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DYNAMIC MODEL AND EXPERIMENTAL TESTS OF A SYSTEM COUPLING PROTON EXCHANGE MEMBRANE FUEL CELL AND METAL HYDRIDES HYDROGEN STORAGE

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The Thermochemical Power Group (TPG) is investing its knowhow and experience in the development of design tools to spread the hydrogen technology into the maritime sector. The TPG gave birth to the UNIGE spin-off named H2Boat S.c.a.r.l. that collaborate along with Fincantieri S.p.a. also into the new HI-SEA Joint Laboratory. The goal of these studies is to evaluate power generation technologies and energy storage technologies experimentally with small scale prototypes.
The studies have been conducted on two systems: PEM fuel cell and MH hydrogen storage system. For both, a Simulink dynamic model has been constructed based on the experimental data collected into the laboratory.

The balance of plant has been modeled taking into account:
- Mass balance equation
- Energy equation
- Equilibrium properties and reaction kinetics

The characteristics of the *PEM fuel cell model* are:
- Mono-dimensional (0-D)
- Semi-empirical
- Easily adaptable to different kind of PEM-FC starting from experimental data regression of the characteristic I-V curve
- Influence of partial pressure and temperatures variations

The characteristics of the *Metal hydrides model (LaNi5)* are:
- Mono-dimensional (0-D)
- Semi-empirical approach to simulate absorption and discharge
- Easily adaptable to different kind of canister and MH starting from experimental data regression of the characteristic Pressure-Composition-Temperature PCT curve (Figure 1).
- Detailed thermal management

