

# Electricity price forecasting of the South East European power exchanges

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**Abstract**— The deregulation of the electricity market is a process which is currently very hot topic in the Southeast European region. Namely, few of the countries have their own power exchanges from long time ago, but few of them have just formed ones and the remaining countries need to decide in the near future the direction they are going to follow towards resolving this problem. With the introduction of the power exchanges and the fact that half of the power markets in the Southeast European region exist less than one year, forecasting the electricity price on those markets is becoming very attractive research area and is of great importance. In this paper, 24-hours ahead forecasting of the electricity price in these newly formed power exchanges is. To this end, an artificial intelligence models, specifically neural networks are used in this paper, which as an input use all information that are relevant for the corresponding power exchange price forecasting. The results show that among the newly formed power exchanges in the region, the price in Bulgarian power exchange is the most unpredictable one, while, on the other hand, the price in the Serbian power exchange is the most predictable one. Additionally, the results present in which hours of the day and in which days in the week the prices have the highest variations.

## I. INTRODUCTION

The electricity market is in the process of deregulation that started in countries around the world since the 90s. In this process, the traditional monopolistic power companies have been replaced by a competitive electricity markets. In the region of Southeast Europe (SEE) this process is still ongoing. Namely, in some of countries in the SEE region there already exists day-ahead market, while the remaining countries are in the process of deciding whether they should create their own markets or make coupling with an existing power exchanges. The oldest power exchange in the region is the market in Romania, which is launched in 2000 and administrated by OPCOM. Following are the power exchanges in Greece, which was at a process of establishment in the period from 2005-2010 and the power market in Hungary (HUPX) which exists since 2010. Relatively new are the power exchanges in Bulgaria (IBEX), Serbia (SEPEX) and Croatia (CROPEX), which are created in the first quarter of 2016.

With the introduction of the power exchanges and the fact that half of the power markets in the Southeast European region exist less than one year, forecasting the price of those markets is becoming very attractive topic and is of great importance. Furthermore, with proper

accuracy of the predictions a power company can optimize its strategy on the market as well as its production or consumption in order to minimize the financial risk and maximize the profit [1]. Compared with the forecasting of electricity consumption, the price has greater variability and significant spikes.

In this paper, 24-hours ahead forecasting of the electricity price in the newly formed power exchanges in the Southeast region is done. For this purpose, an artificial intelligence model, specifically neural networks is implemented, which as an input use all information that are relevant for the corresponding power exchange price forecasting.

Electricity price forecasting is a problem that has attracted much attention in the research area. Primarily, all those studies differ in the model used to perform the forecasting, and the area in which the corresponding power exchange is located. According to these two conditions the input characteristics upon which the electricity price forecasting depends on are determined. The models used in this research area may generally be divided into five groups: multi-agent, fundamental, reduced-form, statistical and computational intelligence based models [1, 2]. The most widely used model, using which many authors report excellent results in the literature are the neural networks which belong in the field of computational intelligence [1]. Basically, neural networks are very flexible and can cope with complex and non-linear problems, which makes them suitable for short-term predictions. Due to these reasons, the neural networks were also used in this study for day-ahead electricity price forecasting. When it comes to the areas in which the power exchanges that are analyzed are located, in the literature electricity forecast analyses are made for the power exchanges in various countries such as Austria [3], India [4], Ontario [5], Scandinavian countries [6], Greece [7] etc. In this paper, main emphasis is given to the new day-ahead markets in the Southeast region, which, to the best of our knowledge, have not been analyzed in the literature yet.

The paper is structured as follows. First, the methodology used is described, or the model of neural networks. Afterwards, detailed analyses of the input data is made in the following section, from which the selection of the input variables of the neural network is made. The results and a corresponding discussion is presented in section IV, and finally the next section concludes the paper, where directions for further research are also presented.

## II. NEURAL NETWORKS

The neural networks that are used in this paper are represented as a directed acyclic graph, which has several layers - an input layer, one or several hidden layers and an output layer, and specifically the multi-layer feed-forward perceptron (MLP) structure is used. The connection between the input  $x$  and the output  $y$  is presented with the following equation:

$$y = \sum_{j=0}^h \left[ w_j f \left( \sum_{i=0}^d w_{ji} x_i \right) \right] \quad (1)$$

where  $w_j$  and  $w_{ji}$  represent the weight and biases that connect the layers.

