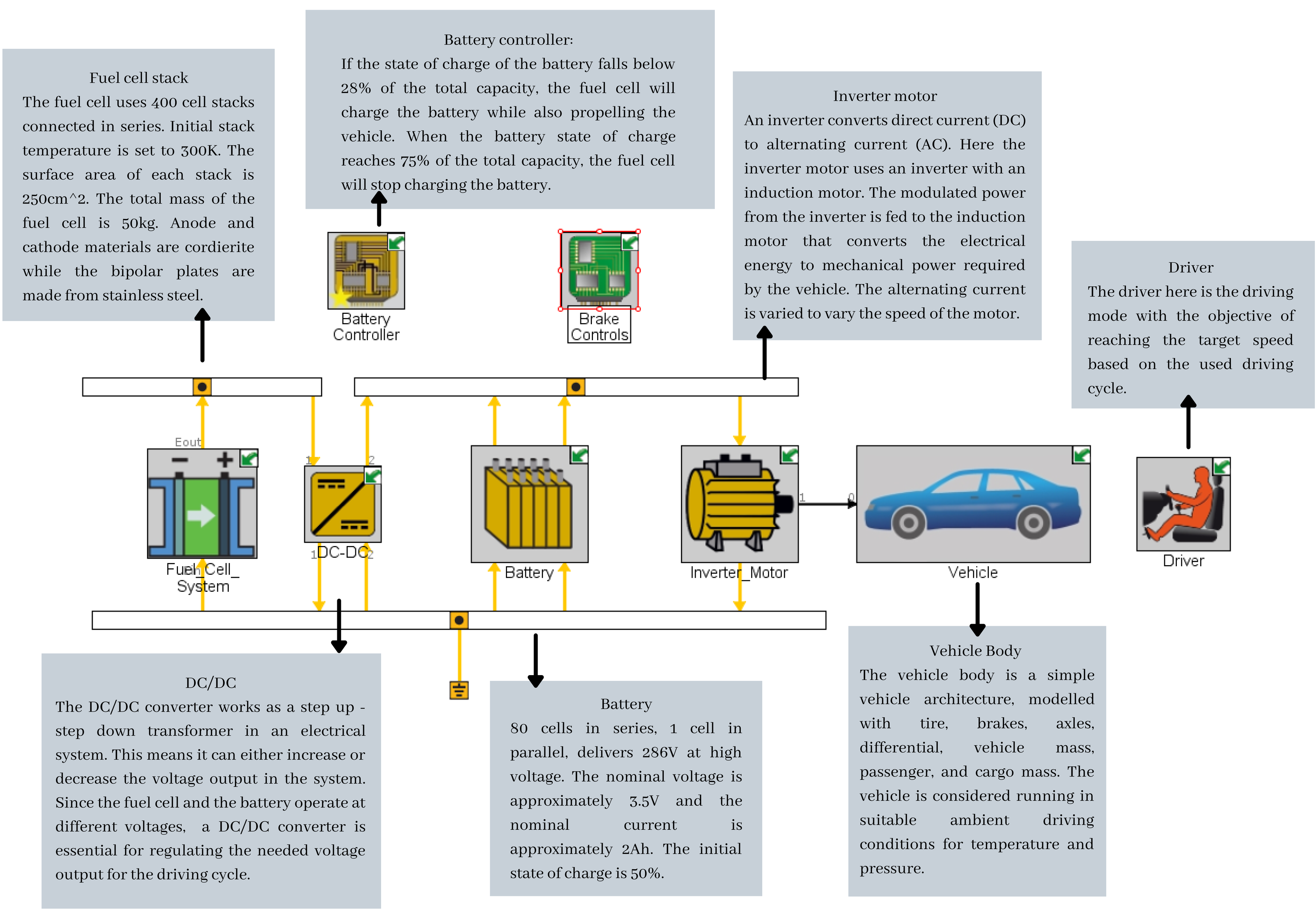


Figure 1

The vehicle studied in this project is a FCEV, a fuel cell electric vehicle, and works much like an electric hybrid vehicle. When the power demand from the vehicle is low a battery is used to deliver electricity to an inverter motor for propulsion. In the case that the power demand increases, the PEMFC is used to produce a higher amount of electricity. In the case where the power demand is very high, both the battery and the PEMFC are used in parallel to provide electricity from two sources. The battery is then charged from the use of regenerative braking as well as directly from the fuel cell when the battery state of charge falls below a set limit.

