Artificial immune system-based parameter extraction of proton exchange membrane fuel cell

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For a better understanding of the characteristics, performance evaluation and design analysis of proton exchange membrane fuel cell (PEMFC) system an accurate mathematical model is an imperative tool. Although various models have been developed in the literature, because of the shortage of manufacture information about the precise values of the parameters required for the modeling, the parameter extraction is an essential task. So, in order to obtain the PEMFC actual performance, its parameters have to be identified by an optimization technique. Artificial immune system (AIS) is a soft computing method with promising results in the field of optimization problems. In this paper, an AIS-based algorithm for parameter identification of a PEMFC stack model is proposed. In order to study the usefulness of the proposed algorithm, the AIS-based results are compared with the obtained results by the genetic algorithm (GA) and particle swarm optimization (PSO). It is shown that the AIS algorithm is a helpful and reliable technique for identifying the model parameters so that the PEMFC model with extracted parameters agrees with the experimental data well. Moreover, the AIS algorithm outperforms the GA and PSO methods. Therefore, the AIS can be applied to solve other complex identification problems of fuel cell models.

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1. Introduction

The expectations of very low emissions and relatively high efficiencies can be satisfied in fuel cell-based power generation systems. Fuel cells are not only distinguished by lower pollution and higher efficiency than conventional power sources, but they have superior dynamic response, good stability and low noise. Among different kinds of the fuel cells, because of relatively low operating temperature, fast response, small size, high current density, no waste, and zero emission if it is run with pure hydrogen, proton exchange membrane fuel cell (PEMFC), can be a great alternative for power generating sources in the coming years, especially in the automotive, distributed power generation, and portable electronic applications [1,2].

The PEMFC system is a nonlinear, multi variable, and strongly coupled system that is hard to model by conventional methods. Recent research on the fuel cells is concerned to model an exact and proper polarization curve (V–I) of the fuel cell system. A V–I model which can indicate an exact and accurate description of the PEMFC performance is an extremely helpful tool for a better understanding of the characteristics, simulation, design analysis, and optimization of PEMFC operating points. In the previous literature, various models have been developed for the PEMFC system [3–11]. Due to the shortage of manufacture information about the precise values of the parameters required for the modeling and in order to obtain accurate simulation results, the parameter identification issue is indispensable. With the help of an optimization technique, the parameter identification problem can be solved.

On the other hand, the performance of a PEMFC system is affected by many operating parameters such as cell temperature, air flow rate, hydrogen flow rate, air pressure, hydrogen pressure, oxygen excess ratio. One of the most important parameters of fuel cells which has to be adjusted accurately is the oxygen excess ratio (Lambda O2) [12–14]. The Lambda O2 is taken into account as an important parameter which has a great effect on the health of the stack. It is important to mention that although the operating parameters of a PEMFC system can be optimized, too, but optimization of these parameters is out of the focus of this investigation. However, optimization of fuel cell operating points depends on V–I characteristics [15,16]. Therefore, it is important to exactly model the V–I characteristics of the PEMFC system which is mainly the focus of this paper.

In recent years, a lot of population-based optimization algorithms have been applied in the research of fuel cell systems, such as the genetic algorithm (GA) [1,17–20] and particle swarm optimization (PSO) [21]. Although these algorithms give better results than traditional methods, but have some limitations. The GA frequently finds out the promising regions of search space very quickly, but it suffers from two drawbacks: the lack of good local