The main advantage of the artificial neural networks is the ability to learn. For the purpose of forecasting a certain variable, which belongs to the regression analyses problem, the supervised learning is used. In this case, the cost function used in order to find the optimal weights of the network is the mean-squared error:

$$E_D = \frac{1}{2} \sum_{i=1}^N \{y_i - t_i\}^2 = \frac{1}{2} \sum_{i=1}^N e_i^2 \quad (2)$$

where  $y$  represents the forecasted values and  $t$  represents the actual data.

For minimizing this non-linear function, the Levenberg-Marquardt algorithm is used, as one of the fastest and most stable algorithm. As a metric of the ability of the network to generalize, the well-known mean absolute percent error (MAPE) is used, given by the following equation:

$$MAPE = \frac{1}{N} \sum_{i=1}^N \left( \frac{|e_i|}{t_i} \times 100 \right) \quad (3)$$

## III. INPUT DATA

As input the data for the hourly electricity prices on the following power exchanges were used: IBEX [8], CROPEX [9] and SEEPEX [10] for 2016 (as each of the three power exchanges were formed in 2016).

As it can be noticed the electricity price on the Bulgarian power exchange is mainly in the range between 20 and 60 EUR/MWh, with increasing trend at the end of the year up to around 80 EUR/MWh (Figure 1).

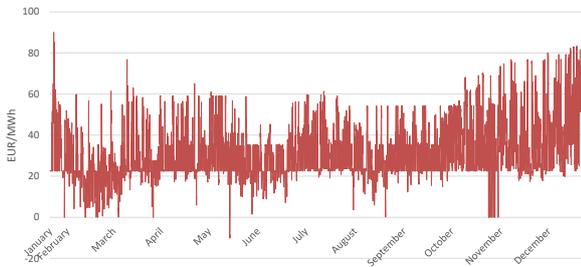


Figure 1. Electricity prices on IBEX (2016)

The electricity price on the Croatian power exchange has more constant trend of increasing during the analyzed period with some peaks of up to about 95 EUR/MWh (Figure 2).

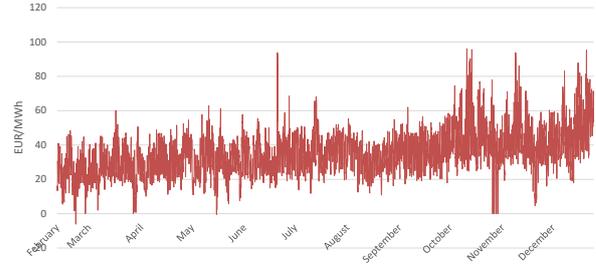


Figure 2. Electricity prices on CROPEX (2016)

Finally, the electricity prices on the Serbian power exchange have also increasing trend, with highest peaks at the end of the period up to about 90 EUR/MWh (Figure 3).

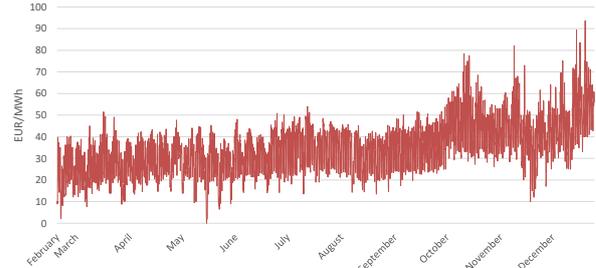


Figure 3. Electricity prices on SEEPEX (2016)

In order to analyze the relationship between the prices of the three analyzed power exchanges, correlation analyzes is made using the Pearson coefficient. The results are presented on Figure 4. As it can be noticed, there is a strong positive correlation between the Croatian and the Serbian power exchanges and a moderate correlation between the Serbian and Bulgarian and between the Croatian and Bulgarian power exchanges.

