SYNTHESIS BASE OF FAZZY KNOWLEDGE ANFIS-CONTROL OF REACTIVE CAPACITY AND VOLTAGE IN DISTRIBUTIVE ELECTRIC NETWORKS

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ABSTRACT

The question of synthesis of base of fuzzy knowledge ANFIS - networks for control streams of reactive capacity and voltage of knots considered in distributive electric networks. Synthesis base of fuzzy knowledge and term on basis of the received regime reports executed for schemes 14 knots electric networks with method application subtractive clustering. Root mean square error parameter adjustment of a method shows to adequacy of control of a mode in DEN.
Keywords. Distributive electric networks, reactive capacity, voltage, clustering, fuzzy neural network, control.

I. INSTRUCTION

Scientific and technical progress at the present stage of development has created preconditions for creation of intellectual control systems of the continuous technological processes having certain complexities and uncertainty. Besides, in the majority of cases of a problem of modern control because of complexity of the mathematical models describing them cannot effectively solved by classical methods. In these conditions application of modern technologies of processing of the information, including paradigms Soft Computing and their hybrids (neural networks, likelihood methods, fuzzy logic, genetic algorithms, and theory of chaos) has special values [1].

Based on the hybrid neuro-fuzzy network including paradigms of fuzzy logic and neural networks it is possible to synthesize the effective control systems, allowing overcome lacks peculiar to these paradigms separately. On the basis the device of fuzzy logic, the logic decision makes, and based on algorithm of training of a neural network parameters corresponding function of an accessory [2] adjusted.

From the point of view of uncertainty and quality of the multivariate initial information actual is application of neuro -fuzzy systems (ANFIS-network) for control of modes of complex distributive electric networks (DEN). Uncertainty at the decision of questions control of streams of reactive capacity and knots voltages caused stochastic by changes of active and reactive loadings, discrepancy or absence of the information on them, insufficient maintenance with measuring devices, and circuit changes at operation of electric networks. Also full maintenance of objects with measuring complexes does not give an opportunity of the account stochastic change of electric loadings in all time intervals.

In view of abovementioned, in the given work questions of synthesis of the fuzzy knowledge base for control streams of reactive capacity and knots voltages in DEN with use of an ANFIS-network are considered.

II. ANFIS-MODEL CONTROL OF REACTIVE CAPACITY AND KNOTS VOLTAGES IN DEN

At control of reactive capacity and a voltages in DEN power supply systems with numerous central point effectively to present system of fuzzy logic conclusions in the form of hybrid neuro - fuzzy networks (ANFIS-model [2,3]). It caused by that in fuzzy logic expert knowledge of structure of object in the form of linguistic statements used, and neural networks create an opportunity of effective training. On fig.1 shown structure of ANFIS-network with *n* in entrance parameters. The architecture and a rule of work of each layer of an ANFIS-network are given in [1,4]. The system ANFIS-control based on use of fuzzy knowledge base Sugeno.

In Sugeno model, the fuzzy knowledge base, describing dependences between entrance parameters $X = (x_1, x_2, ..., x_4)$ and target parameter*,* described by a polynomial of the first order in the following form [4]:

$$d_j = b_{j,o} + \sum_{i=1}^{m} b_{j,i} x_i \tag{1}$$

where, $b_{j,i}$ - some real numbers $i = \overline{0, n}$.

The degree of membership of an entrance vector $X^* = (x_1^*, x_2^*, ..., x_n^*)$ to values d_j defined by following system of the fuzzy logic equations:

$$\mu_{d_j}(X^*) = \underset{p=\overline{1,k_j}}{\vee} \underset{i=\overline{1,n}}{\wedge} \left[\mu_{jp}(x_i^*)\right], \qquad j = \overline{1, m} \tag{2}$$

where $\vee(\wedge)$- operation from *S-norm (t-norms)*, i.e. from set of realizations of logic operations *or (and)*.

