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Electric load forecasting using a fuzzy ART&ARTMAP neural network

Mara Lúcia M. Lopes*, Carlos R. Minussi, Anna Diva P. Lotufo

Department of Electrical Engineering, São Paulo State University (UNESP), P.O. Box 31, Zip 15385-000, Ilha Solteira, SP, Brazil

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Abstract

This work presents a neural network based on the ART architecture (adaptive resonance theory), named fuzzy ART&ARTMAP neural network, applied to the electric load-forecasting problem. The neural networks based on the ART architecture have two fundamental characteristics that are extremely important for the network performance (stability and plasticity), which allow the implementation of continuous training. The fuzzy ART&ARTMAP neural network aims to reduce the imprecision of the forecasting results by a mechanism that separate the analog and binary data, processing them separately. Therefore, this represents a reduction on the processing time and improved quality of the results, when compared to the Back-Propagation neural network, and better to the classical forecasting techniques (ARIMA of Box and Jenkins methods). Finished the training, the fuzzy ART&ARTMAP neural network is capable to forecast electrical loads 24 h in advance. To validate the methodology, data from a Brazilian electric company is used.

Keywords: Adaptive resonance theory; Electric load forecasting; Electric power systems; Neural networks; Fuzzy logic; Fuzzy ART&ARTMAP neural network

1. Introduction

Expansion planning, load flow, economic operation, security analysis and electric energy systems control are some of studies that effectively depend on the behaviour of the load profile [1], i.e., forecasting of future information of a time series based on passed values. In the literature, there are many methods to effectuate load forecasting, for example, multiple or simple linear regression, exponential smoothing, state estimation, Kalman filter, ARIMA of Box&Jenkins methods [1–3]. All of these methods need a previous modelling to be applied a posteriori. It is necessary to know some information as for example: cloudy days, wind velocity, sudden temperature variation and non-conventional day effects (holidays, strikes, etc.), to model the load.

* Corresponding author. Tel.: +55 18 37431222; fax: +55 18 37431163.
E-mail addresses: mara@dee.feis.unesp.br (M.L.M. Lopes), minussi@dee.feis.unesp.br (C.R. Minussi), annadiva@dee.feis.unesp.br (A.D.P. Lotufo).

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After modelling the load, and using this information, the algorithm is initialised to take the results.

The use of neural networks is nowadays an alternative method that is becoming an efficient technique to solve the electric load-forecasting problem.

There are researches that treat this problem using the Back-Propagation algorithm [4,5]. This algorithm is considered on the specialised literature a benchmark in precision. However, the convergence is slow, although there are some adaptations to improve the performance [4,6]. Therefore, the idea is to use a neural network that combines good results with a faster processing. The ART neural networks are architectures based on adaptive resonance theory, having two fundamental characteristics for the network processing: the stability and the plasticity (capacity of learning new patterns without loosing the memory or the patterns already trained) [7]. These two characteristics provide to the network a stable learning and a faster convergence [8]. The objective of this work is to develop another neural network based on the ART architecture, called fuzzy ART&ARTMAP neural network [9], and apply it to the electric load-forecasting problem [10–12].

The fuzzy ART&ARTMAP neural network is composed of two modules: (1) fuzzy ART and (2) fuzzy ARTMAP. The ART network is architecture based on a supervised training for multi dimensional mapping (several inputs and several outputs), composed of two ART modules connected to an inter-ART module [7]. The fuzzy ART module classifies the input vectors in categories, composed of analog data that are converted to binary values by an active/binary code converter. The input set of fuzzy ARTMAP module is composed of binary data (that have already been converted in binary), plus the binary information referred to time (month, day of the week, holiday, and hour, etc). The fuzzy ARTMAP output module is composed of electric load values referred to the subsequent hour, and are processed in classes/areas and codified in binary. This way, this network aims to solve, or at least reduce the imprecision of the forecasting results, by a mechanism that separate the analog and binary data, and processing them separately. The fuzzy ARTMAP module receives only binary data, allowing applications in large-scale systems. It is important to emphasise that this architecture preserves the plasticity, allowing the implementation of continuous training, thus becoming an important tool for electric load forecasting.

To illustrate the proposed method, an example is presented considering historical data from a Brazilian electric company.

It is emphasised that, in this work, for convenience the vectors are represented by rows and not by columns (as usually).

2. ART (Adaptive Resonance Theory)

In 1976, Grossberg introduced the adaptive resonance theory [13,14], concept as a cognitive human information process, through a self-organisation, effectuating stable category recognition and answering an arbitrary sequence of input patterns [7,15–17]. This kind of network has a self-organisation and a self-stabilisation that allows solving the stability–plasticity dilemma. Thus, the ART network is capable to assimilate new things while maintaining those already instructed [15].

The ART network structure is composed of three layers as shown on Fig. 1 [18]:

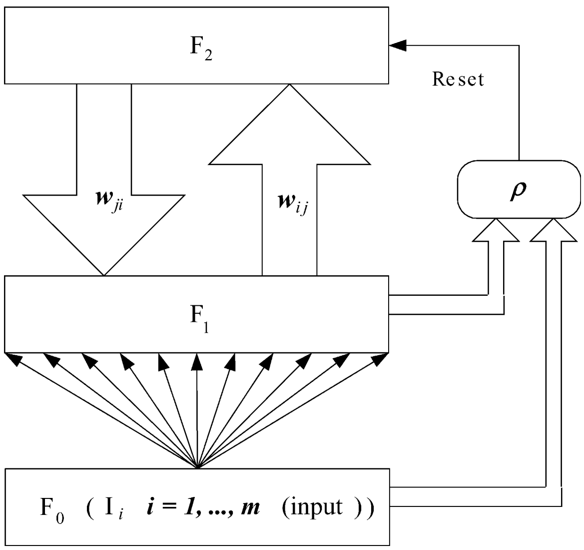

Fig. 1. ART network structure.