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# Air Supply Study of Fuel Cell Hybrid Power for Renewable Energy Backup

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## Extended Abstract

The Proton Exchange Membrane Fuel Cell (PEMFC) has emerged as a reliable solution to address the intermittency of renewable energy sources, such as solar and wind, by serving as a backup or complementary energy source in hybrid renewable energy systems [1]. The high Maximum Power Density Point (MPDP) is critical for compact renewable power system. In particular, as the PEMFC is operated at MPDP, the short term deficit of hybrid renewable sources can be compensated with reduced volume of the PEMFC stack [2].

Even though the MPDP is beneficial to cope with intermittency of renewable power sources, the operation of PEMFC at MPDP is still required to resolve technical barriers. A key challenge is to manage cathode flooding at high current density. The flooding results in performance drop as well as acceleration of degradation. In particular, as cathode flooding hinders oxygen transport to the reaction site that results in concentration losses. The concentration drop is then consecutively decreases limiting current densities. Consequently, flooding reduces the MPDP of PEMFC. On the other hand, besides the electrochemically produced water vapor, the flooding is also caused by induced water vapor from cathode inlet. Even though exact estimation of product water is expected, the flooding is difficult to be controlled due to induced water vapor from cathode inlet. Accordingly, the effect of inlet air relative humidity (RH) is necessary to be evaluated for achieving higher MPDP of PEMFC [3].

In this study, a comprehensive simulation model of PEMFC system is presented that has dynamic PEMFC stack model with prediction of oxygen starvation, air supply system with static humidifier, the hydrogen supply system, and cooling system. Notably, the dynamic PEMFC stack is based on in-house code of multi-layered cell model [4]. That can include the effect of flooding with oxygen shortages on the concentration overpotential. The stack model is then validated with the experimental polarization curve with various the limiting current density so that simulation model is capable of performance prediction across a wide range of current densities, as well as the oxygen transport limitation in both dry and flooded conditions.

The system simulations were conducted to examine the influence of air supply conditions on the MPDP under various load ramping-up time scenarios. The results show that low inlet RH levels lower overall efficiency but mitigate cathode flooding during high current density operation, allowing the PEMFC stack to achieve the highest MPDP of 185 W/cm² at a current density of 2.15 A/cm². In contrast, high inlet RH levels promote cathode flooding, reduce oxygen transport capacity, and lower the MPDP to 136 W/cm² at a current density of 1.4 A/cm². Additionally, load ramping-up time also affects the MPDP, with shorter ramp times resulting in lower MPDP values, especially under high inlet RH conditions, due to insufficient time for water removal.

As a result, the MPDP of PEMFC is strongly coupled with flooding effect of cathode side. These findings suggest that while high RH levels benefit long-term operation, supplying drier air enhances the immediate MPDP, making it advantageous for short-term peak demand scenarios. The observation provides valuable insights for developing operation strategies that enable the PEMFC stack to function effectively during periods of high-power demand and low renewable energy output.

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