COMPONENTS AND METHOD USED



Brake control strategy:

When the driver uses the brake pedal friction brakes are applied to the vehicle. If the driver chooses not to press the brake pedal, the car uses regenerative braking to slow the vehicle down while at the same time charging the battery.

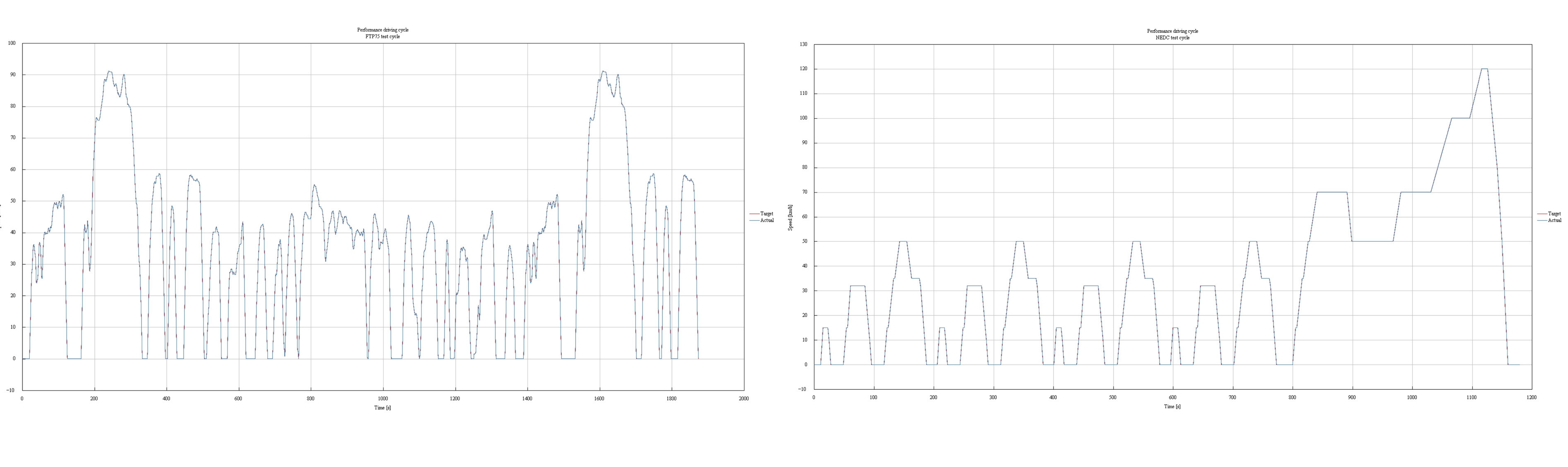
Control strategy

Power distribution between the fuel cell and the battery:

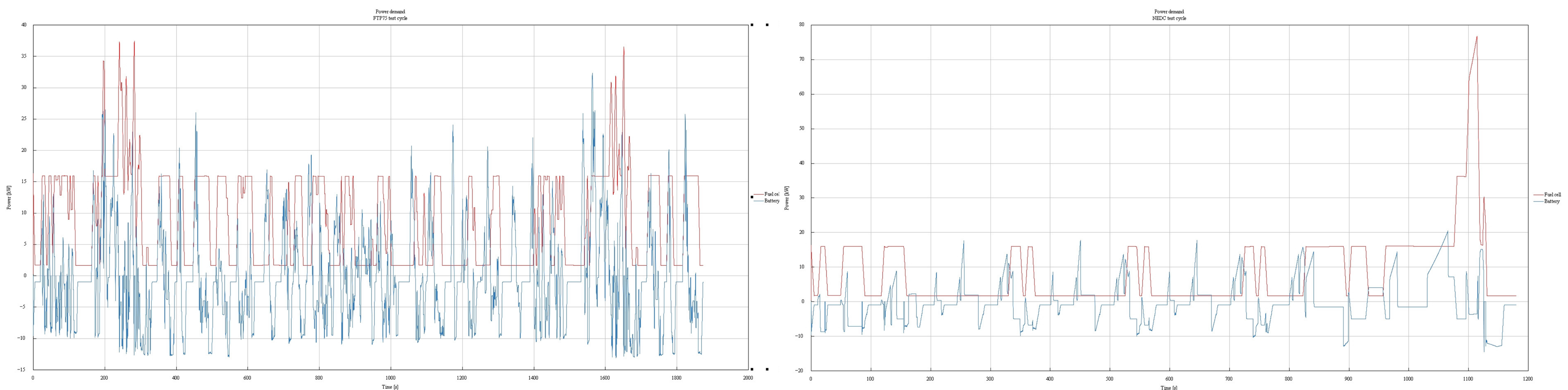
If the required power from the vehicle and the power from the fuel cell together are greater than the power required to charge the battery, then the battery is supplied with electricity and charged. If the required power from the vehicle and the power from the fuel cell together are lower than the power required to charge the battery, then the battery is discharged.

DRIVING CYCLES

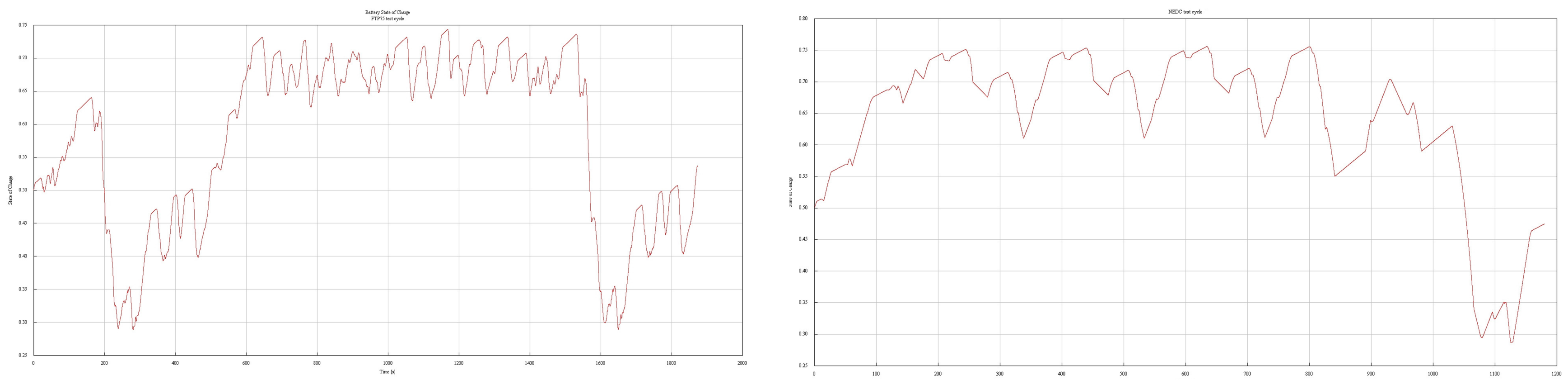
For this project, the vehicle is tested for two test driving cycles and analyzed. The first driving cycle is the most common American driving cycle FTP75 which is approximately 18km in total distance with an average speed of 34.12 km/h. The second test cycle is the most common European driving cycle, NEDC, which is approximately 11km in distance and has an average speed.