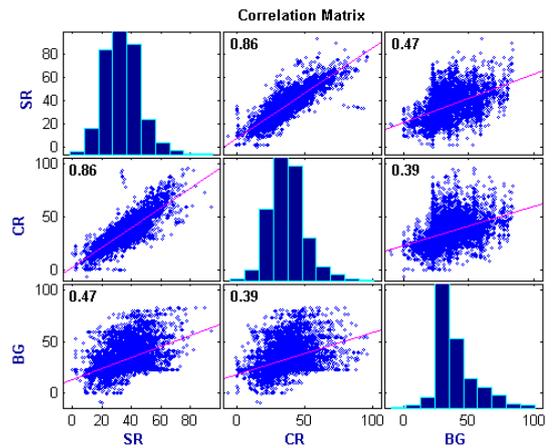
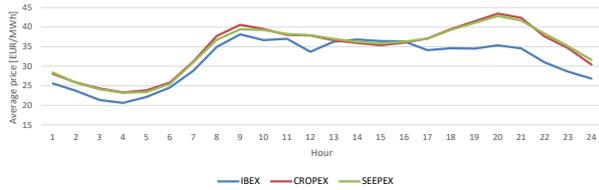


Figure 4. Correlation between the electricity prices on IBEX (BG), CROPEX (CR) and SEEPEX (SR)

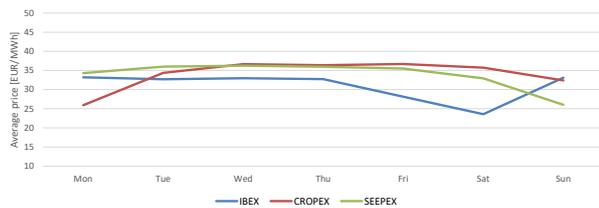
There is obvious daily trend of the electricity prices at hourly level on the three power exchanges (Figure 5). For each of the power exchanges there is evident peak of the price in the morning period and there is one more peak in the afternoon period for the Croatian and Serbian power

exchanges. Understandingly, the lowest price for each power exchange is during the night between 4 – 5 a.m.



**Figure 5. Daily trend of the average hourly electricity prices**

The weekly trend of the average daily electricity price is presented in Figure 6. The lowest price on the Serbian power exchange is on Sunday, on the Croatian power exchange is on Monday and Sunday, and the lowest price on the Bulgarian power exchange is on Saturday. The highest consumption on each of the three power exchanges is mainly during the working days of the week.

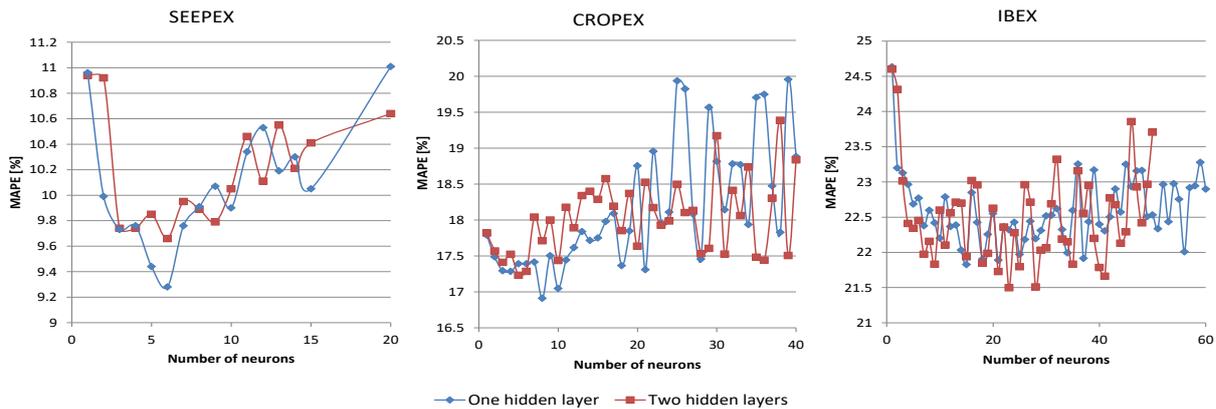


**Figure 6. Weekly trend of the average daily electricity prices**

*A. Selection of input variables*

Based on this analyzes of the data, a selection of the input variables upon which the forecasting of the electricity price depends on is made. Particularly, the following inputs for the neural network were selected:

