A neural model supported by the Evolutionary Algorithm inspired by quantum calculations to determine prices at the Polish Power Exchange Day Ahead Market

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Abstract. The paper contains selected results of research related to the nature and the implementation of the neural model supported by the evolutionary algorithm inspired by quantum calculations for determination of prices at the Polish Power Exchange. Numeric data quoted at the Day Ahead Market in the period of 1st January 2015 to 30th June 2015 were used to train the artificial neural network in the model of the system. Attention was paid to quantization method, dequantization method and the method of quantum calculations. Significant improvement of the neural model supported by the quantum-inspired evolutionary algorithm was obtained compared with the model without quantum inspiration.

1 Introduction

The object being modelled is the system of the Polish Power Exchange[a] (PPE) concerning the concluded transactions quoted on the Day Ahead Market (DAM) with 24 input quantities and 24 output quantities [4-5,7-8]. Input quantities are streams of electrical energy (ee) volume supplied and sold at the PPE [MWh] in each hour of the 24-hour day, and output quantities are streams of average prices obtained for sold ee weighted by the volume of ee in each hour of 24-hour day [PLN/MWh]. Numeric data, i.e. the data related to quotations on the DAM in the period of 01.01-30.06.2015 were obtained from the TGE S.A. webpage[b]. A multi-layer unidirectional Artificial Neural Network[c] (ANN) was selected in order to design, implement and teach the neural model of the PPE system [2-4, 7], and error backpropagation method was selected to perform the training process. The neural model was implemented in MATLAB and Simulink environment using Neural Network Toolbox. Both the input and the output layer consisted of 24 neurons, with the neurons in the input layer corresponding to the supplied and sold ee in each hour of the 24-hour day, and the neurons in the output layer corresponding to the average weighted prices obtained for the sold ee. The structure of the ANN also contained one hidden layer with 24 neurons. Activation functions logsig() and purelin() were selected for the neurons in the hidden layer and in the output layer, respectively.

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[a] as a subsystem of polish Towarowa Giełda Energii S.A. (TGE S.A.).
[b] www.tgee.com
[c] perceptron ANN.

2 Quantum Calculations Algorithm

It was assumed that quantum calculations algorithm may be divided into three basic algorithms, i.e. the algorithm of quantization of the training file as well as the weights and biases file, the algorithm of quantum calculations performed using vector-matrix calculus and the algorithm of dequantization of quantum numbers into real numbers, which was described in detail in works [4-5, 7-8]. Quantization algorithm involves determination of quantum vectors of mixed numbers based on real numbers. Quantum numbers calculations, in particular, multiplication, addition and exponentiation of quantum vectors of mixed numbers were performed using vector-matrix calculus, and the algorithm of dequantization was performed using the ANN trained in dequantization. [4, 6-7]. There are also other methods of performing quantum calculations, e.g. calculations using quantum gates, wave function, quantum circuits, quantum registers and tensor product, etc. [6].

3 Quantum Inspired EA supporting the neural model of the PPE

The ANN was developed and trained in the model of the PPE system using the data quoted on the DAM. Further, support of the ANN with the evolutionary algorithm was proposed in order to obtain the improvement of the neural model [1-3]. Finally, quantum-inspired evolutionary support of the neural network was proposed, and the obtained algorithm was named Quantum-Inspired Evolutionary Algorithm supporting the ANN (QIANN) – fig. 1.

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The use of the algorithm allowed to obtain the best results for the quantum inspired ANN (from -0.04% to 0.05%) compared with the evolutionarily supported ANN (from -0.11% to 0.12%), which indicates the degree of the improvement of the neural model of the PPE, when the error ranged from -0.17% to 0.18%.
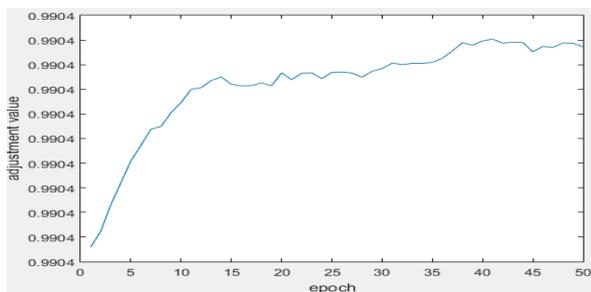

Fig. 1. Adaptation of the neural model of the PPE improved by means of the QIEA. Denotations: epoch – successive population obtained using the QIEA. Adjustment value – Mean Squared Error calculated as a difference between values obtained from the QIANN model and the real system. Source: Own compilation [4,7].

The obtained results of research are presented in table 1 and the graphs in fig. 2. The research focused on determination of the degree of the improvement of the parameters of the model and the accuracy of generation of prices by individual models of the PPE in the MATLAB and Simulink environment. It proved that the quantum inspired ANN supported by the EA improved the MSE by one order of magnitude from the range (from -0.17 to 0.18)% to the range (from -0.04 to 0.05)%, disregarding the fact that the errors were relatively low.

Table 1. MSE between the courses of prices within 24 hours in the period of 181 days, i.e. between the real course on the DAM and the courses of the following models: neural (ANN), neural model supported by the EA (EANN) and neural model supported by the EA with quantum inspiration QIANN. Source: [4, 7].

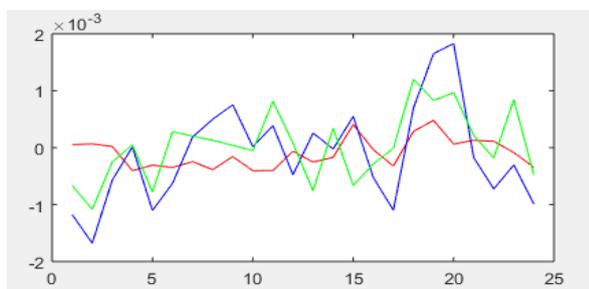| Type of model	ANN	EANN	QIANN
Maximum value	0.001829 (0.18%)	0.0012 (0.12%)	0.00048 (0.05%)
Minimum value	-0.00168 (-0.17%)	-0.00108 (-0.11%)	-0.00041 (-0.04%)

Fig. 2. Courses of mean squared errors (MSE) for the three models in 24 hours determined as mean values based on data for 181 days. Denotations: red – course of MSE for QIANN, green – course of the EANN, blue – course of the ANN, x axis – hours of 24-hour day [h], y axis – value of MSE. Source: Own compilation [4, 7].

3 Final remarks and conclusions

A hybrid model of the PPE consisting of the neural model with weights modified by the EA (neural-evolutionary model) was developed and designed, which model improved the parameters of the model of the PPE system, followed by the improvement of this model's parameters by designing and implementing the neural model supported by the AE with quantum inspiration (neural-evolutionary-quantum model), which further improved the parameters by one order of magnitude. Moreover, it was shown that quantum-inspired neural modelling and quantum-inspired neural modelling supported by the evolutionary algorithm was possible.

The obtained results of the research indicate the correctness of the chosen direction of research. Quantum methods are appropriate for classic computers, although they considerably slow down calculations.

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