POWER DEMAND

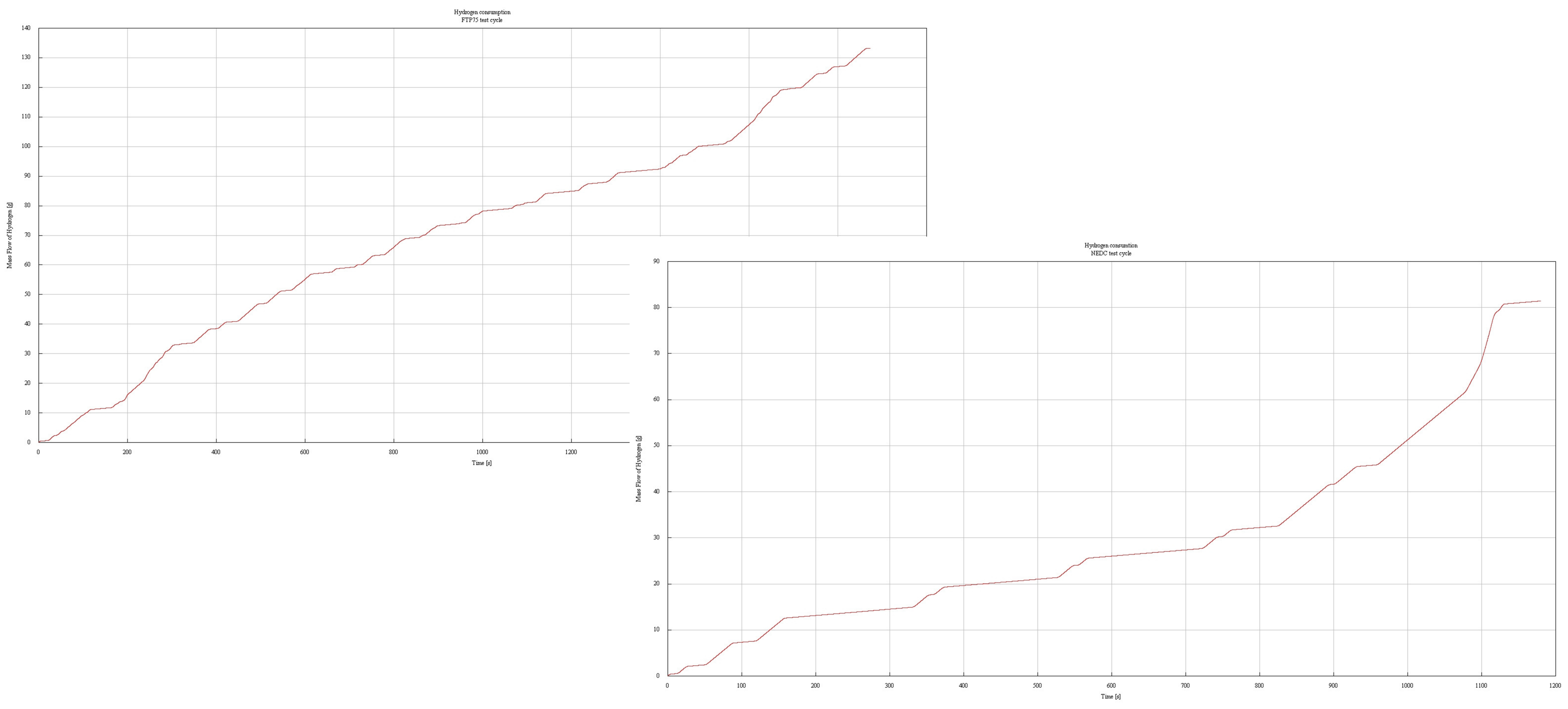


For the test cycles the battery receives negative power whenever the vehicle brakes or regenerates. During low or medium power demand, the battery propels the vehicle if it has the sufficient state of charge. During high load demand, as can be seen twice for the FTP75 cycle, both the fuel cell and the battery will generate power. When the state of charge of the battery falls below the minimum value, the fuel cell delivers all the power requirement. This can be seen in the end of the NEDC cycle.



