International Conference on
Theoretical and Applied Computer Science and Engineering
(ICTACSE, 2017)
Ankara, Turkey, November 10-11,2017

Bond graph modelling and simulation of single cell solid oxide fuel cells

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Over the last decade, fuel cells and hydrogen energy technologies have received attention in power generation and automobile industries. Use of the fuel cells in these sectors has remarkable advantages like high efficiency, zero emission, no noise and low heat transmission. A fuel cell is an environmentally friendly device which is capable of converting chemical energy obtained from fuel into electrical energy and produces fewer pollutants (water and heat). Therefore, fuel cells are considered as low pollution power source among other power conversion technologies.

A fuel cell system is, inherently, multidisciplinary because it is composed of interacting subsystems or parts from different engineering disciplines requiring an integration of chemical engineering, process engineering, mechanical engineering, electrical engineering and control engineering. Bond graphs provide a unified approach to the modelling and analysis of dynamic systems and are ideally suited for modelling fuel cell systems because the coupling between different domains can be easily modelled.

A bond graph model of a solid oxide fuel cell is presented in this paper. The constitutive relations of a C-field for two species of gases are formulated in order to model the cathode and the anode channels of the fuel cell. For given values of system operating pressure, the air source and hydrogen source pressures, the outlet pressures and the inlet gas compositions, the fuel utilisation (FU) and air utilisation are interpreted in terms of the partial pressures of the gases in the anode channel and cathode channel. The developed model satisfactorily captures all the essential dynamics of the SOFC system.

Keywords: Hydrogen, Fuel cell, Bond graph model, Software packages, Electrochemical phenomena