Development of Levenberg-Marquardt theoretical approach for electric networks

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Abstract. The algorithm for artificial neural networks is presented for the optimal distribution of tasks in electric networks in an automatic mode without operator participation. The article presents the artificial neural networks algorithm based on Levenberg-Marquardt approach that implements the specified task, as well as substantiation of its characteristics. It is proposed to use the technology of artificial neural networks (ANN), which on the basis of the developed multi-criteria evaluation electricity system of ARES allows ranking. The ANN architecture with Levenberg-Marquardt algorithm of weights optimization and their efficiency is estimated. As indicators of efficiency, the F-measure and the percentage of correctly made decisions (accuracy) were chosen for optimal network parameters. The obtained ANN was successfully tested.

1. Introduction

Improving the reliability of power systems is one of the main tasks of modern electric power industry. The solution to this problem depends on the correct approach to the organization of timely operational services [1].

For this comprehensive study of normal and emergency modes of operation is necessary electric networks and taking measures to ensure their uninterrupted.

ANN parameters should be selected experimentally depending on specifically solved the problem of the subject area, therefore, the aim of the work is to justify artificial architecture and training algorithm neural network to choose the preferred alternatives for the development of power grid facilities comrade to do this, solve the following tasks [2]:

- write a description of each alternative development of electrical networks (ARES) based assessment criteria characterizing economic technical, efficiency level reliability and unification of decisions, their compliance social and environmental requirements. For this develop mathematical models of criteria and calculate their values for each alternative, using the parameters of the elements of electric power lines readings and objects of electrical substations (length, line type; number of lines and chains; type of support, etc.).
- form for training a neural network data set containing criteria values scores for each alternative and class number, to which ARES belongs [3-4];
- choose the type of neural network and algorithms training corresponding to the task of classification; determine the range of hidden layers and new to them;
• choose metrics that determine effective classification of ARES by neural networks various architecture and training algorithms [5, 6];
• experimentally determine the best training algorithm and optimal PA dimensions of the ANN architecture.

Below is a solution to each of the above listed tasks.
ARES development involves many goals their functioning, which leads to the feasibility of multi-criteria evaluation of alternatives [7, 8].
The classic approach is to transform a multicriteria problem to a single criterion due to the convolution of criteria, because of which the decision maker will be provided with one optimal solution. However, according to modern optimization principles noted in the work, a multi-criteria support system for decision-making should form a multitude-preferred alternatives followed by ranking.

2. Materials and methods
To obtain indicators, characterize the effectiveness of alternatives sponsored by system of criteria for assessing ARES has been laid down [9].
The method is based on existing general theoretical substation criteria models (PS) and power lines (power lines) [10]. Criterion for damage from a break in the electrical supply (technical and economic criterion):

\[ D = P D_0 \left[ \sum_{i=1}^{n} \omega_i \sum_{j=1}^{n} \mu_j T_{i j} T_{i j} + \sum_{i=1}^{n} \omega_i \sum_{j=1}^{n} \omega_j T_{i j} \frac{T_{i j}}{T_{i j} + T_{i j}} A_{i j} \right] \]  \hspace{1cm} (1)

where \( P \) is the maximum power of PS consumers, \( D_0 \) - specific damage from the violation of electro-supply, \( \text{Price/kW} \cdot \text{h} \); \( \omega \) is the equipment failure rate blowing 1 / year; \( \mu \) - frequency of planned repairs, 1 / year; \( T_{i j} \) - average duration finding an element in a planned simple year; \( T_{i j} \) - the simultaneous idle time of two electors, i of which is in a forced simple, and j - in the planned year; \( T_{i j} \) - mean time me recovery, year; \( A_{i j} \) - a matrix of states and events; \( s \) - the average cost of restoration is damaged equipment, \( \text{Price/} \text{failure} \); \( n \) - the number of POV equipment

The output indicated technical classification solutions. For training ANN use really existing, existing stations and power lines feeding them.

\[ N = [0 \leq n \leq 1, n \in R] \]  \hspace{1cm} (2)

where \( n \) - the value of the criterion at the output of the ANN: 0 – from the absence of combinations in the practice of exploitation; 1 - full coincidence with real ones power grid facilities.

3. Results and Discussion
The task of choosing the preferred solution for development of power grid facilities with ANN is a binary classification task. According to the input vector describing ARES, the crown network determines the degree of its ownership class of preferred or inappropriate different solutions.
The authors used a multilayer perceptron, as the simplest and most suitable the type of ANN given for the classification problem; for training, the inverse method was chosen error spaces to match weights for the connections between us [11, 12, 13].

For the training of ANN, an input was formed the vector \( X = \{X_1, X_2, \ldots, X_m\} \) with the values of the criterion and their corresponding output values \( T = \{T_1, T_2, \ldots, T_n\} \), where \( T_n \) took the value 0 or 1. The value "0" corresponded to the fact that the alternative is inappropriate solutions, and the value "1" - to the class of preferred accurate decisions. When learning to significant decisions were all really significant existing substations and power lines, to impractical - all unrealized alternatives.

In order for the neural network to encompass shield experience in choosing preferred ARES for substations and power lines, significant for transmitting various power, input values of the first four criteria \( \{C_m, W_m, D_m, S_m\} \) were reduced to a unit power [14,15,16]:
The choice of network architecture, training algorithm. The experiments were carried out experimentally and evaluated by the performance at control sample - data not used in learning process. In the experiment we used there were neural networks with two and three hidden layers. Layer A contained 2 to 10 neurons (only for a three-layer network); layers B and C from 2 to 30 neurons. The use of hidden layers allows you to improve to sew the result of the ANN with multidimensional input-signal. The number of connections $w$ between all neurons we in the network, should be less than the number of examples $i$ in the training set $w \leq i$ [17,18, 19].

To assess the performance of the class metrics such as percentage correctly made decisions, accuracy and completeness, F-measure, representing the average harmony exact accuracy and completeness of decision making:

$$F = \frac{TP}{2TP + FN + FP}$$  \hspace{1cm} (4)

where $TP$ is the number of truly positive solutions; $FN$ is the number of false negative decisions; $FP$ is the number of false positive decisions.

The closer the F-measure is to 1, the more effective more often the work of the ANN on the classification of decisions on development of electrical networks and inappropriate [20, 21].

To assess the effectiveness of classification ARES neural networks with different architectures swarm and workout algorithms at work were used percentage of correctly made decisions and F-measure as a metric allowing simultaneously take into account both the accuracy and completeness of the classification of genius [22, 23].

4. Conclusions
The authors made the choice of preference solutions for the development of electric networks based on artificial neural technology networks market [25, 26].

For this, a multi-criteria system for evaluating alternatives for the development of electric network objects, allowing to determine it. Decisions of efficiency of the solution are: technical, economic, technical and economic, technical operational, socio-environmental. The authors substantiated the architecture of the ANN, a comparative analysis of the algorithms of optical weighing of weights and their efficiency at different numbers of layers and neurons in them.

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