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Abstract — **The paper presents the possibility of using criterion programming and neuro-fuzzy modeling in determining the value of planning technical power losses. Proposed is an optimal control in normal mode power grids which considers the value of planned technical power losses. Improved method for determining normative values of technical energy losses using the criteria programming and neuro-fuzzy modeling is presented.**

Keywords - power grids, substations, distrubuted power generation, power control, renewable energy sources.

I. INTRODUCTION

Tasks of optimal control of active and reactive power flows are real concerns for grids of different voltages. Authors in [1-3] show that the criterion of optimality can be used to minimize active power losses. Very fast development of renewable energy sources (RES) [4, 5] and their integration in power grids had required to design new technology optimal control power grids with distributed power generation (DPG). Considering the last report of The National Commission for state regulation in the energy and utilities domain (NCSREU) in Ukraine for 2018, distribution grids (transmission lines and substations) are requiring reconstruction and renewal [4, 5].

One possibility of cost-effective way to improve power system efficiency is to design new algorithms for optimal control of parameter modes distribution power grids and operation modes RES [6, 7].

Prior to creation of new algorithms for optimal control of DPGs we need to consider factors, stochastic in nature, such as generation of energy by non-guaranteed RES (wind power plants and photovoltaic power plants); operation mode dependence on weather conditions in case of small hydropower plants, operation mode dependence on location fuel in case of bio-power plants; etc.

Besides this, we also need to take into account energy consumption, which can be forecasted with big accuracy by taking into account statistic information, for example, increase in number of electric vehicles produces new consumption - charging stations, storage power systems and other special equipment; development of big agricultural complexes, usually situated near raw material base, requires quality power supply, etc. This problem can be partially resolved by using different types of RES, which can compensate mutual influence of each other [6, 7]. Therefore, actual task is determination of optimality criterion, according to which control actions will be formed.

Nowadays, control of the parameters of normal modes (NMs) power system is carried out for the purpose of safe and reliable operation of the equipment, ensuring the normative indicators of the quality of electricity achieving the optimum economic performance of both individual equipment and the electric power company as a whole. However, the problems of such management are the need to use outdated but costly equipment, whose passport resource has long been exhausted, the lack of modern electrical equipment to control the parameters of NMs and equipment parameters in the pace of the process, in the absence of methods and mathematical models, that would more accurately take into account the current state of electrical equipment and NMs parameters in order to manage them more effectively, combining both organizational and technical measures.

Organizational measures include the normalization of electricity losses as one of the indicators that characterize the technical and economic aspects of the power system operation. Implementation of effective measures to approximate the value of the loss rate causes the company to reduce the difference between the actual losses and this indicator due to the optimal control of NMs parameters, the use of automatic or automated control of these parameters, means of control of mode and energy parameters, optimization of algorithms and control mathematical methods and models underlying them, etc. Insufficiently substantiated or inaccurate determination of the

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normalized value of losses results in inefficient use of existing controls, unjustified costs associated with the improper use of both new and existing electrical equipment when managing NM parameters. Therefore, it is important to analyze the existing methods of normalization of electricity losses. Frequent use of the transformer may not be advantageous, because in the older transformer faults arising from having to remove the transformer will be more expensive than saving money from reducing power losses.

We propose to do control influences by not using minimum value but rather normative value of power losses. It gives the possibility to keep technical resources of equipment control substation and transmission lines and to engage RES maneuverability. Also, using RES to control power flows we need to consider distribution point flows. For realization of control influence we need to use transformers with regulator under load and reclosers for changing power flows in transmission lines [8-10]. The problem of incomplete input data is partially addressed by using criterion method and neuro-fuzzy modeling.

The task of reducing electricity losses during transmission is urgent. One of the ways to reduce losses is the use of new optimal control algorithms that will use the normative value of electricity losses as criteria for optimality [11-13]. In order to achieve the normative value of technical losses of electricity, it is necessary to monitor the current active power losses. It is necessary to optimally control the normal operating modes of the power grids so that the current power losses do not exceed their planned value. Therefore, with optimal control of normal power grid modes, it is advisable to use the active power losses as an optimality criterion and try to reduce their values to the planned one. This guarantees that at the end of the reporting period, the value of electricity losses will not exceed the desired. Therefore, it is urgent to improve the existing and develop new methods for power grids mode optimization, when the criterion of optimality is the loss of electricity during its transmission, taking into account the planned value of technical power losses and technical condition of control devices in the conditions of the incompleteness of the input data. In order to calculate the planned value of power losses, it is necessary to determine the planned value of generation and load, as shown in [7]. Our paper is an attempt to improve existing methods of determining the normative value of electricity technical losses using criterion programming and neuro-fuzzy modeling.