As membership function analytical models of membership functions of a variable x to any fuzzy term in the form of calumniated functions [4] are used:

$$\mu(x) = \frac{1}{1 + \left|\frac{x-c}{a}\right|^{2b}} \tag{3}$$

where *a*, *b*, *c* – some numerical parameters accepting any valid values and ordered by a parity $a \langle b \langle c$, where parameter $b \rangle 0$; *a* – factor of concentration of membership function; *b* – factor of a steepness of membership function; *c* – coordinate of a maximum of membership function.

The algorithm of control in the beginning demands formalization of the knowledge base depending on entrance signals (a deviation of reactive capacity and a voltage on each unit) and their quantities. With this purpose, the quantity a term-subsets of linguistic variables of reactive capacity and a voltage defined. For the decision of the considered question the method subtractive clustering (mountain algorithm clustering) [4] is used.

III. ALGORITHM SUBTRACTIVE CLUSTERING

On a first step of algorithm it is necessary to generate the potential centers *(Q)* cluster having final numbers q_r , where $r = \overline{1, n}$. The quantity possible cluster equal $Q = q_1 q_2 ... q_n$.

On the second step of algorithm, the potential of the centers cluster under the following formula pays off:

$$P(Z_h) = \sum_{k=\overline{1,M}} \exp(-\eta D(Z_h, X_k)), \; h = \overline{1, Q} \tag{4}$$

Where $Z_h = z_{1,h}, z_{2,h}, ..., z_{n,h}$ – the potential center of h-th cluster;
η – Positive constant; $D(Z_h, X_k)$ – distance between the potential center cluster (Z_h) and object clustering (X_k). In Euclidean space, this distance pays off under the formula:

$$D(Z_h, X_k) = \sqrt{\|Z_h - X_k\|^2} \tag{5}$$

On the third step of algorithm as the centers cluster, choose coordinates of «mountain tops». The center of the first cluster appoints a point with the greatest potential. Before a choice, following cluster the center it is necessary to exclude influence just found cluster. For this purpose from current values of potential, subtract the contribution of the center just found cluster.