- Hour of the day
- Day of week
- Holiday flag
- Average price of the previous day
- Price for the same hour of the previous day
- Price for the same hour-day combination of the previous week



**Figure 7. MAPE of the electricity price forecasting in respect to the number of neurons and number of layers for SEEPEX, CROPEX and IBEX**

**IV. RESULTS AND DISCUSSION**

The hourly data of the last two months for each power exchange were used for testing, and the rest of the data were used for training.

At the beginning a comparison is made between the MAPE obtained when using one and two hidden layers and different number of neurons in the hidden layers for each of the three analyzed power exchanges (Figure 7). As it is shown the most suitable network structure for SEEPEX is a network with one hidden layer and six neurons in the hidden layer, by which MAPE of 9.28% is achieved.

The price in the Croatian power exchange (CROPEX) is more unpredictable, presenting a minimal MAPE of 16.9%. This value is obtained by using one hidden layer with eight neurons. The results for the Bulgarian power exchange (IBEX) show that the price on this market is much more unpredictable compared to SEEPEX and CROPEX and the minimal value is obtained with completely different structure of the neural network. Namely, the minimal MAPE is 21.5%, obtained by using two hidden layers with 23 neurons in each of them. This unpredictability may be a result of the higher share of renewable energy sources in Bulgaria, which are very variable and affect the price on the market at a large extent.

A comparison between the actual data and the forecasted data for the electricity prices for SEEPEX is presented on Figure 8. It can be noted that the two curves match quite well. As presented in Figure 9, for CROPEX, there are more peaks in the actual data, which are not predicted by the neural network. The results for IBEX (Figure 10) show that there are a lot of peaks of the price in the testing period that are not predicted, mainly because these peaks were not present in the data for the training period.

