ABSTRACT

Fuel cells are clean, highly efficient, scalable power generators can be fuelled by a variety of fuels which contain hydrogen, hence it can be used for versatile applications. Among many types of fuel cells, Proton Exchange Membrane Fuel Cells (PEMFCs) seems to be more promising than other types of fuel cells and are particularly suitable for automotive applications, since they are compact and produce a powerful electric current relative to their size. They operate at a relatively low temperature which allows for faster start-up and rapid response to changes in the demand for power. This makes PEMFCs ideally suitable for transportation and smaller stationary applications. In spite of its excellent benefits, commercialization of fuel cells is very challenging because of the high cost of materials and low reliability, hydrogen generation and storage technologies.

PEMFC is an electrochemical energy conversion device that converts chemical energy into electrical energy due to oxidation of hydrogen and reduction of oxygen. Heat and water are the by-products of electrochemical reactions. Studies on PEMFC systems, includes influence of flow field design, water and thermal management issues, and material properties have been carried out. Parameters that influence water removal rate, flow field design, operating condition control, electro-osmotic pumping and MEA design incorporating the membrane thickness, optimization of GDL and microstructure of the catalyst layer have also been studied.

The power requirement is more, which requires scaling up or increasing the active area of the cells will be much more than 25 cm^2 and stacking up or increasing the number of cells. Based on the literature, it could

be concluded that both scaling and stacking have found to reduce the power density of PEMFC. This is due to, ineffective cooling, water lodging at the cathode, improper distribution of reactants species on anode and cathode, passive conduction of protons by catalyst, etc. most of these issues are associated with flow fields. Many researches are going robustly in order to address the above problems for augmenting the overall performance of the PEMFC. Hence, the present work is design and development of scalable and stackable PEMFC systems with serpentine and interdigitated flow fields. Also, optimization studies are carried out for identifying the optimum combinations of operating and design parameters to attain the maximum performance of PEMFC.

A single cell PEMFC having an active area of 25 cm^2 with serpentine and interdigitated flow fields on cell performance has been studied by using various back pressure (0, 0.5, 1 and 1.5 bar) and various landing to channel ratios (1:1, 2:2). The study establishes a strong relation between back pressure and power output of a PEMFC. Among all other flow fields consider for studies, the interdigitated flow field with L:C ratio of 1:1 having 65 % higher power density for back pressure varying from 0 bar to 1.5 bar. The development of scalable PEMFC from 25 cm^2 to 70 cm^2 active areas and experimental investigation on their performance of scalable PEMFC with various landing to channel ratios (1:1, 2:2) for serpentine and interdigitated flow fields has been studied. When scaled up from 25 cm^2 and 70 cm^2, the power density decreased 40.4 % for interdigitated flow field of L:C-1:1. The performance of 70 cm^2 decreases comparing to the 25 cm^2 PEMFCs as larger area stringently requires homogeneity of gas distribution for uniform reaction rate. If the area is still increased, the losses can increase too, unless proper thermal and water management techniques are to be used.

Performance studies of two cells stack with the effect of cooling channels by natural and forced convection have been studied for both 25 cm^2 and 70 cm^2 of PEMFC. The results revealed that maximum power density has reduce from 0.331 to 0.329 W/cm^2 for 25 cm^2 and 0.194 to 0.178 W/cm^2 for 70 cm^2 of PEMFC for a single cell and two cells stack respectively. The peak power density of two cells stack has marginally lower than that of a single cell. The results point out that the power output of a fuel cell as tested in a single cell fixture may not be reproduced when stacking up with identical flow geometries, due to several reasons (ie) difference in performance could be due to reactant concentration was different in each cell, ohmic losses from the increased number of graphite plates, and uneven fuel flow between the cells in the stack. Also, the cooling channels exhibited considerable improvement in performance at higher operating temperatures by enabling the cell temperature to be kept at optimum level.

Taguchi technique and analysis of variance (ANOVA) methodology has been used to obtain the optimum combination and their contributions to the 25 cm^2 PEMFC performance with serpentine and interdigitated flow fields. It gives the optimum combinations within the selected parameter are 1 bar for back pressure, 60°C for cell temperature and L:C of 1:2 under these conditions, maximum power density has obtained 0.263 W/cm^2 and 0.265 W/cm^2 for serpentine and interdigitated flow fields respectively. Consider all the operating and design parameters for optimization studies, the back pressure contributing major influence on peak power performance with 69.8% for serpentine flow field and 81.80% for interdigitated flow field followed by L: C and cell temperature. Also, studies have been carried out for multiple regression analysis, and the results concluded that the regression co-efficient (R^2) has obtained as 94.2 % and 94.3 % for serpentine and interdigitated flow fields with allowable maximum deviation limit has 5.8 %. The maximum deviation has 1.156 % between the experimentation data's with regression model on our studies.