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REACTIVE POWER AND VOLTAGE CONTROL BY GENETIC ALGORITHM AND ARTIFICIAL NEURAL NETWORK

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Abstract- The paper is devoted to the reactive power and voltage control in distributive electrical networks. The main purpose is to determine proper high-voltage capacitor bank regulation step and tap setting of the transformer tap changer to minimize total costs. In this paper the problem has been solved for single distributive substation by methods of artificial intelligence on the one hand to simplify the decision and on the other hand to use the effective methods.

Keywords: Electrical Networks, Reactive Power, Voltage Control, Planning, Genetic Algorithms, Neural Networks.

I. INTRODUCTION

The inattention to the problem of reactive power planning both from consumers and from the network organizations has led to the present situation with increasing reactive power flows that is the reasons of increase in losses, decrease in controllability and reliability of distributive electric networks.

Thereupon the problem of reactive power planning has passed in the category of the key aspects of maintenance of reliable and economic operation of electric networks.

II. PROBLEM FORMULATION

At technical statement of the problem there are two aspects: first, the decrease of reactive power flows because of the installed VAR sources, secondly, the possibility of reactive power control by these sources.

Many papers are devoted to the reactive power and voltage control problem. In these papers the basic questions of this problem are stated in detail enough: requirements to formulation of mathematical model, features of used methods, the analysis of VAR sources characteristics etc.

Therefore in this paper the attempt is undertaken on the one hand to approach the decision of the problem to operational level with corresponding statement of the problem, and on the other hand to use the new and perspective methods of the artificial intelligence as especially scientific approach.

In this case it is supposed to solve the reactive power and voltage control problem for single substation of electric networks to provide decrease in losses, optimal voltage, and also the loading of transformers.

For this purpose on the basis of the spent power flow analysis in 35-220 kV electrical networks the busses with high level of reactive power consumption have been revealed. Also the analysis of network substations loading is carried out. Among substations with high level of reactive power consumption the substations with high percent of transformers loading have been allocated. The example of one such substation is considered.

The mathematical formulation of the problem is the following:

- Objective function

$$F(Q_k) = C_{Qk} + C_{\Delta P} \to \min \tag{1}$$

- Subject to inequality constraints
  - o VAR sources limits

$$Q_{k,\min} \le Q_k \le Q_{k,\max} \tag{2}$$

  - o Bus voltages limits

$$U_{\min} \le U \le U_{\max} \tag{3}$$

The components of the objective function

$$C_{Qk} = EKQ_k \tag{4}$$

$$C_{\Delta P} = C\left(\begin{array}{c} \dfrac{(Q-Q_k^2)}{U_f^2} R_{line}\tau_{\max} + \\ + \Delta P_{fe} 8760 + \Delta P_{cop} \dfrac{(Q-Q_k^2)}{S^2}\tau_{\max} \end{array} \right) \tag{5}$$

where Q_k – reactive power of VAR sources; E – norm of discount; C – cost of the active power losses; τ_{max} – number of maximum losses hours; K – cost of high-voltage VAR souses; Q – reactive power loading of the substation; R_{line} – active resistance of transmission lines; U_f – voltage on feeding substation; ΔP_{cop} – copper losses of transformer; ΔP_{fe} – iron core losses of transformer; S – transformer rated power.

The reactive power is directly concerned with voltage level in electric network. Therefore it is necessary together to define the optimal value of VAR sources reactive power and also the setting of tap changer of the substation transformer.

The voltage is defined as follows:

$$U = \frac{U_f - \dfrac{(Q - Q_k)(X_{line} - X_{tr})}{U_f}}{\left(1 + \dfrac{nD}{100} K_{tr}\right)} \qquad (6)$$

where X_{line}, X_{tr} – reactive resistance of transmission lines and the transformer; K_{tr} – rated tap setting; D – magnitude of the additional voltage per tap step; n – actual tap setting.

As researches have shown, it is possible to simplify a mathematical model considering only reactive power flow as it in this case has the defining influence on the result of control.

III. THE PROPOSED ALGORITHMS

For the problem decision it is proposed to apply the methods of artificial intelligence: genetic algorithms (for optimal reactive power of VAR sources) and artificial neural networks (for regulation reactive power and voltage level according to a daily substation loading).

This problem is many-dimensional nonlinear discrete optimization problem, which requires the use of heuristic and combinatorial algorithms, in particular of evolutionary algorithms as they allow receiving the best solution on a comparison with classical optimization methods. All evolutionary approaches are based on the modeling of natural mechanisms of inheriting and natural selection. The most known from them are the genetic algorithms.

