Heavy Duty Fuel Cell System Improvements

Status: Available

Group Members: TBD

Sponsor(s): Ballard

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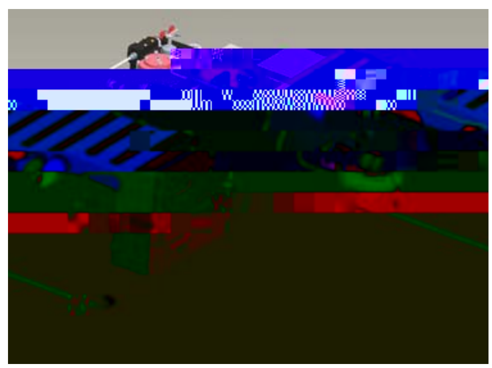
Project Description

The purpose of this document is to briefly describe and provide requirements for a Capstone project that will develop improved fuel management systems for a future generation of Ballard's Heavy Duty Fuel Cell Module. Figure 1 presents two drawings of the current Ballard HD6 Fuel Cell Module: a) as packaged in its enclosure (left); and, b) viewed from the other end showing its internal components (right).



HD6 Module

Figure 1: Packaged & Internal Views of Ballard FC-Velocity HD6 Fuel Cell Module

The Ballard HD6 FC Module comes in 75 and 150 kW models (utilizing 1 or 2 Ballard 1100 series PEM* fuel cell stacks respectively), & includes the following subsystems:

Air humidification system (water spray-based humidifier)
Hydrogen recirculation blower for anode (H2) circuit
Condenser for water recovery & management
CAN and power supply connections, and
Control system

Figure 2 shows a highly simplified schematic of

Figure 2: Simplified Schematic of Air and Fuel Systems in HD6 Module
(Air Humidification & Water Recovery Sub-systems not shown.)

In the arrangement given in Figure 2, air from an upstream air compressor is supplied to the module with its flow controlled by the electrical current requirements of the fuel cells. The anode loop is supplied with fuel (H2) through a bias-pressure controlled Regulator, to maintain the fuel at a small overpressure (a few psi) above the air pressure supplied by the compressor. This fuel is re-circulated in the anode loop by a Hydrogen Recirculation Blower (HRB), and is also consumed (i.e., split into protons that pass through the membrane, and electrons that become the electrical current from the cells).

Unfortunately, in operation, nitrogen from the air (Cathode) side of the fuel cells diffuses across the membranes, and tends to build up in the anode loop over time. To compensate for this, a Purge valve is provided that is currently used intermittently to vent the hydrogen/nitrogen mix from the anode loop, and permit resupply of a higher hydrogen concentration from the supply Regulator. This purged H2/N2 mixture is vent been characterized with air, but will need to be characterized with 100%H_2 and with different H_2/N_2 concentrations, so that flow through the valve as a function of its orifice position is known for all possible anode loop conditions.

The last area targeted for system improvement is the area of cathode hydrogen emissions management. This is a bit of an eclectic area, where Ballard has been studying the use of catalytic converters, downstream dilution with injected air, and/or possibly intentionally igniting and flaring-off the emission inside the cathode exhaust piping. The idea here is to deal with possible crossover-leak driven H_2 emissions (from failed cells), and also start-up emissions, where H_2 can diffuse across the membranes when the stack is shutdown, leading to the ejection of a possibly ignitable mixture on start-up. The likely path for this last improvement is currently envisioned to be the use of a highly-controllable variable-orifice (butterfly) air bypass valve that adds dilution air to the initial H_2/N_2/Air mixture that is forced out of the cells on start-up. Previous attempts to do bypass dilution using an on/off solenoid-operated bypass valve have not been successful, but more recent work recognizing a variable mixing valve could possibly deliver a more carefully-controlled variable ratio bypass mix may permit dealing with these emissions by either dilution, or by dilution to a lean mixture that is then safely flared.

As an industrially-sponsored Capstone project, Ballard would help the students involved by providing sample valves, flowmeters, and test equipment to permit characterizing these components for use in a fuel cell module. The intent would be to set up a flow characterization bench at SFU, and/or provide supervised use of Ballard equipment at Ballard. The goal of the project would be to do enough work in these various areas that “first-cut” solutions could be tried out in test modules here at Ballard, and test data gathered for the students on their effectiveness.

To explain the collaborative nature of this project, Ballard is currently involved with the SFU Mechatronics Systems department (and UVic) to develop some aspects of these ideas as part of an Automotive Partnerships Canada funded project on improved heavy duty fuel cells and diagnostics systems, and through an NSERC CRD project with Professor Farid Golnaraghi targeting fuel cell systems improvements.

For these other projects, Masters and Ph.D. students are currently working on the higher-level aspects of these improvements (e.g., design of a variable-purge flow algorithm, use of AC

Appendix A: PEM Fuel Cell Description

Fuel cells transform chemical energy into electrical and thermal energy by electrochemical reactions that take place in between electrodes and an electrolyte. In proton exchange membrane