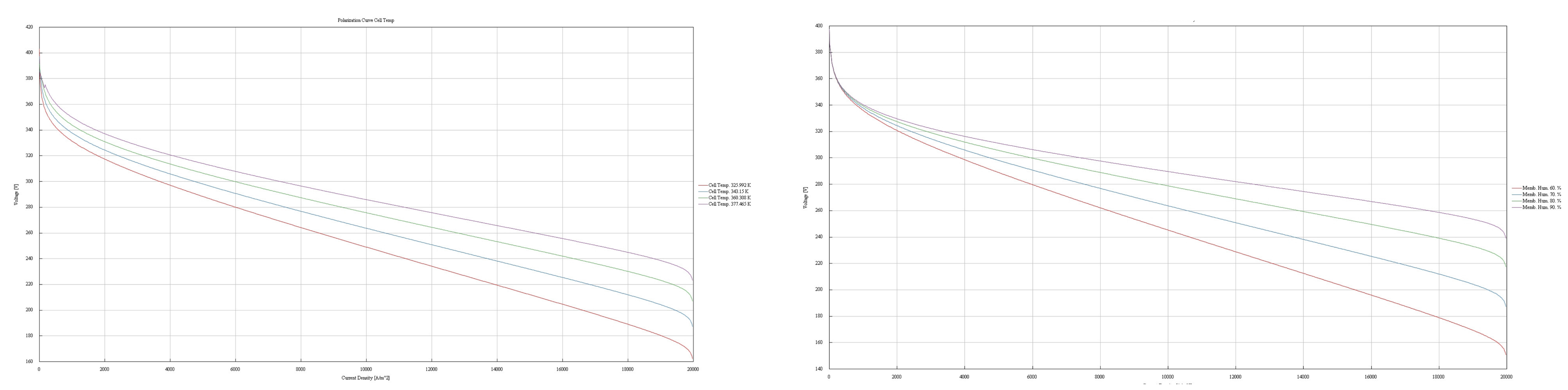
HYDROGEN CONSUPTION

The consumption of hydrogen for the FTP75 test cycle is 133g per cycle and for the NEDC the consumption is 81g. Looking at the storage capacity in a hydrogen tank under 700bar pressure, a full tank can store up to 5.6kg of hydrogen. (2) This would mean that the FTP75 cycle can be run for 42 cycles before having to refuel, a total distance of 756km. The NEDC cycle can run for 69 cycles before refueling and a total distance of 759km.



POLARIZATION CURVES

The fuel cell was operated at four different temperatures and four different humidity levels. As can be seen in the results, the polarization curve that can give the most voltage is the curve with the highest temperature 377K. This is because the activation and the ohmic losses are less when operating at high temperatures. Similarly for the humidity comparison, the polarization curve operating at high humidity levels can provide a higher voltage.



RESULTS AND CONCLUSIONS

After modelling the vehicle drive train in GT-suite, the performance of the fuel cell as well as the battery was obtained. The graphs presented in Driving Cycles both show that the target test cycle could be achieved by the system model powertrain. It is clearly shown that it is beneficial to run the fuel cell at both a high temperature and humidity. To make this possible in a real driving scenario, the fuel cell system needs to be implemented with a correct cooling/heating system. This type of system model is possible to implement into road vehicles for common driving, but the challenge lies with the storage and handling with hydrogen, which is not taken into consideration in this project.

References:

(1): *Fuel Cell Electric Vehicles*, AFDC U.S. Department of Energy's Vehicle Technology Office, 2022-02-27, https://afdc.energy.gov/vehicles/fuel_cell.html

(2): *Toyota Mirai Fuel Cell Electric Powertrain Technology Wins 2022 AJAC Best Green Innovation Award*, Hydrogen Central, published 2022-02-03, https://hydrogen-central.com/toyota-mirai-fuel-cell-electric-powertrain-technology-2022-ajac-best-green-innovation-award/

(3): Figure 1 - Proton Exchange Fuel Cell Diagram - https://upload.wikimedia.org/wikipedia/commons/6/63/Proton_Exchange_Fuel_Cell_Diagram.svg