II. Normalization Methods Analysis for Technical Losses of Electricity in Power System

In general, the standard refers to the estimated cost of material resources that are used to plan and manage the economic activity of enterprises. The standards are divided into perspective and current ones. For practical determination of the standard, three methods are shown in Fig. 1.

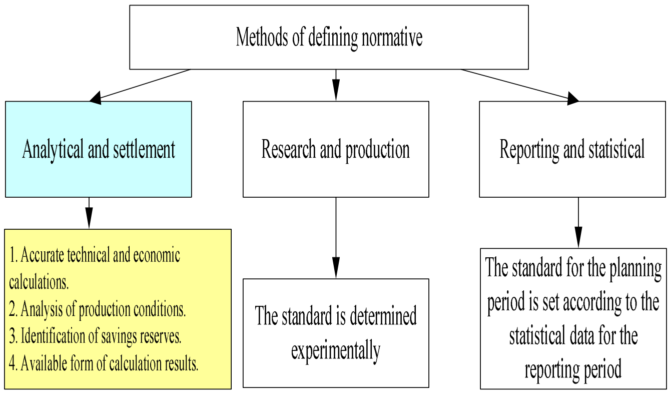

Figure 1. Methods for determining the standards and their features

For the normalization of electricity losses, the analytical and calculation method was proven to be the most progressive and scientifically grounded one. Leading scientists, Yu. Zhelezko, V. Vorotnitsky, O. Danylyuk, O. Potrebych, amongst others, have been engaged in the regulation of electricity losses. Yu. Zhelezko defines the normalization of electricity losses as formation of satisfactory economic criteria for the level of electricity losses, which is taken into account in electricity tariff structure. According to V. Vorotnitsky, the standard of electricity losses in power networks is economically justified and documented technological costs of electricity during its transportation, related to taxable resources and aimed at generating revenue for the energy supply organization. In order to improve the accuracy of determining the rate of loss of electricity in power networks, it should be divided into four voltage levels: HV (110-750 kV); MV1 (35 kV); MV2 (20–1 kV); LV (0.38 kV and below). The accuracy of determining the rate of loss affects the accuracy of estimating excess losses and, accordingly, the effectiveness of measures to reduce them. The normative value of technological costs of electricity for the billing period is calculated by the expression:

$$\Delta W_{\mathrm{NVTPL}} = \Delta W_{\mathrm{TR}} + \Delta W_{\mathrm{SON}} + \Delta W_{\mathrm{MI}}, \tag{1}$$

where ΔW_{TR} – the total technical power losses in the elements of power grids; ΔW_{SON} – total regulatory costs of electricity for own needs of substations; ΔW_{MI} – estimated electricity consumption for ice melting in the power grid.

When calculating the technological costs of electricity in power grids we consider the calculated technical losses of electricity in transmission lines and transformers, which are calculated for the very short time interval when method of operational calculations is used. In expression (1), the calculated technical losses of electricity in the power grid elements are determined by the expression:

$$\Delta W_{\mathrm{TP}} = \sum_{i=1}^{k} \Delta W_{\mathrm{TR}i} + \sum_{i=1}^{k} \Delta W_{\mathrm{TRv}i} + \sum_{i=1}^{k} \Delta W_{\mathrm{TRc}i} + \sum_{i=1}^{k} \Delta W_{\mathrm{RES}i} + \sum_{i=1}^{k} \Delta W_{\mathrm{OTH}i} \tag{2}$$

where $\sum_{i=1}^{k}\Delta W_{\text{TR}i}$ - the total variables of the estimated electricity losses in the power line and the i-th degree of voltage; $\sum_{i=1}^{k}\Delta W_{\text{TRv}i}$ - total variables of the calculated losses of electricity in the transformers of the i-th degree of voltage; $\sum_{i=1}^{k}\Delta W_{\text{TRc}i}$ - total conditional and permanent electricity losses in transformers of the i-th degree of voltage; $\sum_{i=1}^{k}\Delta W_{\text{RES}i}$ - total calculated electricity losses due to RES usage; $\sum_{i=1}^{k}\Delta W_{\text{OTH}i}$ - total calculated electricity losses in other elements such as shunt reactors, synchronous compensators, valve arresters, surge arresters, current and voltage transformers, static battery capacitors, etc. of the first degree of voltage.

