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Short-term electricity prices forecasting in a competitive market: A neural network approach

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Abstract

This paper proposes a neural network approach for forecasting short-term electricity prices. Almost until the end of last century, electricity supply was considered a public service and any price forecasting which was undertaken tended to be over the longer term, concerning future fuel prices and technical improvements. Nowadays, short-term forecasts have become increasingly important since the rise of the competitive electricity markets. In this new competitive framework, short-term price forecasting is required by producers and consumers to derive their bidding strategies to the electricity market. Accurate forecasting tools are essential for producers to maximize their profits, avowing profit losses over the misjudgement of future price movements, and for consumers to maximize their utilities. A three-layered feedforward neural network, trained by the Levenberg-Marquardt algorithm, is used for forecasting next-week electricity prices. We evaluate the accuracy of the price forecasting attained with the proposed neural network approach, reporting the results from the electricity markets of mainland Spain and California.

Keywords: Price forecasting; Competitive market; Neural network; Levenberg-Marquardt algorithm

1. Introduction

All over the world, the electricity industry is converging toward a competitive framework and a market environment is replacing the traditional monopolistic scenery for the electricity industry. In 1982, Chile was a pioneer country to introduce new market-oriented approaches in the electricity industry sector, later spreading to countries such as England and Wales, Norway, Argentina, Australia, Spain, and various regions of the United States.

In the regulated framework, electricity supply was considered a public service with the electric energy industry organized as regulated and vertically integrated, joining generation, transmission and distribution of electricity in government owned monopolistic companies. Thus, predicting future prices involved matching regional electricity demand to regional electricity supply. The future regional demand was estimated by escalating historical data, and the regional supply was determined by stacking up existing and announced generation units in some wise order of their variable operating costs [1].

As such, electricity prices tended to reflect the government's social and industrial policy, and any price forecasting which was undertaken was really based on average costs. In this respect, it tended to be over the longer term, taking a view on fuel prices, technological innovation and generation efficiency [2]. Hence, in the regulated framework, the electric energy industry's attention mainly focused on load forecasting, existing little need for tools hedging against price risk given the deterministic nature of electricity prices.

Electricity has been turned into a traded commodity in nowadays, to be sold and bought at market prices, although with distinct characteristics since it cannot be queued and stored economically with the exception of pumped-storage hydro plants when appropriate conditions are met. Two ways of trading are

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usually assumed: the pool trading and bilateral contracts trading. In the pool trading, producers and consumers submit bids respectively for selling and buying electricity on established intervals, typically on an hourly basis. Finally, a market operator clears the market by accepting the appropriate selling and buying bids, giving rise to the electricity prices.

The new electricity industry competitive framework, coming from the deregulation of the electricity markets, was intended to encourage competition among companies in order to decrease the cost of electricity. Unfortunately, occurrences seldom happening in the regulated framework, such as outages, blackouts and price peaks are now subject of increasing concern. Moreover, deregulation brings electricity prices uncertainty, placing higher requirements on forecasting. In particular, accuracy in forecasting these electricity prices is very critical, since more accuracy in forecasting reduces the risk of under/over estimating the revenue from the generators for the power companies and provides better risk management [3]. Forecast errors have significant implications for profits, market shares and ultimately shareholder value [4].

An accurate forecast of electricity prices has become a very important tool for producers and consumers. In the short-term, a producer needs to forecast electricity prices to derive its bidding strategy in the pool and to optimally schedule its electric energy resources [5]. In a regulated environment, traditional generation scheduling of energy resources was based on cost minimization, satisfying the electricity demand and all operating constraints [6]. Therefore, the key issue was how to accurately forecast electricity demand. In a deregulated environment, since generation scheduling of energy resources, such as hydro [7] and thermal resources [8], is now based on profit maximization [9], it is an accurate price forecasting that embodies crucial information for any decision making. Consumers need short-term price forecasts for the same reasons as producers.

It should be noted that price series exhibit greater complexity than demand series, given specific characteristics existing in price series. In most competitive electricity markets the series of prices presents the following features: high frequency, nonconstant mean and variance, daily and weekly seasonality, calendar effect on weekend and public holidays, high volatility and high percentage of unusual prices [10].

Price forecasting has become in recent years an important research area in electrical engineering, and several techniques have been tried out in this task. In general, hard and soft computing techniques [11] could be used to predict electricity prices.

The hard computing techniques, where an exact model of the system is built and the solution is found using algorithms that consider the physical phenomena that govern the process, include time series models [10], auto regressive — AR models [9] and auto regressive integrated moving average — ARIMA models [12]. This approach can be very accurate, but it requires a lot of information, and the computational cost is very high [13]. More recently, generalized autoregressive conditional heteroskedastic — GARCH models [14] and the Wavelet-ARIMA technique [15] have also been proposed.

The soft computing techniques, namely artificial intelligence techniques, do not model the system; instead, they find an appropriate mapping between the several inputs and the electricity price, usually learned from historical examples, thus being computationally more efficient. In particular, neural networks approaches, that have been widely used for load forecasting with successful performance [16,17], are now used to predict electricity prices [18–24], using Fourier and Hartley transforms as filters to the price data [25], using extended Kalman filter [26] or combined with fuzzy logic in a hybrid approach [13,27,28].

Neural networks and ARIMA models are often compared with mixed conclusions in terms of forecasting capacity. A comparison of neural networks and ARIMA models to forecast commodity prices showed that neural network forecasts were more accurate than ARIMA forecasts. Moreover, the success of ARIMA models is conditional upon the underlying data generating process being linear, while neural networks can account for nonlinear relationships [29]. Hybrid methodologies, that combine neural networks and ARIMA models, have been also proposed [30] to take advantage of the unique strength of each model in linear and nonlinear modeling.

Neural networks are simple, but powerful and flexible tools for forecasting, provided that there are enough data for training, an adequate selection of the input–output samples, an appropriate number of hidden units and enough computational resources available. Also, neural networks have the well-known advantages of being able to approximate any nonlinear function and being able to solve problems where the input–output relationship is neither well defined nor easily computable, because neural networks are data-driven. Three-layered feedforward neural networks are specially suited for forecasting, implementing nonlinearities using sigmoid functions for the hidden layer and linear functions for the output layer.

This paper proposes a neural network approach to forecast next-week prices in the electricity market of mainland Spain. The Levenberg-Marquardt algorithm is used to train a three-layered feedforward neural network. Previously reported approaches to forecast prices in the electricity market of mainland Spain were mainly based on time series models, namely the ARIMA technique. Neural networks approaches are comparatively easy to implement and show good performance being less time consuming. The proposed neural network approach is also applied to forecast next-week prices in the California electricity market, to further assess the validity of the approach.

This paper is structured as follows. Section 2 presents the neural network approach. Section 3 provides the importance of price in electricity markets and the main factors that influence it, as well as the different criterions used to assess the validity of the proposed approach. Section 4 presents the case studies, based on real-world electricity markets, to evaluate the accuracy of the neural network approach in forecasting short-term electricity prices. Section 5 outlines the conclusions.

2. Neural network approach

Neural networks are highly interconnected simple processing units designed in a way to model how the human brain performs a particular task [31]. Each of those units, also called neurons, forms a weighted sum of its inputs, to which a constant term