The genetic algorithm is the method of optimization working by the analogy of the evolution of biological kinds in nature. It simulates in artificial systems such properties of natural systems as selection, adaptability to the environment, inheriting by offspring some vital properties from the parents etc. The evolution of a population is considered as a cyclic process of crossing of individuals and change of generations.

The given approach works with a population of individuals each of them represents a possible solution of the given problem. Each individual is evaluated by a measure of fitness, which is the value of the objective function for this solution. From a mathematical point of view the genetic algorithms are a variety of optimization methods joining features of probabilistic and deterministic optimization algorithms.

The multilayer artificial neural network is the universal method of any non-linear continuous function approximating. Usually the artificial neural network comprises the input layer, output layer and one or more hidden layers of neurons. Each neuron receives impulses from other neurons and gives them a specific weight. The designing of the neural network assumes the two main stages: training and testing.

The training of the neural network is the modification of the weights in order to achieve that each neuron gives the correct output, in all situations that it has to learn. The synaptic weights are defined using input-output data of the training set. After that the performance of the neural network is tested on the sample data set.

IV. SIMULATION AND RESULTS

The proposed approach has been approved on the example of 35/10 kV substation. The distributive substation is shown on Figure 1. The calculation parameters:

- Transformer (S=10 MVA, U_1=35.75 kV, U_2=10.5 kV, ΔP_{fe} =12 kW, ΔP_{cop}=60 kW, tap changer ±9x1.78%).
- Transmission line ($R_{0,line}$=0.198 Ohm/km, $X_{0,line}$=0.406 Ohm/km, length 9 km).
- High-voltage capacitor bank (1800 kvar, regulation step 450 kvar, cost 700 roubles/kvar).
- Number of hours maximum losses τ_{max}= 6400 hours.
- Voltage on feeding substation U=37 kV.
- The maximum substation loading (January, 11th-12th) is shown of Figure 2.

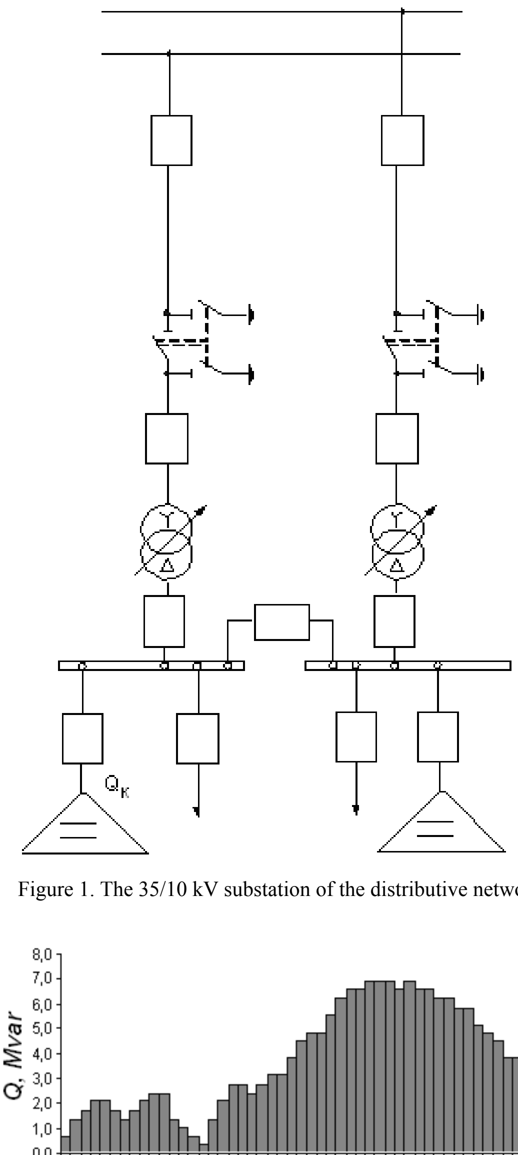

Figure 1. The 35/10 kV substation of the distributive network

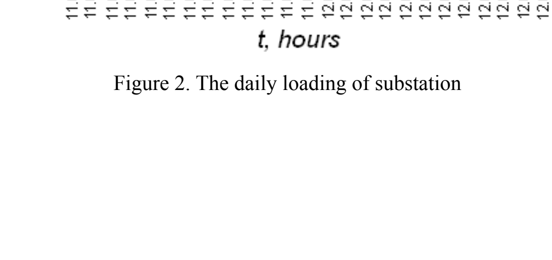

Figure 2. The daily loading of substation

The regulation criterion on a daily time interval is to find the optimal values of the capacitor bank reactive power and tap settings of the transformer tap changer at which the total costs will be minimal and voltage will be in specified limits.

