

## Chapter 13

# A Fuzzy Model with Thermodynamic Based Consequents and a Niching Swarm–Based Supervisor to Capture the Uncertainties of Damavand Power System

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### ABSTRACT

*In this investigation, a novel fuzzy mathematical program based on thermodynamic principles is implemented to capture the uncertainties of a practical power system, known as Damavand power plant. The proposed intelligent machine takes the advantages of a niching bio-inspired learning mechanism to be reconciled to the requirements of the problem at hand. The aim of the bio-inspired fuzzy based intelligent system is to yield a model capable of recognizing different operating parameters of Damavand power system under different operating conditions. To justify the privileges of using a niching metaheuristic over gradient descend methods, the authors use the data, derived through data acquisition, together with a machine learning based approach to estimate the multi-modality associated with the training of the proposed fuzzy model. Moreover, the niching bio-inspired metaheuristic, niching particle swarm optimization (NPSO), is compared to canonical PSO (CPSO), stochastic social PSO (SSPSO), unified PSO (UPSO), comprehensive learning PSO (CLPSO), PSO with constriction factor (PSOCF) and fully informed PSO (FIPSO). Through experiments and analysis of the characteristics of the problem being optimized, it is proved that NPSO is not only able to tackle the deficiencies of the learning process, but also can effectively adjust the fuzzy approach to conduct the identification process with a high degree of robustness and accuracy.*

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## **1. INTRODUCTION**

Deriving a robust identification system which is capable of estimating several operating parameters in power plants is of great value for surveyors and control engineers. It is crucial to authorities and industrialists to provide an online tool to measure several characteristics of the power plant during the operational procedure. To name only a few, one can mention to several important characteristics such as estimating the power output of the power plant, predicting the operational and maintenance cost of the components, predicting the thermal and electrical efficiencies of the power system and etc. There exist copious reports in literature which aim at proposing accurate controlling and identification tools to monitor several characteristics such as fuel rate, gas flow, velocity of the flows and input/ output energy balance in power systems. On the other hand, several researchers aim at developing some controlling and modeling approaches to estimate some financial characteristics. This in turn allows industrialists to forecast the productivity and efficiency of the large scale power systems. The importance of developing predictive, optimizing and identification systems can be inferred from an increasing interest among researchers to disclose their findings and take some huge strides toward tackling the defects associated with monitoring the power systems. Mozaffari et al. (2012a) developed a synchronous parallel shuffling self-organized Pareto strategy algorithm (SPSSOPSA) and a neural network (NN) to analyze, control and optimize the operating parameters of Damavand power plant as the biggest power plant of Middle East (Samadian et al., 2013). Esen et al. (2007) engaged different intelligent tools such as adaptive neuro-fuzzy inference system (ANFIS) and support vector machine (SVM) to find the optimum operating parameters of a ground-coupled heat pump. Mozaffari et al. (2013a) utilized three different bio-inspired methods, i.e. the great salmon run (Mozaffari et al., 2012b), bee algorithm (Mozaffari et al., 2013b) and particle swarm optimization (Yang, 2008), for optimal arrangement of thermo-electric cells to reuse the waste energy in compressors. Katsigiannis et al. (2012) proposed a hybrid bio-inspired algorithm based on integration of simulated annealing (SA) and tabu search (TS) for optimal sizing of autonomous power systems. Zhao (2009) proposed a hybrid optimization method based on genetic algorithm (GA) and a linear planning methodology for SVC planning in large scale power systems.

In this investigation, the authors intend to take the advantages of hybrid fuzzy-physical system to develop a robust identification system. The structure of TSK fuzzy inference system (FIS) provides the authors with an opportunity to embed the physical equations to the structure of fuzzy scheme. In fact, the consequent section of the rules in TSK rule base is implemented based on the law of thermodynamic. It is expected that such a design can be advantageous since it pursues the physic-based modeling in a fuzzy thought, and besides the use of a bio-inspired metaheuristic can be of great value for adapting the characteristics of the TSK-FIS.

The rest of the paper is organized as follows. In Section 2, the authors scrutinize the problem at hand. A fuzz based machine learning approach is proposed in Section 3. The entire steps required to implement the characteristics of the fuzzy identifier is explained. Section 4 is devoted to the results and discussions. Finally, the paper is concluded in Section 5.

## **2. PROBLEM DEFINITION**

Figure 1 depicts the schematic illustration of one phase of Damavand power plant. The power plant consists of 12 symmetric and similar phases that work corporately. In each phase, the steam turbine

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