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Forecasting electricity prices for a day-ahead pool-based electric energy market

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Abstract

This paper considers forecasting techniques to predict the 24 market-clearing prices of a day-ahead electric energy market. The techniques considered include time series analysis, neural networks and wavelets. Within the time series procedures, the techniques considered comprise ARIMA, dynamic regression and transfer function. Extensive analysis is conducted using data from the PJM Interconnection. Relevant conclusions are drawn on the effectiveness and flexibility of any one of the considered techniques. Furthermore, they are exhaustively compared among themselves.

Keywords: Electricity market; Day-ahead price forecasting; Time series models; Neural networks; Wavelet models

1. Introduction

1.1. Electric energy markets

During the last two decades the electric power industry all over the world has undertaken significant restructuring. In most countries, a cost minimization paradigm has been replaced by a profit maximization one. In the cost minimization framework, a Central Operator (CO) decides centrally how the generating machines should be operated to minimize total cost while serving all demands. In contrast, in the profit maximization framework, producers, retailers and consumers interact through a market seeking to maximize their respective profits. Two market structures arise commonly in practice: a bilateral contract framework and a pool.

In a bilateral transaction market, any given producer agrees with retailers to supply specified amounts of energy during a contract horizon. Those physical contracts are implemented with the help of an Independent System Operator (ISO) that takes care of the physical requirements needed for the transactions to take place in a secure manner.

In a pool, producers submit to the Market Operator (MO) production bids that typically consist of a set of

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energy blocks and their corresponding minimum selling prices for every hour of the market horizon. Analogously, retailers and large consumers submit to the MO consumption bids that consist of a set of energy blocks and their corresponding maximum buying prices. The MO uses a market-clearing algorithm to clear the market, which results in a market-clearing price as well as the scheduled production and consumption for every hour of the market horizon. The market-clearing price is the price to be paid by retailers and to be charged by producers. Finally, the ISO checks for technical feasibility and, if needed, introduces the minimal required changes to attain a secure operation.

This pool-based electric energy market is the most common arrangement in practice. Sometimes, it coexists with a bilateral contract framework. In this case, the ISO ensures a technical secure operation of the pool plus the simultaneous bilateral contract arrangements. This paper considers the framework above, i.e., a pool that may include bilateral contract arrangements.

1.2. Why forecasting electricity prices?

Producers need to forecast market-clearing prices to respond optimally to the pool and to efficaciously engage in bilateral contracts.

In the short-run, a producer with low capability of altering market-clearing prices (price-taker producer) needs day-ahead price forecasts to optimally self-schedule and to derive its bidding strategy in the pool. In the medium-term, a price-taker producer requires market-clearing price forecasts for several months in order to sign favorable bilateral contracts.

Retailers and large consumers need day-ahead and medium-term market-clearing price estimates for the same reasons as producers. Those price forecasts constitute fundamental information for the retailers (large consumers) to self-schedule and to bid efficiently in the pool; and to engage in profitable bilateral contracts.

1.3. Forecasting framework

Within the framework of a pool-based electric energy market, this paper considers forecasting techniques to estimate the 24 day-ahead market-clearing prices.

Three families of techniques are considered: time series, neural networks and wavelets. Time series techniques are treated with greater detail because they revealed themselves, through many realistic studies, as the most efficacious tools for day-ahead market-clearing price forecasting. Time series techniques considered include ARIMA, dynamic regression and transfer function.

A naïve but challenging test is used to characterize all forecasting procedures that are analyzed. The 24 market-clearing price forecasts using any technique can be compared to the 24 market-clearing prices of a day *similar* to the one to be forecast. A *similar* day is characterized as follows. A Monday is similar to the Monday of the previous week and the same rule applies for Saturdays and Sundays; analogously, a Tuesday is similar to the Monday of the same week, and the same rule applies for Wednesdays, Thursdays and Fridays. The naïve test is passed if hourly errors for the estimates using any forecasting technique are smaller than the market-clearing prices of the *similar* day. More often than expected, forecasting procedures not carefully tuned up do not pass this test. This naïve test is used in the case studies that are analyzed in this paper.

The time framework to forecast day-ahead market-clearing prices in most markets is explained below and illustrated in Fig. 1. The market-clearing price forecasts for day d are required on day $d-1$, typically at hour h_b (around 10 am). On the other hand, data concerning results for day $d-1$, including market-clearing prices and demands, are available on day $d-2$ at hour h_c (around noon). Therefore, the actual forecasting of market-clearing prices for day d can take place between hour h_c of day $d-2$ and hour h_b of day $d-1$. Additionally, producers and retailers use this period to optimally self-schedule and to produce appropriate bids.

To perform a fair comparison, available data for price prediction is identical for all techniques. To compute price forecasts for hour 1 to 24 of day d, data available to all procedures include price and demand historical data up to hour 24 of day $d-1$, and demand predictions for the 24th hour of day d. The considered historical data spans 53 days.