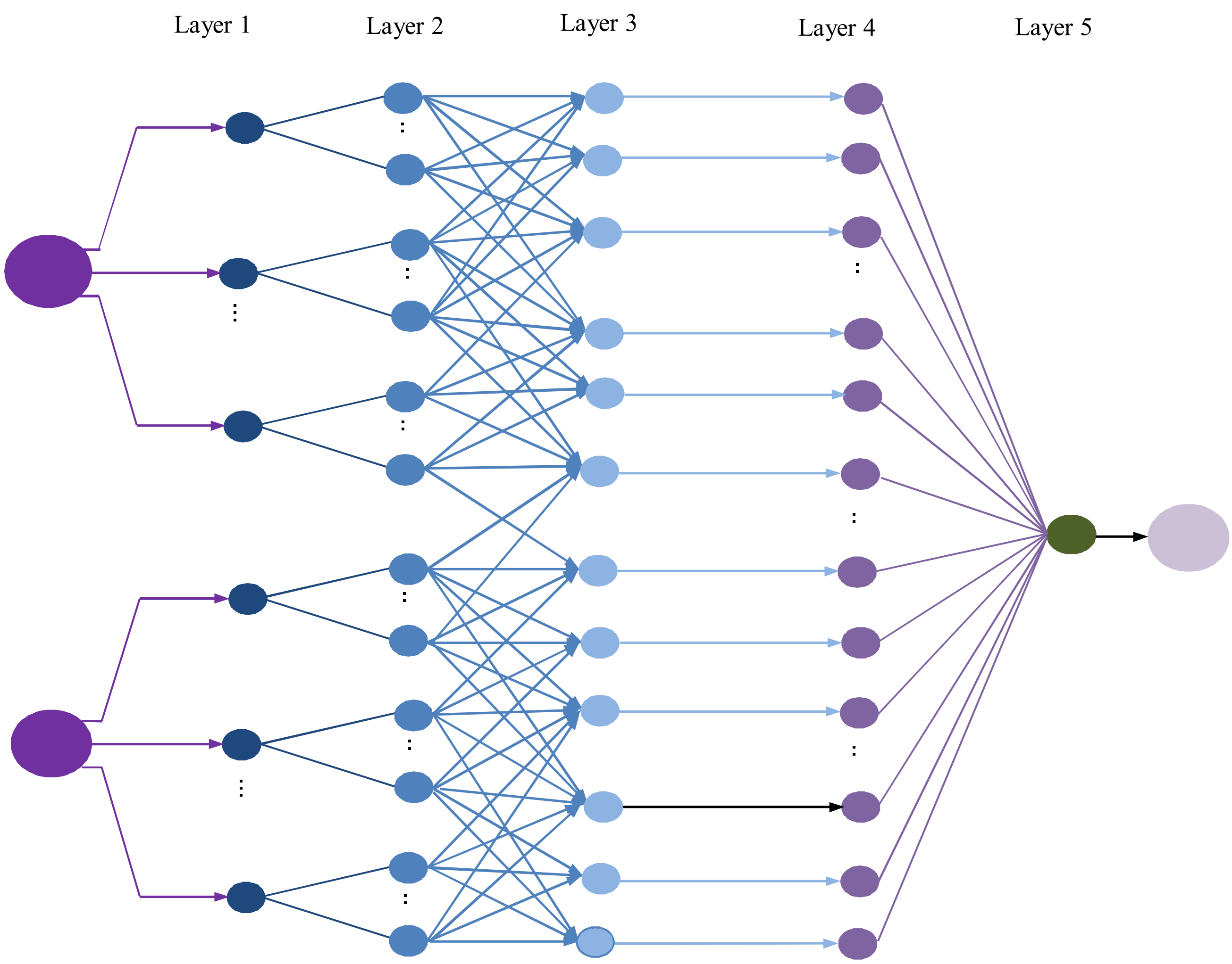


Fig. 1. Structure ANFIS – networks control of reactive capacity

Recalculation of potential occurs under the formula:

$$P_2(Z_h) = P_1(Z_h) - P_1(V_1)\exp(-\beta D(Z_h, V_1)),\ Z_h \neq V_1,\ h = \overline{1,Q} \tag{6}$$

where P(·) - potential on 1-st iteration; $P_2(.)$ – potential on 2-th iteration; β- A positive constant; V_1 – the center of the first found cluster.

$$V_1 = \underset{Z_1, Z_1, \ldots, Z_k}{\arg} \max(P_1(Z_1), P_1(Z_2), \ldots, P_1(Z_Q)) \tag{7}$$

The center of the second cluster defined on the maximal value of the updated potential:

$$V_2 = \underset{Z_h : Z_h \neq V_1, h=\overline{1,Q}}{\arg} \max(P_2(Z_1), P_2(Z_2), \ldots, P_2(Z_Q)) \tag{8}$$

Then value of potentials again recalculated:

$$P_3(Z_h) = P_2(Z_h) - P_2(V_2)\exp(-\beta D(Z_h, V_2)),\ Z_h \neq V_1,\ h = \overline{1,Q} \tag{9}$$

Iterative procedure of allocation of the centers clusters proceeds until the maximal value of potential exceeds some threshold. The algorithm subtractive clustering not fuzzy, however it often use at synthesis of fuzzy rules from data.

IV. RESULTS OF PRACTICAL REALIZATION

The first stage of procedure of construction of fuzzy Sugeno model is definition of quantity a term-subsets and fuzzy rules on experimental data or by expert estimations. The volume of the knowledge base is defined as F=TG, where T – quantity of terms of one entrance variable; G – quantity of entrance variables, for example, at T=4 and G=5 we receive quantity of rules 45=1024, and already at T=7 and G=14 the quantity of rules considerably increases up to 714.