Depending on the initial information, it is suggested to use the following methods for determination of normative values of the electricity load losses: (i) average loads and variances, (ii) characteristic modes, (iii) dominant harmonics, and (iv) elemental calculation. The first two methods are used for electrical networks up to 150 kV. The method of dominant harmonics is suitable for any electrical network, but to obtain the desired accuracy you must consider harmonics whose numbers exceed the dominant ones. The most accurate value of the loss rate can be obtained by the elemental calculation method.

Of all the loss components, the most difficult to calculate and present in a form that is convenient and understandable to use is the technical loss, especially their load component. In order to simplify the calculation of electricity load losses [10, 11] it is proposed to use the normative characteristic of technical losses i.e. dependence of a satisfactory level of electricity losses on the factors that are reflected in the official reporting. To determine the coefficients of the regulatory characteristics of technical losses of electricity, it is necessary to know the planned value of technical power losses.

One of the ways to increase energy efficiency is to regulate the losses of agricultural enterprises (agro-industrial complexes). In most cases, it is advisable to place farms closer to raw material base. With large production volumes such agro-industrial facilities are energy intensive. Considering the state of distribution networks, it is not easy to ensure uninterrupted energy supply. Therefore, it is suggested that in such enterprises, taking into account seasonality and location, alternative sources of electricity (solar panels, wind power plants) should be installed. In order to further control and encourage the agricultural enterprise owners, it is necessary to take into account the use of electricity from non-traditional sources of electricity and in particular when determining the normative value of electricity technical losses. The selection of influential factors that are involved in determining the normative value of technical losses of electricity in agro-industrial complexes, namely the calculated coefficients of the normative characteristic of technical losses, is proposed to be carried out considering the capacities of electricity obtained from renewable sources of electricity. In addition, it is known that agriculture is a powerful source of renewable energy (bio fuels).

III. Normative Characteristics Model of Technical Losses Using the Interplay of Influential Factors

To take into account the mutual influence of factors, the equation (3) is used:

$$\Delta P = \sum_{i=1}^{s}\sum_{j\geq 1}^{s} A_{ij}\cdot P_i \cdot P_j + \sum_{i=1}^{s} B_i \cdot P_i + C \tag{3}$$

where A, B are regression coefficients, C is an approximation constant and Ps are influential factors. Once determined these factors can be used for certain time. If you choose such influential factors that their value can be changed by the available controls (power flows along the lines, power of RES), the normative value technical power losses (NVTPL) can be used for optimal control problems. The planned value of technical power losses is calculated by substituting the values of influential factors in the normative characteristic of technical power losses. Planning value technical power losses serves as a guideline for optimal control of the normal modes of the power grid and limits the intensity of operation of the control devices. The objective function is written in the following form [5]. We want to minimize:

$$y = f(P_1, P_2, P_3) \tag{4}$$

under the conditions:

$$P_1 + P_2 + P_3 = P_c,$$
$$P_{i\,min} \leq P_1 \leq P_{i\,max},\ P_{i\,min} \leq P_2 \leq P_{i\,max}, \tag{5}$$

where P_c is an influential factor whose value does not change in the pace of the process or which it cannot influence with the help of control devices, so it will be consider as constant. Let us draw the objective function (3)

$$y = \sum_{i=1}^{s}\sum_{j\geq 1}^{s} A_{ij}\cdot P_i P_j + \sum_{i=1}^{s} B_i \cdot P_i \tag{6}$$

where A_{ij} and B_i are the coefficients of the model, P_i and P_j factors are the influential factors (power consumption of renewable electricity).

In expression (6) the approximation constant C is not considered, because its value will be considered constant. For the three influential factors whose values are optimized, let us write equation (3) in the minimizing form

$$\begin{aligned} y = {} & A_{11}P_1^2 + A_{22}P_2^2 + A_{33}P_3^2 + A_{12}P_1P_2 + \\ & + A_{13}P_1P_3 + A_{23}P_2P_3 + B_1P_1 + B_2P_2 + B_3P_3, \end{aligned} \tag{7}$$

employing conditions (5).

At certain situations, all input data will not be available [10].