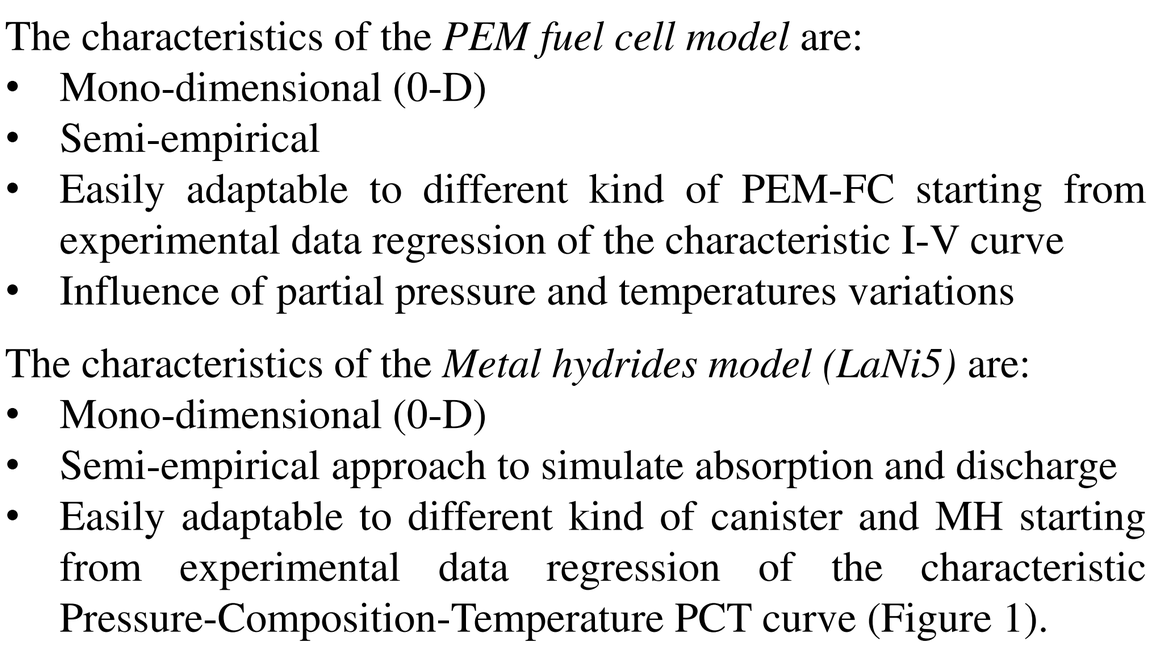

Figure 1. Dynamic and static point hysteresis

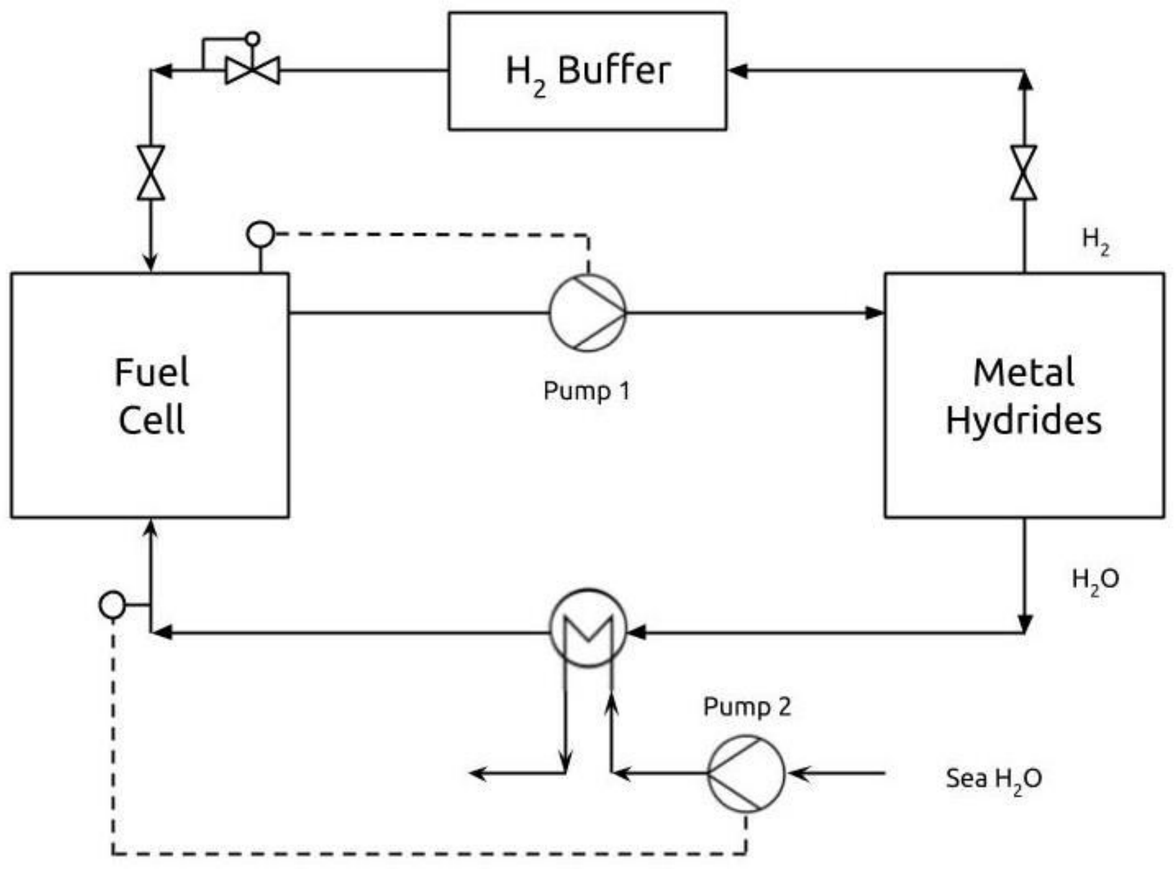

Figure 2. System P&ID

The coupled system has been created connecting the water cooling system of the PEM-FC to the water MH heating system. A secondary sea water cooling system has been simulated to control the PEM-FC temperature. Figure 2 presents the coupled system concept.

The *control strategy* optimize the heat transfer from the FC to the MH by Pump 1. T_{FC} is computed inside the FC module while $\dot{m}_1$ is the parameter controlled by Pump 1. Inside the MH model T_{MH} is calculated while the temperature of the FC cooling inlet passing through the heat exchanger is controlled by Pump 2 on the base of the required FC temperature, considering a constant temperature of sea water equal to 15°C.

The models have been set up and validated against experimental data collected by the *prototype developed by H2Boat*. The former consist of a 300 W water cooled low temperature PEM-FC directly connected to a hydrogen storage system composed by three canister of 500 Nl AB5 low temperature MH.

The present work represents the first step towards the assessment of hydrogen technology for ships and boats that will be conducted in parallel with the HI-SEA laboratory. It has been demonstrated that a direct thermal coupling PEMFC and MH is feasible. A simulation model has been validated, that will be used for future studies on the system control and sizing to increase the total system efficiency.

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