Chapter 8

Hierarchical Method Based on Artificial Neural Networks for Power Output Prediction of a Combined Cycle Power Plant

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ABSTRACT

The increasing demand for electricity the last decades leads towards the more frequent use of Combined Cycle Power Plants (CCPPs) because of the quite efficient way these units are capable to produce electricity. Hence, the prediction of the output of these units is of significant interest and constitutes the cornerstone towards the attainment of economic power production and a reliable power generation system as a whole. To that end, the aim of this paper is the development of a hierarchical predictive method based on Artificial Neural Networks (ANNs) in order to efficiently predict the power plant's output. The under consideration features are the hourly average ambient variables of Temperature (T), Ambient Pressure (AP), Relative Humidity (RH) and Exhaust Vacuum (V) for predicting the hourly power output of a CCPP. A parellel, but equally important, aim of this study is to assess the effectiveness of ANNs in this type of applications.

1. INTRODUCTION

The combined cycle power plants are utilized more and more all around the world due to the more efficient power production that these units can offer. A combined cycle power plant is the result of a combination of two or more thermodynamic cycles aiming to exploit wasted forms of energy in order to produce more electricity - compared to the one produced by a conventional power plant - from the

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same fuel source (Singh, 2016). Moreover, the deregulation of the power system and the structure of new generation power markets, formed as a two settlement system that combines day-ahead, as well as, real-time transactions and balancing actions, renders the development of anticipation applications more pressing than ever. In new generation power markets, the customers and the power generators participate in a bid-based market seeking and offering real power for specific time intervals. This is the way that the supply and the demand of the system are formed. Then, a central entity, the System Operator (SO), is responsible to match supply and demand in the most economic way, while trying to retain the power system safe and uninterrupted. In other words, it is responsible to settle on which power units will be dispatched in order to meet the demand for both types of transactions; the day-ahead and the real-time (Hogan, 1998; Foti &Vavalis, 2015). Hence, the accurate prediction of the power generation of such type of power plants, plays a significant role helping the system operator to make precise decisions and take the necessary actions towards the proper operation and coordination of all the engaged parties. The reliability and the economic viability of the power system as a whole is consequently strengthened.

In parallel, it is highly recognized that the power output of these units, strongly depends on features related to the hourly average ambient variables of Temperature (T), Ambient Pressure (AP), Relative Humidity (RH) and finally, Exhaust Vacuum (V). Any sharp variation even on one of these features may affect the power output of the generation system and decrease its overall performance. Hence, any predictive effort has to deal with these features. To that end, the present paper proposes a new method for predicting the power output of a CCPP based on artificial neural networks regarding the aforementioned parameters. In fact, the contribution and the main goal of this study is to develop a predictive method that decreases as much as possible the forecast error; a common side effect of all regression applications. Towards that direction, a two layer hierarchical architecture that combines different types of ANNs is developed and evaluated. A detailed description follows in Section 3, but in a nutshell, through this stratification we aim to reduce the error that would be produced if only one neural network was used for the same purpose. A parellel, but of equal importance goal, is the competence assessment of neural networks in such type of applications.

The rest of this paper is organized as follows: in Section 2 a discussion about the state-of-the-art methods that have been already implemented and presented in the literature follows. A brief description of the method and the neural networks used in this study is presented in Section 3, while the experimental results of the proposed method are presented in Section 4. Finally, the conclusions of this study and a brief discussion about the results can be found in the last Section.

2. LITERATURE REVIEW

A plethora of Artificial Intelligence (AI) techniques has been proposed in the literature towards the development of anticipatory methods in order to confront the challenges related to new generation power systems. A medium term load forecasting method is developed in (Alamaniotis et al., 2016). More precisely, two different models based on kernel machines, namely Gaussian process and relevance vector regression combined with Gaussian kernels, were developed and compared against the ARMA (2,2) model with very promising results. Neural networks have been used in a previous work (Fainti et al., 2016), in order to define prediction intervals regarding the ampacity level of each phase of a distribution system. Support Vector Machines (SVMs) and fuzzy inference techniques are combined to produce an anticipatory system regarding the states of a complex power system in (Alamaniotis & Agarwal, 2014).

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