IV. CRITERION METHOD

The criterion method can be used to optimize a solution in energy utility companies [14, 15]. In addition, neuro-fuzzy modeling was used for finding value of power losses [13]. This paper proposes using combination of the criterion method together with neuro-fuzzy modeling [11, 12] as it is the best combination and gives good results in finding the optimal value even when incompleteness of input data exists.

The task can be represented as finding minimum value of the expression (8):

$$y(x) = \sum_{i=1}^{m_1} a_i \cdot \prod_{j=1}^{n} x_j^{\alpha_{ji}} \tag{8}$$

using conditions:

$$q_k(x) = \sum_{i=m_k+1}^{m_{k+1}} a_i \prod_{j=1}^{n} x_j^{\alpha_{ji}} \le G_k \tag{9}$$

where $k = \overline{1,p}$ $x_j \rangle 0$, $j = \overline{1,n}$

$y(x)$– the total criterion of optimality; a_i, α_{ji} are constant coefficients during certain time interval, x_j are variable values, m_1 is a number of criterion equation members (8) and m_{k+1} is a number of combined limitations for immediate task function of criterion programming (CP) (8) - (9).

We are using "orthogonality" and "normality" conditions (equations (11) and (12)) to create the similar double task, hence find maximum value as shown in (10).

$$d(\pi_o) = \prod_{i=1}^{m} \left(\frac{a_i}{\pi_{io}}\right)^{\pi_{io}} \prod_{k=1}^{p} \left(\frac{\lambda_k}{G_k}\right)^{\lambda_k}, \tag{10}$$

$$\sum_{i=1}^{m} \alpha_{ti}\pi_i = 0, \; s = \overline{1,n}, \tag{11}$$

$$\sum_{i=1}^{m_1} \pi_i = 1, \tag{12}$$

where π_i is the likeness criterion and $\lambda_k = \sum_{i=m_k+1}^{m_{k+1}} \pi_{io}$ are defined Lagrange multipliers.

The system expressions ("orthogonality" and "normality") in CP are represented as:

$$\alpha \cdot \pi = b, \tag{13}$$

$$\alpha = \begin{vmatrix} \alpha_{11} & \alpha_{12} & \alpha_{13} & \dots & \alpha_{1m} \\ \alpha_{21} & \alpha_{22} & \alpha_{23} & \dots & \alpha_{2m} \\ \dots & \dots & \dots & \dots & \dots \\ \alpha_{n1} & \alpha_{n2} & \alpha_{n3} & \dots & \alpha_{nm} \\ 1 & 1 & 1 & \dots & 1 \end{vmatrix} \quad \pi = \begin{vmatrix} \pi_1 \\ \pi_2 \\ \pi_3 \\ \dots \\ \pi_m \end{vmatrix} \quad b = \begin{vmatrix} 0 \\ 0 \\ 0 \\ \dots \\ 1 \end{vmatrix}$$

where α is the matrix of degrees; π is the array of likeness criterion and b is the array of free members;

α is a square matrix, and it can be used only when the total amount of criterion function members and restrictions per unit is larger than the number of variables the system of equations (6) can easily solve by any known method. In the case when α is not a square matrix the system of equations is not defined and has a lot of solutions hence we need to find another approach.

If number of rows equal to the number of columns in the matrix α then the solutions can be found by using all famous methods (exactly, the measure of complexity of solving a problem is determined by the number of members of a binary function, its limitations, and the number of variables). On the other hand, if the α matrix is not square, but rectangular, that is, the total number of all members of the objective function and the constraints is greater than the number of variables, then the solution is difficult to find using traditional methods.

The solution is not a single point on the plane but a straight line.

In papers [11-13] it is shown that likeness criteria of the system "orthogonality" and "normality" expressions (11) - (12), are determined using expression (14) :

$$\pi_i = \beta_{i0} + \sum_{j=1}^{s} \beta_{ij} \cdot \pi_j \tag{14}$$

where β_{i0} is "normality" array; β_{ij} is the residual array; π_j is the basic likeness criteria and s=m-n-1 is the level of the complicacy of a CP task.

Likenesses criteria is presented using "basic" criteria and "normality" and "residual array" of double function and similar approach can be shown in (14) where T_k is an array which contains indexes of members of k- limitations.