In conformity with it for complex DEN, the quantity of fuzzy rules turns out significant and use of expert knowledge connected with the certain difficulties. Therefore with the purpose of control reactive capacity and a voltage in DEN uses algorithm subtractive clustering for synthesis of fuzzy rules. The fuzzy knowledge bases reflecting every possible variant of rules as a result received.

Data subtractive clustering used as fast algorithm for synthesis of fuzzy rules. Besides for ANFIS-algorithm this method is as though an index point for training synthesized fuzzy model. The basic advantage of application clustering for synthesis of fuzzy model consists that rules of the knowledge base turn out object-oriented. It reduces an opportunity so-called «combinatory explosion», i.e. catastrophic increase in volume of the knowledge base at a plenty of entrance parameters. Below questions of synthesis of system of a fuzzy logic conclusion of type Sugeno (fig.2) with application of a method subtractive clustering are considered.

By means of subroutine Clustering [5] packages Fuzzy Logic Toolbox, are executed allocation cluster pair initial data (value of knots voltages and reactive capacities). On fig.3, results clustering on initial data shown and in table 1 value of their fashion given.

For synthesis of fuzzy rules of developed neuro- fuzzy network ANFIS at control of reactive capacity in DEN, results of regime calculations 14 central electric networks IEEE14BUS are used. Calculations executed by means of program complex ETAP [6].

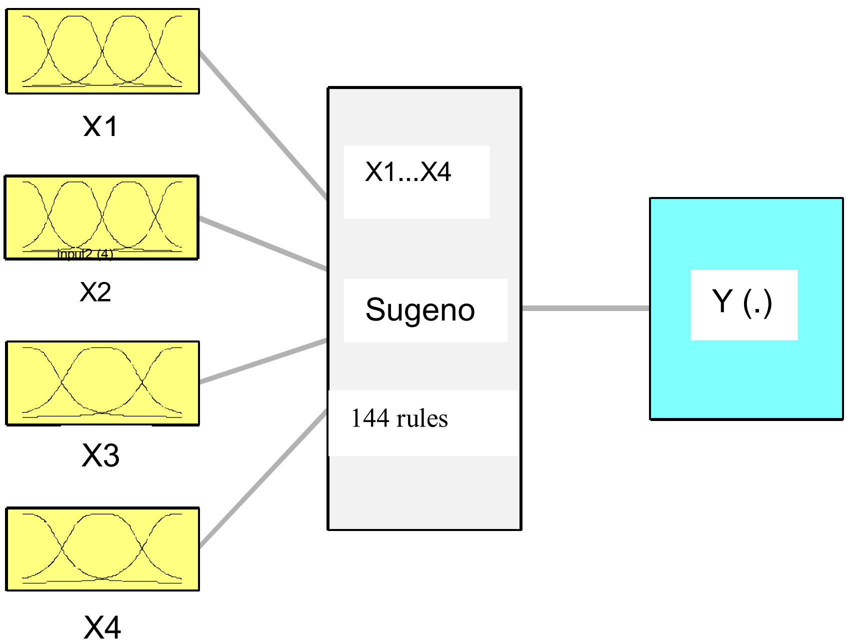
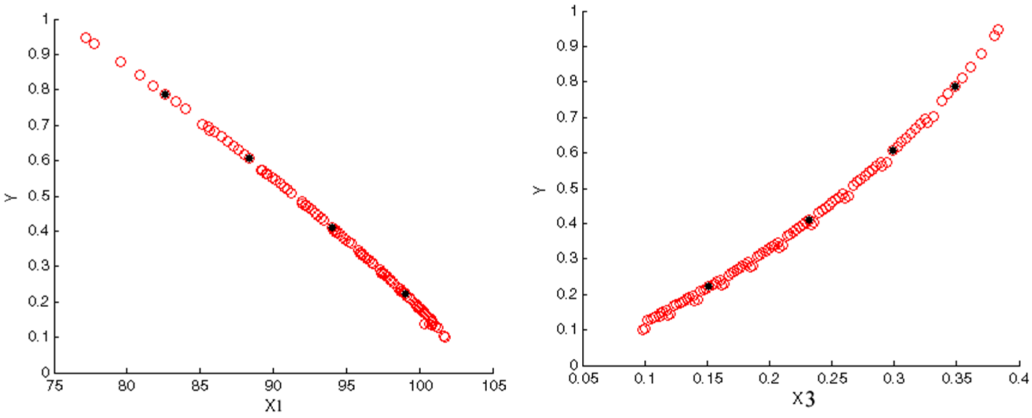


