J Fundam Renewable Energy Appl 2017, 7:6(Suppl)
DOI: 10.4172/2090-4541-C1-036

Steady state modeling of hydrogen P2P system: BoP and stationary study

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Nowadays, the wider penetration of renewable energy sources is creating in time an increasing mismatch between demand and supply as well increasing fluctuations of national electrical grids. With wide penetration of variable energy sources in the market, it is required a new concept of management of the overall electrical infrastructures. There are a limited number of potential solutions and supports, sometime complementary among each other; one of the most relevant is to store excess of intermittent production in hydrogen using a technology configured as a power to power unit. In the case of solid oxide cells, this technology can be reversible using one single stack. On one side, hydrogen can be generated by high temperature electrolysis process (e.g. using green power). On the other side, hydrogen can react in a solid oxide fuel cell to produce electrical power with high efficiency (around 60% on HHV). Within the technology scheme, the storage of hydrogen plays a crucial role. H_2 solid state storage in metal hydrides represents a valid alternative compared to compressed vessels, provided of a higher gravimetric density (7.6 % w/w for magnesium hydride). It has indeed a high desorption enthalpy, which has to be balanced at the system level. The scope of this study is to present a steady state modeling of system integration between a H_2 storage tank based on magnesium material with embedded heat management (which reversibly accumulates hydrogen at 600 K) and a reversible solid oxide cell, which works as fuel cell and electrolyser. A proper mathematical model based on EES (Equation Engineering Solver) platform was realized. The model included an optimized heat exchangers' network, a hydrogen burner, a hydrogen storage tank and a solid oxide cell. Two different models were developed to describe fuel cell and electrolyser working modes. Solid oxide cell was carefully modeled, taking into consideration all overvoltage contributions: activation, ohmic resistance and diffusion both for hydrogen production or consumption modes. The model was used to develop a proper Balance of Plant (BoP) for the European FP7-FCH JU-EDEN project, sizing and optimizing the components for specific working condition which were selected by the solution here identified. Finally, the experimental data obtained from EDEN prototype have confirmed the correctness of the models.

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