To decide a task when our function is convex, it is always possible to replace definition by definition of a stationary function point because arrays of maximizing points of these functions coincide [1]. Algorithm defined is shown in Fig.2. Using mathematical transformations, it can be shown in equation (15).

$$d(\pi_j) = \prod_{i=1}^{m} \left(\frac{a_i}{\beta_{i0} + \sum_{j=1}^{s} \beta_{ij} \cdot \pi_j} \right)^{\beta_{i0} + \sum_{j=1}^{s} \beta_{ij} \cdot \pi_j} \times \prod_{k=1}^{p} \left(\sum_{i \in T_k} \left(\beta_{i0} + \sum_{j=1}^{s} \beta_{ij} \cdot \pi_j \right) \right)^{\sum_{i \in T_k} \left(\beta_{i0} + \sum_{j=1}^{s} \beta_{ij} \cdot \pi_j \right)} \tag{15}$$

Take the derivative of expression (16) by basic criteria of likeness (17). Having set it equal to zero and having found an antilogarithm of it, received a expression system from which it is possible to take condition of maximum doubly function.

$$\left(\ln d(\pi_j)\right)' = \ln \prod_{i=1}^{m} a_i^{\beta_{ij}} - \sum_{i=1}^{m} \beta_{ij} \cdot \ln \left(\beta_{io} + \sum_{j=1}^{s} \beta_{ij} \cdot \pi_j \right) - \sum_{i=1}^{m} \left(\frac{\beta_{io} + \sum_{j=1}^{s} \beta_{ij} \cdot \pi_j}{\beta_{io} + \sum_{j=1}^{s} \beta_{ij} \cdot \pi_j} \right) \cdot \beta_{ij} + \tag{16}$$

$$+ \sum_{k=1}^{P} \sum_{i \in T_k} \beta_{ik} \cdot \ln \sum_{i \in T_k} \left(\beta_{io} + \sum_{j=1}^{s} \beta_{ij} \cdot \pi_j \right) + \sum_{k=1}^{P} \left(\frac{\sum_{i \in T_k} \beta_{io} + \sum_{j=1}^{s} \beta_{ij} \cdot \pi_j}{\sum_{i \in T_k} \beta_{io} + \sum_{j=1}^{s} \beta_{ij} \cdot \pi_j} \right) \cdot \beta_{ik}.$$

or

$$d(\pi_j) = \left(\prod_{i=1}^{m} \left(\beta_{io} + \sum_{j=1}^{s} \beta_{ij} \times \pi_j \right)^{\beta_{ij}} / \prod_{i=1}^{m} a_i^{\beta_{ij}} \right) \times \left(1 / \prod_{k=1}^{P} \left(\sum_{i\hat{I}T_k} \left(\beta_{io} + \sum_{j=1}^{s} \beta_{ij} \times \pi_j \right) \right)^{\sum_{i\hat{I}T_k} \beta_{ik}} \right) = 1, j = \overline{1,s} \tag{17}$$

The given approach offered in [1], can be applied only when t is small. When t is about 10 its use is uncertain as it is necessary to solve systems of the nonlinear equations of high order.

V. Defining Optimal Criteria Likeness Using Similarity Method and Neuro-Fuzzy Modeling

Membership function is similar to likeness criteria and is in relationship with some system parameters. Likeness criteria are dimensionless. When likeness criteria are calculated by the integrated analogues method, the weight coefficients become members of criterion function (rated to the unit). Membership function and likeness criterion range from 0 to 1. It is possible to find an analogy between membership function and similarity criterion. Similarity between membership function and likeness criterion allows using membership function instead of similarity criterion defining optimising vector of similarity criterion for difficult tasks. In our work we consider replacing basic likeness criteria by membership functions such as:

$$\pi_i = \beta_{i0} + \sum_{j=1}^{s} \beta_{ij} \cdot \mu_j \qquad (18)$$

where μ_j are the membership functions for basic likeness criteria and $s=m-n-1$ is the level of complexity of a CP task. Likeness criteria are declared through membership functions for basic likeness criteria.