In this paper the neural network is employed to regulate the reactive power of capacitor bank and voltage depending on substation loading. Artificial neural network used in this paper includes three layers: the input layer, the output layer and one hidden layer. The neurons in the input layer receive the initial information – value of substation reactive power loading. The neurons in the output layer give out the resultant value of capacitor bank reactive power and tap setting.

For training data set and also as the algorithm for minimization of the training error the genetic algorithm is applied. The application of the genetic algorithm is caused mainly by the discrete character of variables (regulation step of capacitor bank and tap setting of the transformer tap changer).

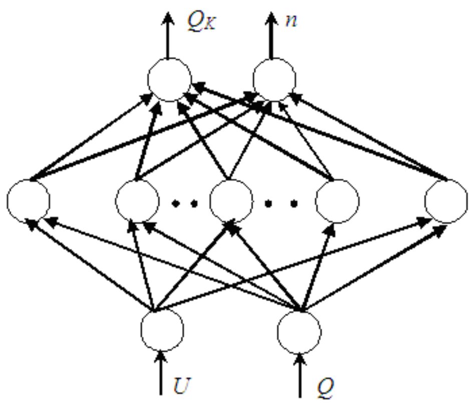

Figure 3. The structure of artificial neural network

The structure and the method of artificial neural network training were defined by means of software package STATISTICA Neural Networks. The optimal structure of the neural network for all cases is multilayer perceptron. After the neural network has been trained and checked up, it can be applied to reactive power and voltage control.

The results are shown on Figures 4-6.

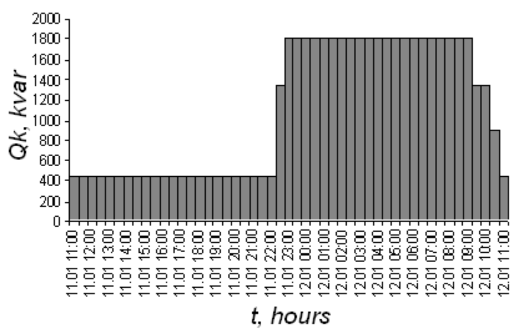

Figure 4. Reactive power of capacitor bank

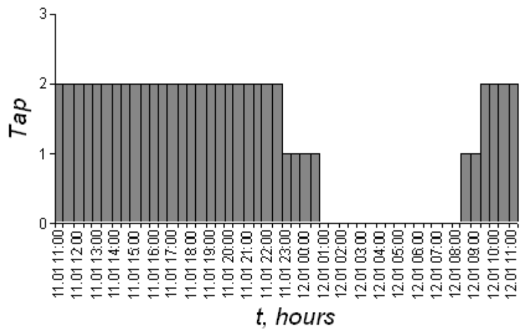

Figure 5. The settings of the transformer tap changer

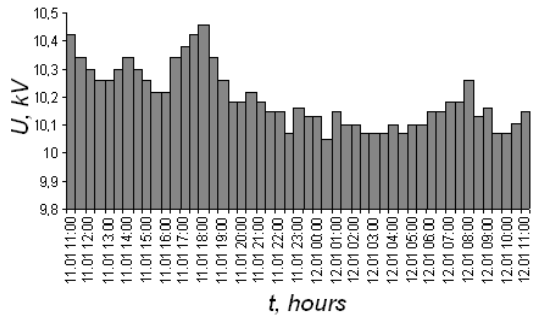

Figure 6. Voltage level

The obtained results show optimal reactive power of regulated capacitor bank according to its regulation step and also the appropriate tap setting. The limits of reactive power are in a range from 450 kvar (1 step) to 1800 kvar (4 steps). Tap setting varies in a range from zero tap to the second tap. It allows to carry out daily planning of the substation loading and to keep voltage in specified limits 10-10.5 kV.

V. CONCLUSIONS

The main purpose of the reactive power and voltage control problem is to increase the electric network effectiveness. It allows to reduce the electric power losses, substation loading and by that to solve the problem of supplying the additional consumers that is the most actual at present.

In this paper the regulation of reactive power and voltage by parallel application of artificial neural network and genetic algorithm is offered.

The basic feature of this approach consists on its sufficient simplicity and efficiency. The artificial neural networks are universal and effective means for the different control problems.

The application of the genetic algorithm for optimization problem and also for neural networks training is based on discrete character of the optimized variables. The combined use of such methods of the artificial intelligence allows solving the reactive power and voltage control problem with higher level of its reliability and quality.

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BIOGRAPHIES

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