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Comparison of proton exchange membrane fuel cell static models

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ABSTRACT

Using experimental study results, this paper aims at evaluating the different analytical models that are used for modeling Proton Exchange Membrane Fuel Cell Stack (PEMFC). Three static models such as those of Amphlett, Larminie–Dicks and Chamberlin–Kim are demonstrated. These models are studied and validated experimentally with identification of their parameters separately. Hence, experimental results are compared for fuel cell test bench for two rated powers (400 W and 700 W). Furthermore, simulation results explicitly verify the accuracy and efficiency of these static models.

1. Introduction

Renewable energy (RE) sources (sun, wind and other sources) are attracting more attention as alternative energy sources if compared to conventional fossil fuel energy sources. This is not only due to the diminishing fuel sources, but also because of their environmental pollution and global warming problems. Different energy sources and converters need to be integrated to meet sustained load demands while accommodating various natural conditions; for example [1], focuses on the hybridization and the integration of photovoltaic (PV), fuel cell (FC) and ultra-capacitor (UC) systems for power generation. In addition, hybridization of wind, PV and FC is designed to supply power demand from generation system. The aim of this design is to minimize the annual cost of the hybrid system over its 20 years of operation, and the optimization problem is subject to reliable supply of the demand. The searches prove that hybrid energy systems are best suited for isolated applications [2,3].

The power system feasibility, based on FCs, has been widely demonstrated throughout the world. FC technology is suitably integrated into RE energy schemes when it is fueled with hydrogen obtained from RE resources. Moreover, the field observations show that hybrid systems are feasible and reliable enough, and required less maintenance [4]. Focusing on low temperature FC, the main thrusts in PEMFC research and development are to lower the cost of the FC stack, to increase its durability and to improve the global efficiency of the FC power system.

As PEMFC may be a powerful tool in the development and widespread testing of alternative energy sources in the next decade, the authors in [5] have proposed a co-generative system allowing achieving electrical efficiencies up to 40%. To analyze the FC based power generation systems, suitable PEMFC models should be obtained. Many research works have already been performed on modeling and simulation of PEMFC [3,6–9]. A reliable mathematical model allows a better understanding of the parameters that affect the PEMFC system's performance. In addition, the time and cost are reduced in the analysis and design of FC systems.

From the literature, most of the models are validated by experimental data. The general validation method is to compare the polarization curve computed by analytical model giants the polarization curve measured by experimental investigation. If two V–I curves are in good agreement, the model is considered reliable [10]. In [11], the performance of a bench scale FC stack, which runs on hydrogen/air, is experimentally measured for different air flow rates and temperatures. The experimental data are used in estimating the parameters of a complete analytical model that describes the V–I curve.

In [12], the dynamic process of stack voltage is analyzed when a step current is applied. It discusses the process regarding the following four aspects: voltage variation rate, initial value of dynamic voltage, time to reach steady state and dynamic resistance factor.

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