Normalisation and nullity vectors for double function are shown in:

$$d(\mu_j) = \prod_{i=1}^{m} \left(\frac{a_i}{\beta_{i0} + \sum_{j=1}^{t} \beta_{ij} \cdot \mu_j} \right)^{\beta_{i0} + \sum_{j=1}^{t} \beta_{ij} \cdot \mu_j} \times \prod_{k=1}^{p} \left(\sum_{i \in T_k} \left(\beta_{i0} + \sum_{j=1}^{t} \beta_{ij} \cdot \mu_j \right) \right)^{\sum_{i \in T_k} \left(\beta_{i0} + \sum_{j=1}^{t} \beta_{ij} \cdot \mu_j \right)} \qquad (19)$$

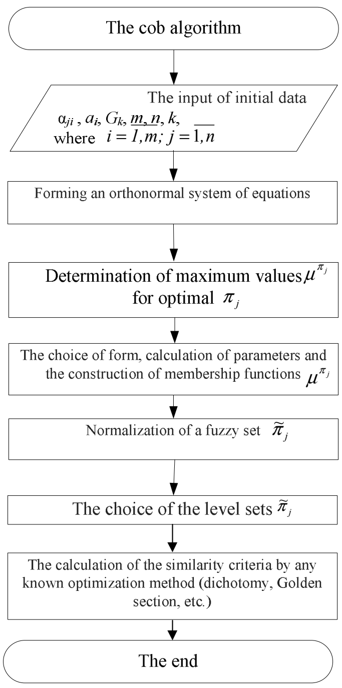

Figure 2. Block diagram of the algorithm that implements the procedure for determining optimum values of membership functions

Defining the membership function form the alternative approach was used. The best results were received using π function: m (x) = мS (x) мZ (x), where мS (x) - S-function, мZ (x) - Z-function. This function in Matlab has a name pimf, order of its parameters: [and b c d], where [a d] is the carrier of fuzzy set; [b c] - core of fuzzy set; [and b] - smf-function parameters smf, [c d] - zmf-function parameters zmf.

Membership function maximum for likeness criterion optimum meaning is defined as:

$$\mu^{\pi_j}(\pi_j) = \frac{a_j}{\sum_{i=1}^{m1} a_i} \qquad (20)$$

Fig. 2 shows a block diagram of the algorithm that implements the procedure for determining optimum values of membership functions, which after the substitution in (19) allows for determining the optimal values of criteria of similarity.

VI. Determination of Normative Characteristics of Technical Power Losses

The double function for (7) is as follows: maximize

$$d(\pi) = \left(\frac{A_{00}}{\pi_1}\right)^{\pi_1} \left(\frac{A_{11}}{\pi_2}\right)^{\pi_2} \left(\frac{A_{22}}{\pi_3}\right)^{\pi_3} \left(\frac{A_{01}}{\pi_4}\right)^{\pi_4} \left(\frac{A_{02}}{\pi_5}\right)^{\pi_5} \left(\frac{A_{12}}{\pi_6}\right)^{\pi_6} \left(\frac{B_0}{\pi_7}\right)^{\pi_7} \times$$
$$\times \left(\frac{B_1}{\pi_8}\right)^{\pi_8} \left(\frac{B_2}{\pi_9}\right)^{\pi_9} \left(\frac{\pi_{10}+\pi_{11}+\pi_{12}}{P_c}\right)^{(\pi_{10}+\pi_{11}+\pi_{12})} \qquad (21)$$

under conditions

$$\begin{cases} 2\pi_1 + \pi_4 + \pi_5 + \pi_7 + \pi_{10} = 0; \\ 2\pi_2 + \pi_4 + \pi_6 + \pi_8 + \pi_{11} = 0; \\ 2\pi_3 + \pi_5 + \pi_6 + \pi_9 + \pi_{12} = 0; \\ \pi_1 + \pi_2 + \pi_3 + \pi_4 + \pi_5 + \pi_6 + \pi_7 + \pi_8 + \pi_9 = 1. \end{cases}$$

A measure of complexity: $s = 12 - 3 - 1 = 8$

To find likeness criteria, it is used their similarity with the membership functions. Using the retrospective data, we train the adaptive network-based fuzzy inference system (ANFIS) network. It forms a training sample: the inputs are the values of the influential factors p_1–p_9, where $p_1=P_1$, $p_2=P_2$, $p_3=P_3$, $p_4=P_1^2$, $p_5=P_2^2$, $p_6=P_3^2$, $p_7=P_1P_2$, $p_8=P_1P_3$, $p_9=P_2P_3$ and the output is the planned technical value power losses for which condition (21) is satisfied. By substituion of the influential factors values into the equation we calculate the membership function and obtain the values of the likeness criterion. The likeness criterion is influenced by the type of membership function and its parameters. The type of membership function is chosen by a variant approach or involving experts.By the set values of the influential factors, the method calculates their approximate optimal values.