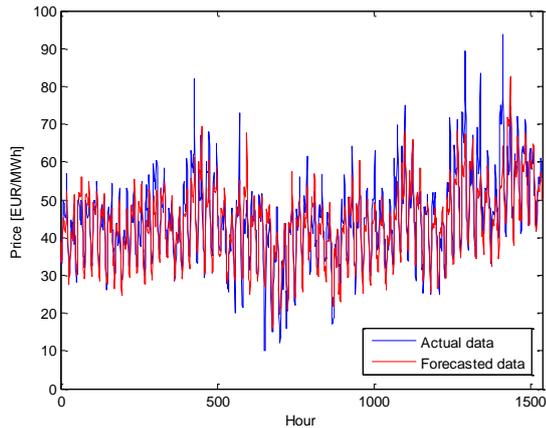


Figure 8. Actual and forecasted electricity prices for SEEPEX

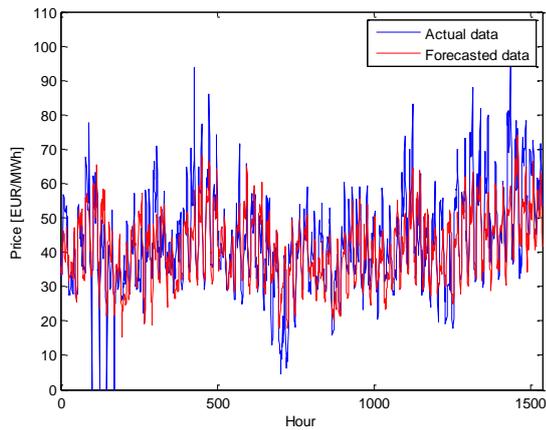


Figure 9. Actual and forecasted electricity prices for CROPEX

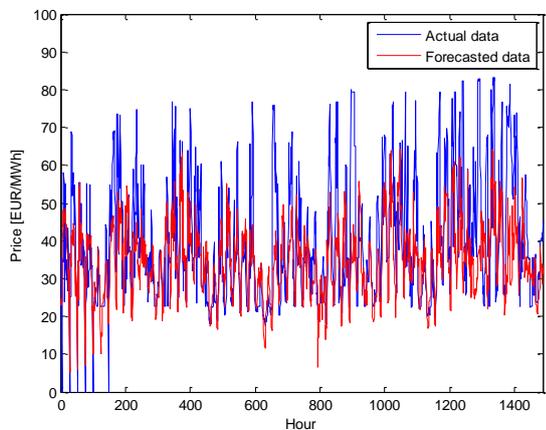


Figure 10. Actual and forecasted electricity prices for IPEX

The forecasting of the prices for the three power exchanges are measured by using MAPE (mean absolute percent error). This metric shows that most unpredictable is the Bulgarian power exchange, with MAPE of about

21%, while the Serbian power exchange is most predictable, with MAPE of about 9% (Figure 11).

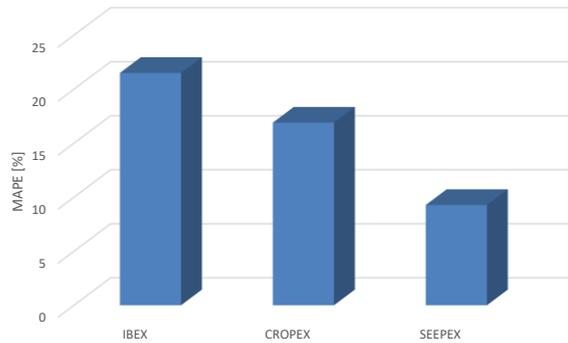


Figure 11. Comparison of the MAPE for IBEX, CROPEX and SEEPEX

Additionally, analyzes were made of the average absolute percent error by hour of a day (Figure 12) and by day of a week (Figure 13). The highest errors in the predictions are during the afternoon peak of the price, the morning peak and during the night hours (when the price is lowest). Concerning the forecasting error in days of a week, the highest error is mainly on Sundays, which means that there are high variations of the price for this day.

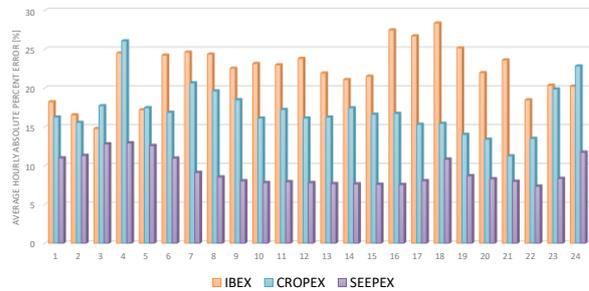


Figure 12. Average absolute percent error by hour of a day

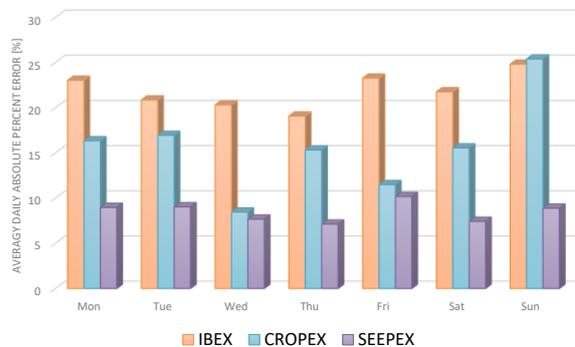


Figure 13. Average absolute percent error by day of a week

## V. CONCLUSION AND FUTURE WORK

Three models based on neural networks were set in this paper for forecasting of the electricity prices for Serbian

(SEPEX), Croatian (CROPEX) and Bulgarian (IBEX) power exchanges.

From the obtained results it can be concluded that:

- there is strong correlation between the new power exchanges in the region,
- the prices on the Bulgarian power exchange are most unpredictable (MAPE 21%),
- the prices of the Serbian power exchanges are most predictable (MAPE 9%).

Additionally, the critical hours of a day and days of week were presented, where the error of forecasting is the highest.

Furthermore, this work may be upgraded in the future by comparing the forecasting of these newly created power exchanges with the older power exchanges in the region.

#### ACKNOWLEDGMENT

This work was partially financed by the Faculty of Computer Science and Engineering at the "Ss. Cyril and Methodius" University.

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