Design of PEM fuel cell systems for stationary and mobile applications using VirtualFCS

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ABSTRACT

VirtualFCS[1] is a cyber-physical platform for fuel cell-battery hybrid system modelling. It comprises a complete hybrid system model is to reproduce and simulate the dynamic behavior of all the components according to the desired architecture. Depending on the possibilities, degradation mechanisms of the components are considered in order to predict the performance losses of the entire system.

In this study, we explore three critical applications of the VirtualFCS library. Firstly, we demonstrate the integration of fuel cell systems with auxiliary power systems, emphasising emission reduction and the utilisation of waste heat. Secondly, we design a multi-megawatt, multi-stack fuel cell system tailored for powering offshore oil and gas hubs, aimed at minimising direct emissions. Lastly, we develop a predictive model for estimating the operational lifetime of fuel cell systems in maritime applications. Collectively, these use cases address pivotal key performance indicators—efficiency, lifetime, and cost—that are significant obstacles to the market penetration of PEM fuel cell technology.

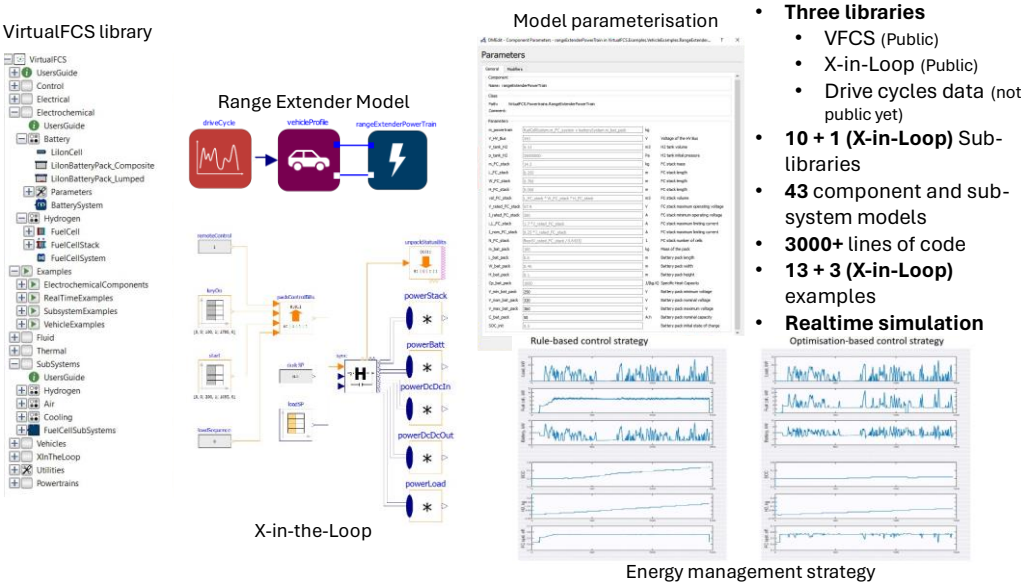

Figure 1 Overview of VirtualFCS modelling library and its features

Develop hybrid heat and power system for stationary application

The Zero Emission Energy System for the Arctic (ZEESA) at Isfjord Radio involves a hybrid energy setup with two 200kW diesel generators, a 400kWh battery storage system, and a 300kWp photovoltaic system (100 kWp roof-mounted and 200 kWp ground-mounted) in an Arctic location off the grid. It includes 250 kWhth thermal energy storage and electric boilers, serving a communication tower, hotel, and research facilities. Plans to add wind turbines and hydrogen technologies, like fuel cells and potentially electrolysis, aim to enhance the site's emission reduction and self-sufficiency.
In the project, Virtual-FCS is used for evaluation of the benefits of replacing diesel generators with fuel cells. A system model was created consisting of load, battery system, diesel generators, and fuel cell system, with a plan to extend with wind turbine model and PV as well. In a preliminary study that was done, using real operational data from the site, it was found that by adding a 30kW fuel cell system in addition to the diesel generators, the diesel consumption could be reduced by ~20%. Later in the ZEESA project, the Virtual-FCS models will also be coupled with a model of the heating system, providing a more holistic view of the system, and giving insight into the practicalities of operation of such a system. Key for this activity is the heat that is being recycled from the diesel generators, against the potential heat recycled from the fuel cell system and the necessary heat upgrading mechanisms related to this.

Sizing of Multi-stack fuel cell systems for stationary application:
CleanOff Hub project is a spinoff from FME Low Emissions. The project aims to demonstrate the extent to which a large-scale offshore hub concept can become an energy and cost-efficient solution to deliver clean heat and firm power to a cluster of offshore installations (oil and gas platforms)
In the Clean Off Hub project, the VirtualFCS modelling platform is used and developed further to test and evaluate different architecture of multi stack fuel system. The goal is to compare different MW fuel systems architectures and evaluate how well they are able to meet requirements regards to power demand and dynamical operation for offshore gas and oil installations. This also include the architecture of the Balance of Plant (BoP) components and whether there should be separated BoP systems for each fuel cell stack or one common one for all the stacks.

Degradation model for mobile application:
ZeroKyst is an NFR-funded project on hydrogen use in maritime applications. One of the goals of the project is to develop methods and tools for the design and operation of hydrogen-electric drivetrains for fisheries and aquaculture industries.
VirtualFCS is used as a modelling tool to model the drivetrain and also predict the degradation of the fuel cell system. A hybrid (physics-empirical) approach is used to model the fuel cell degradation to understand the physical processes occurring during maritime operations.
The data for degradation will be from the fuel cell short stack measurements performed using a maritime drive cycle for 1000s of hours and used as input to the model. This will be relevant stack power management strategies to improve reliability, redundancy and utilisation of the fuel cell.

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ZEESA, CleanOff Hub, ZeroKyst, VirtualFCS projects

References
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