Fig.2. Block diagram of fuzzy Sugeno model



a) b)

Fig. 3. Results subtractive clustering initial selective data

Tab. 1

Value of a fashion found cluster

X1	X2	X3	X4	Y
99,030	99,390	0,152	0,151	0,222
94,060	94,330	0,232	0,231	0,409
88,340	88,320	0,299	0,299	0,606
82,630	82,180	0,348	0,350	0,787

Apparently, from fig.3, for linguistic variables it is enough to accept 4 terms.

At a following stage Sugeno model of the first order with fuzzy rules in quantity 144 synthesized.

Computer realization of fuzzy rules ANFIS-network shown on fig.4.

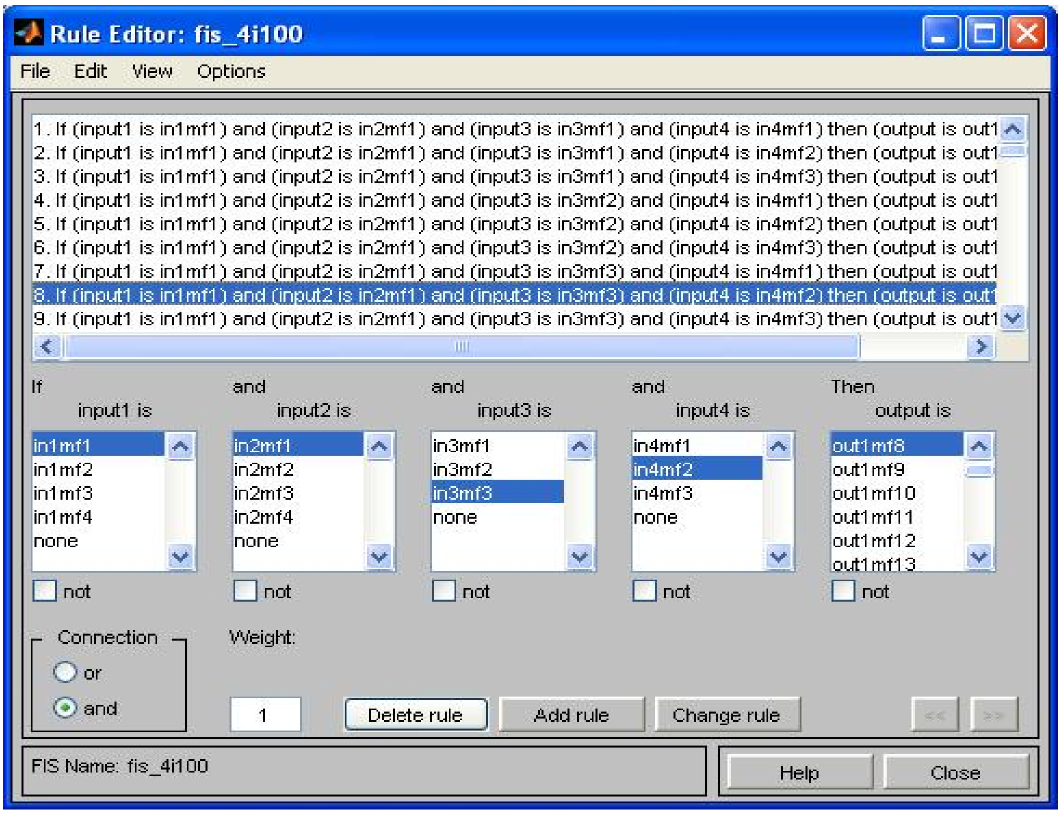


Fig. 4. Computer realization of fuzzy rules of an ANFIS-network

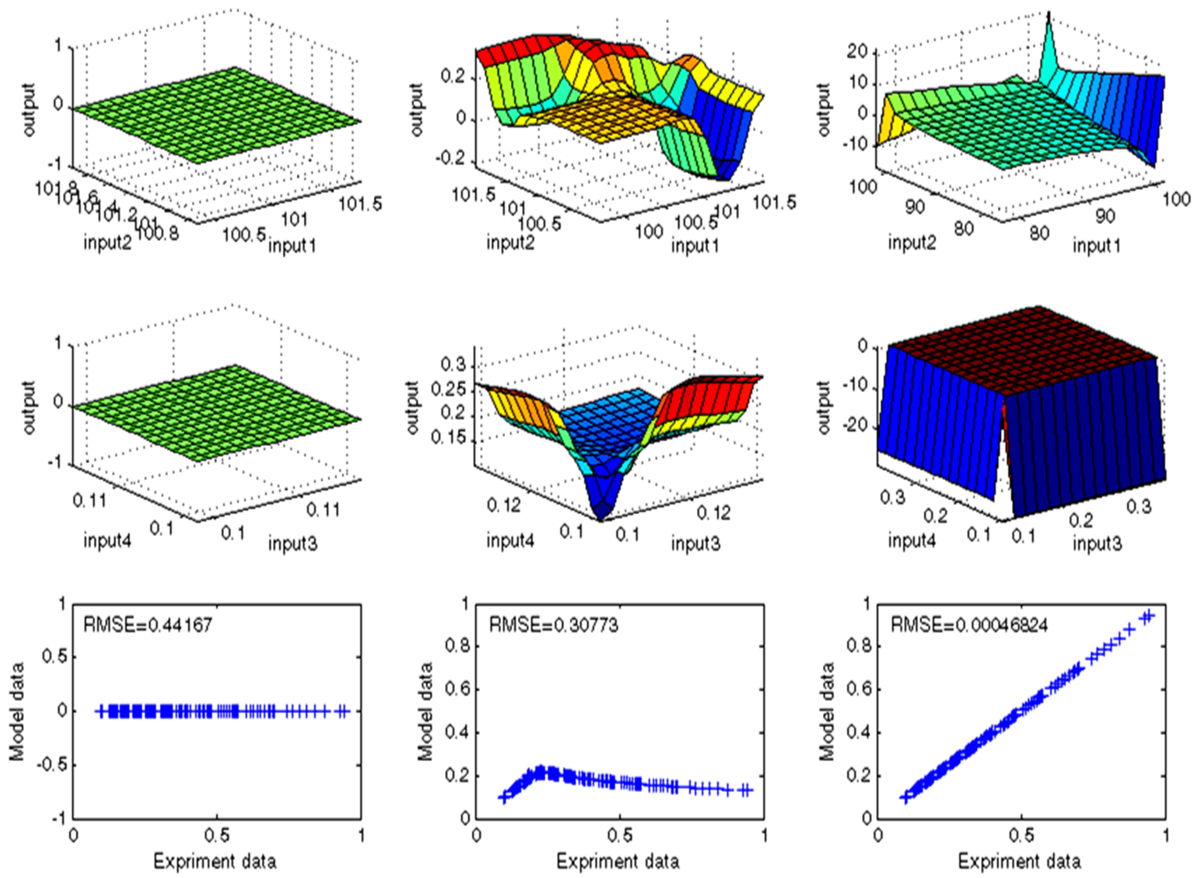
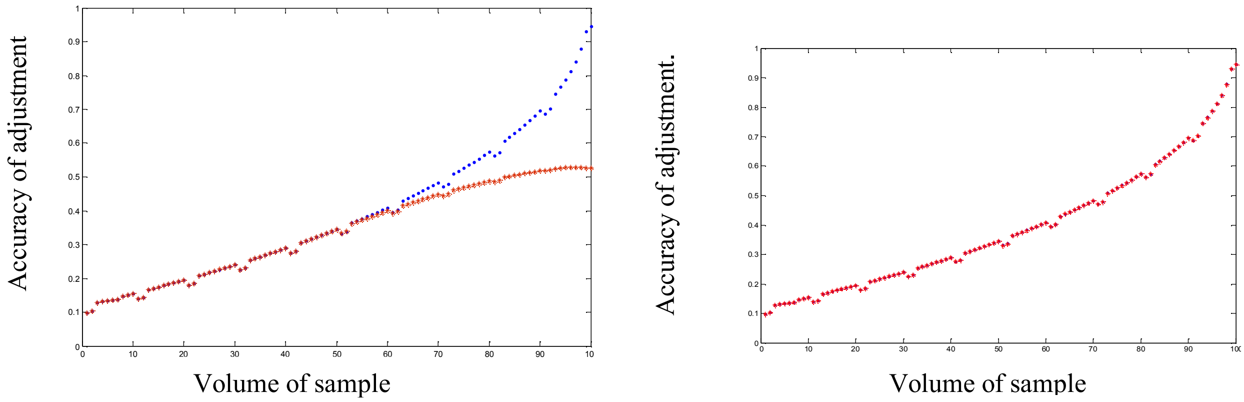


