PERFORMANCE ANALYSIS OF PHOTOVOLTAIC-FUEL CELL HYBRID SYSTEM

ABSTRACT

Hydrogen can be a promising option as energy storage medium in renewable power generators based distributed power system. In the present study, hydrogen storage is used as energy storage medium with photovoltaic (PV) generator. PV electricity is used to generate the hydrogen using the alkaline water electrolyzer (EL). This generated hydrogen is stored in the hydrogen cylinder. This stored hydrogen is converted back into electricity by proton exchange membrane fuel cell (PEMFC). In this study, a special attention is given on the solid hydrogen storage (metal hydride) system for storing the generated hydrogen as it offers advantages such as low working temperature and pressure along with safety.

A simulation study is performed for designing, component sizing, performance and cost analyses of PV-FC hybrid system for given load requirement and Indian operating conditions. An attempt has been made for the cost evaluation of the solid and high-pressure hydrogen storages in the PV-FC hybrid system. Hydrogen storage (solid and high pressure) is also compared with battery storage and grid-connectivity modes in the present hybrid system on the basis of performance and cost. It was found that although the hydrogen storage involves higher cost of electricity but in case of optimized cost scenario of the hydrogen storage system difference in the cost of electricity between the hydrogen and battery storages reduces considerably.

After a feasibility analysis of the hybrid system, a hardware prototype of 5 kWp PV, 0.6 kW EL, 5000 liter metal hydride (MH) cylinder and 1 kW fuel cell (FC) was developed in the laboratory to supply the load demand.

For investigating the MH storage system in detail, a simulation study is performed to evaluate the suitable MH alloy with PEMFC application. A comparative study is performed for different MH alloys (low temperature hydrides). It was found that LaNi₅ is suitable for the hydrogen storage with PEMFC generator.

Dynamic hydrogen charging/discharging characteristics in the MH is studied on the basis of simulation and experimental analysis. The simulation model of given metal alloy (LaNi₅), size
and storage capacity of MH cylinder helps to predict the potential of dynamic hydrogen charging and discharging rates with change in the external cooling/heating management and therefore to design the suitable thermal management system. Thermal management system uses the water for exchange the heat from the MH cylinder. Results show that the hydrogen discharging rate from the MH cylinder can be controlled by varying the temperature and flow rate of water in the thermal management system. It was found that 5000 liter MH cylinder is capable to deliver 65 liter per minute (lpm) hydrogen flow rate at 30°C and 1 lpm of temperature and flow rate of water, respectively. Dynamic operational characteristics of the MH storage with EL and FC show that the appropriate use of designed thermal management system facilitates the proper functioning of overall system.

For evaluating the overall performance of the hybrid system, a mathematical model is developed for hybrid system. PV, FC, EL, battery and MH are mathematically modelled. The performance of hybrid system is evaluated in all different possible operating modes. As MH storage involves cooling/heating requirement during operation, therefore it will affect the overall system efficiency. In present study, the overall efficiency of the system is analyzed considering the effect of cooling and heating demand in MH. Experimental study is also performed to evaluate the performance in terms of energy analysis of the individual system components such as PV, electrolyzer, MH and FC along with the overall hybrid system.