According to the approximate optimal values of the influential factors, we determined the value of the membership function, whereby, if the value of the influential factor belongs to two fuzzy sets at the same time, but with a different membership function, then the set for which the value of the membership function is greater is prefered. The likeness criterion is determined by the expression:

$$\pi_{membership.} = \begin{cases} \max(\mu_1(P_1), \mu_2(P_1)) & for \;\; \mu_1(P_1) \neq \mu_2(P_1); \\ \mu_1(P_1) & for \;\; \mu_1(P_1) = \mu_2(P_1), \end{cases} \qquad (22)$$

where the likeness criterion is calculated using the membership function.

We obtain the planned value of technical power losses by substituting the likeness criteria into expression (7). The optimal values of the influential factors, which could satisfy the planned value of the technical power losses, are calculated to find the criteria of similarity by the method of integral analogs, namely: $P_1 = \frac{\pi_7 y}{B_1}$, $P_2 = \frac{\pi_8 y}{B_2}$, $P_3 = \frac{\pi_9 y}{B_3}$ etc., where $y = \Delta P_{plan}$.

The submission of NCTV in the criterion form allows to control the change of the planned value of technical power losses depending on the deviation of influential factors from their optimal value:

$$y^* = \pi_1 P_1^{2*} + \pi_2 P_2^{2*} + \pi_3 P_3^{2*} + \pi_4 P_1^* P_2^* + \pi_5 P_1^* P_3^* + \pi_6 P_2^* P_3^* + \pi_7 P_1^* + \pi_8 P_2^* + \pi_9 P_3^* \quad (23)$$

VII. PVTPL Calculation on 750-110 kV Fragment of Ukraine Power Grid

To check the developed methods for solving the tasks of high complexity of the criterion programming (in the conditions of incompleteness of the initial data) and methods of calculating NVTPL we calculate the normative characteristic of the technical losses of the fragment of the Ukraine power grids network voltage of 750-110 kV, the scheme of which is shown in Fig. 3.

Method 1 represents the planned value of the technical power losses obtained by specifying the coefficients of the regulatory characteristics of technical losses by the criterion method using neuro-fuzzy modeling. Method 2 represents the planned value of the technical power loss defined by the coefficients calculated by regression analysis. Results of both methods are presented in Table I.

TABLE I. Results of calculation NVTPL of fragment of 750-110 kV Ukraine Power Grids

The value of the dual function d (π)	**NVTPL**		**The current value of technical power losses (MW)**	**Absolute error**		**Relative error**	
	1 method (MW)	**2 method (MW)**		**1 method (MW)**	**2 method (MW)**	**1 method (%)**	**2 method (%)**
38,97	38,97	40,95	38,87	0,1	2,08	0,26	5,35

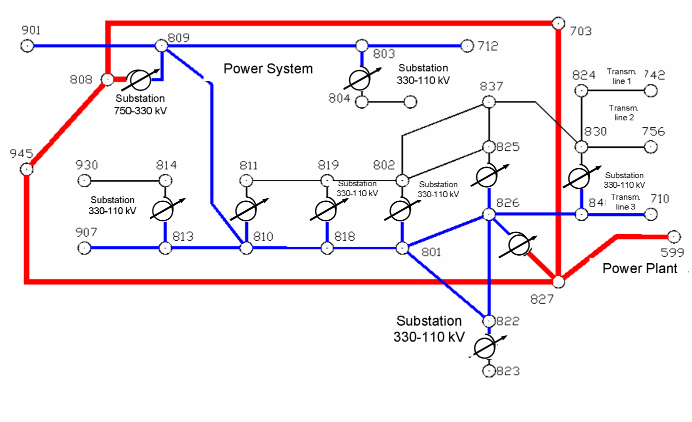

Fig. 3. Fragment of Ukraine Power Grids (red color reffering to 750kV, blue color to 330kV and black color to 110kV grid)

Conclusion

Known methods of determining the planned value of technical power losses are analyzed and the analytical and calculation method of determining the standard is selected for improvement. It is investigated what influential factors are more appropriate to choose for the formation of the normative characteristic of technical power losses (NCTPL). The use of neuro-fuzzy modeling and criterion programming makes it possible to present NVTPL in a criterion-based format that is more convenient for analyzing changes in influential factors.

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