Fig. 5. Adjustment of synthesized fuzzy Sugeno model
a- adjustment; b-after adjustment on 20 samples; c-after adjustment on 100 samples

The surface "inputs-outputs" of initial fuzzy model shown on fig.5a. Apparently, from figure, before adjustment the fuzzy model badly reflects the basic features of identified dependence. Testing of model shows, that an average quadratic deviation (a.q.d.) between settlement data and results of fuzzy modeling makes 0,442. On fig.5b surface of training and distribution a.q.d. between settlement data and results of fuzzy modeling on 20 samples shown. As a result of adjustment, a.q.d. On training sample has decreased with 0,442 up to 0,308. Apparently from figure, after adjustment the fuzzy model well reflects behavior of identified dependence and quality of the synthesized base of fuzzy knowledge improves. On fig.5c the surface of training and distribution с.к.о given accordingly. Between settlement data and results of fuzzy modeling on 100 samples. Apparently, a.q.d. between settlement data and results of fuzzy modeling has decreased up to 0,00047 and the surface reflects identified dependence is better.

On fig.6 dependences of accuracy adjustment on volume of sample shown.

Apparently from fig.6a, the volume of sample equal 60 is not sufficient for full training system that is shown in a divergence between settlements and modeled in operating parameters. From fig. 6б accuracy of adjustment at volume of sample 100 is equal 0,94, that it is possible to consider sufficient for training system.



a) b)

Fig.6. A curve of dependence of errors of adjustment from volume of sample
a-after adjustment on 60 samples; b-after adjustment on 100 samples

CONCLUSIONS

1. Questions of synthesis of terms-subsets and bases of fuzzy knowledge Sugeno of ANFIS-model on the basis of algorithm subtractive clustering for control of reactive capacity and knots voltages in DEN power supply systems are considered.
2. Values a.q.d. between settlement data and results of fuzzy modeling of the synthesized neuro - fuzzy network, received on the basis of results of the limited regime calculations for test scheme IEEE14BUS have shown its adequacy to control of reactive capacity and knots voltages in DEN.

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