Improving the efficiency of reactive power compensation devices through neural analysis

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Abstract. This article reflects the effectiveness of the use of neural analysis in control systems of powerful devices. The features of neural network modeling in the Matlab Simulink Neural Network Toolbox software package are presented. The state of the neural network in the field of error construction in event of a change in the operating mode of an electrical installation is clearly reflected. The application of the “Adaptive Linear Prediction” function in control systems of reactive power compensation devices is proposed. The positive aspects of the application are indicated, which in combination give a positive economic effect in the field of energy efficiency industrial enterprise.

1. Introduction
The competitiveness of modern industry economically depends on the energy efficiency of the electric power sector. Maintaining electricity quality indicators at the required level provides an advantage among other market participants. Maintaining the inductive component of reactive power at an extremely low level ensures minimal costs for manufactured products. This is especially noticeable at high-power metallurgical enterprises. In conditions of high world prices for metals, excess profits can be directed to improving competitiveness, upgrading production clusters, and other items of expenditure.

Many world-class enterprises have sophisticated modern reactive power compensation devices with high performance. In the article [1], ways were given to increase the performance of these devices with the elimination of false positives through statistical analysis methods. In the article [2], analysis of frequency disturbances by means of wavelet decomposition and its application in the control system of static devices were additionally considered.

2. Materials and methods
Due to increased interest in neurotechnology’s that prove their effectiveness in all fields of activity, a lot of research has appeared on the use of neural systems in the field of electric power. This scientific field allows for approximations of electrical characteristics, use of dispatcher control schemes for power flows, and their application in robotic systems and in other areas [3, 21, 22].

There have also been attempts to apply neural networks to analyze the consumption of electrical energy by various types of consumers, which give a great perspective in scientific activity. It should be
noted that in most cases we are talking about study of stationary signals [4]. Indeed, signals of this type are initialized quite successfully by neural networks, certain dependencies are found on extremum points, interpolation and extrapolation operations are performed, and, accordingly, over course of calculated iterations, the error value tends to zero, providing a sufficiently accurate assumed signal [5].

In studies [2; 3; 6], electrical signals that can be attributed to non-stationary were considered, and above approach will either give large errors, or the neural network will be inadequate. To solve this issue, it is possible to use the “Adaptive Linear Prediction” function or, in very difficult cases, the “Time Series Forecasting Using Deep Learning” function. The second case is more demanding of resources, therefore it is not advisable to use it in high-speed systems.

Consider the application of the “Adaptive Linear Prediction” function in the Matlab Simulink R2014a software package on the electrical load graph of a real object. For simplicity of experiment and exact selection of signal delay level, the number of neural layers and neurons, we will give all parameters in relative units [7, 19, 20]. To display the correctness of neural network operation, we will display in Figure 1 operating mode before deep melting of metal in the bath of an arc steel furnace [15-17].

3. Results and discussion
The signal is non-stationary, at the approximately general level of the current graph, noticeable fluctuations occur, which may be accompanied by “white noise”. For the neural network to work, it is necessary to translate the resulting 1x636 matrix into an array using the command “signal = con2seq(signal)”. Neural networks represent time intervals in form of columns of an array of cells, distinguish them from various samples at a given time, which are represented by columns of matrices. We determine the interval of primary training up to 60 readings (value along abscissa axis in Figure 1). As a result, a delay will be performed for this time by means of “timex = time(60:end)”.

![Figure 1. Initial graph of current in the electrical device.](image)

In Figure 2, we will build a model of a neural network, where its functional blocks are displayed. This model creates a linear layer with three layers of neurons with a delay in triggering the last sixty inputs.

In Figure 3, we will display the resulting neural model in comparison with the true graph.
The “adapt” function simulates a network at the input, while simultaneously adjusting its weights and offsets after each time step, depending on how closely its output matches the target.

The presented model with “+” signs reflects a neural model of electrical load analysis. It can be seen that at the beginning, during training, it did not correctly reflect boundaries, but later, from the 400th value, errors are minimized [8].

Let's display the error level in Figure 4, which clearly shows the dynamics of error reduction over time of neural network training.
Figure 4. Errors that occur during the operation of the neural model.

Note that in end, the error fluctuates around zero values, with exception of initial errors. A neural network studies behavior of systems taking into account fluctuations that occur. Note that if there is a change in steady-state operation of electrical installation, the error value will grow exponentially, therefore, this is an extremely effective indicator of making changes to the operation of compensating installation [9–10].

According to [1], the start of operation of an arc steelmaking furnace in a mode close to a short circuit is characterized by sharp current surges through operating phases. Consequently, in this mode, there will be sharp power surges of an inductive nature, which must be quickly compensated [11]. Let's add additional points to original current load graph that will provide a rapid increase in operating current and reflect this in Figure 5. Repeating procedures performed earlier, we get Figure 6 (small scale) and Figure 7, respectively.

Figure 5. The original graph with a sharp set of currents.
Figure 6. A true and calculated model with a sharp current surge.

Figure 7. Graph of neural model errors with a sharp increase in currents.

Figure 7 shows that a sharp outline of the original graph function gives a very large error value, which can be easily detected by any mathematical method by the control system of the reactive power compensation device.

4. Conclusion

Thus, the “Adaptive Linear Prediction” function of neural analysis provides the following important technical properties in control systems of electrical installations:

– high performance, which is necessary in conditions of a sharp change in the operating mode of electrical installations;
– minimum number of layers of neurons provides a minimum of computational resources spent, therefore this method can be used in real-time;
– ability to quickly approximate, if necessary, a more accurate study of graphs of electrical characteristics;
– in absence of sudden changes in operating modes, it is possible to analyze electrical loads to identify preliminary failures.

The use of this simple algorithm in high-power electrical devices will ensure the high energy efficiency of production, which will necessarily affect the final price of the output product [12–14].

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