Optimization OF Energy Losses IN Oil Industry OF Mangystau Region

Erzhanov Kaly, Kartbayev Amandyk

Abstract: The issue of efficient use of electric power due to a sharp increase in its cost is more pressing than ever. A reason requiring a reduction in electricity losses is the power networks that have exhausted their resource and can not manage the increased loads and need modernization. Optimization of electric power regime will help with reduction of production cost and preservation of competitiveness of enterprises. Currently, the main electricity consumers are non-linear, which cause distortions in the current and voltage curve, increase the level of reactive power, which in turn leads to additional losses of electrical energy and equipment failure. The most obvious solution of the problem is to reduce losses and increase network capacity. Neural networks were used to solve the task of optimizing the division of load of the most powerful electrical receivers by time to reduce peak load.

Index Terms: power distortion, electricity, neural networks, power quality, reactive power, higher harmonics.

1 INTRODUCTION

Kazakhstan has large reserves of energy resources (oil, gas, coal, uranium) and is a leading supplier of energy to the world market. The region generates its own energy mainly from gas. The only nuclear power plant in Kazakhstan was located in Mangistau with a 350MW fast neutron reactor. The plant operated in 1973-1999, and at present no nuclear energy is used in Kazakhstan. This article is intended to highlight the problems with electricity supply in the oil fields of Mangistau Oblast. Active power losses occurring in a network element (cable or overhead line, transformer, etc.) depend not only on the value of the flowing active power P, but also on the reactive Q:

$$\Delta P = \frac{P^2 + Q^2}{U^2} r \qquad (1)$$

Therefore, an important direction to reduce losses of active modality and energy is the compensation of reactive power. To solve the task of optimization of the electric network mode and loss reduction, it is necessary to know the distribution of power flows in the network branches. In connection with the operation of a large number of receivers, changes in the configuration of the electrical network, power flows are random processes, and, therefore, the definition of the distribution of flows is a complex problem, especially in the case of branched, ring networks.

One of the most common methods for calculating losses in an electrical network is the equivalent resistance method [1]. According to this method, it is necessary to find the equivalent resistance of some conditional unbranched circuit, the current in which is equal to the current on the main circuit section, and losses are equal to losses in the network. In this case, it is assumed that when the current at the head end changes, the currents and all other parts of the network change proportionally. However, it should be noted that this method of loss estimation is approximate and does not allow determining with high accuracy the distribution of currents in the electrical network of modern industrial enterprises, especially in the presence of sharp and variable loads, various factors affecting the technological process. At present, there are quite a few modern means to solve the above problem. Their appearance is first of all connected with the development of computational digital technology, a great number of specialized software means, and researches in the sphere of artificial intelligence. One of the most progressive and precise methods of solving the task is neural networks [2]. A neural network with error reversal was developed for forecasting. The neural network contains 7 neurons; the learning function is performed using the Levenberg-Marquardt back propagation algorithm. As a modeling tool it is proposed to use Simulink package of MATLAB software system. At modeling a mode of operation of an electric network, active and reactive overloading of consumers are set by independent casual processes with the normal law of distribution and exponential-cosine correlative functions [3]. Despite some disadvantages (complicated configuration, large sample of data for network training) neural networks have an undeniable advantage - during training they "learn" to recreate very complex dependencies taking into account many factors, which ultimately gives an advantage over traditional methods of forecasting [4,5]. Optimization of the reactive power mode in the simulated network is carried out with the help of compensating devices, the mode of operation of which is determined by the results of forecasting reactive loads. To solve such a problem, gradient optimization methods are usually used that use iterative algorithms of gradual approach to the optimal solution [6]. Practical confirmation of developed methods on increase of efficiency of modes of a distributive network by application of compensating devices is received.

2 OVERVIEW

Let's consider application of neural networks for the decision of a problem of calculation and reduction of losses on an example of a site of an electric network resulted in Fig. 1.

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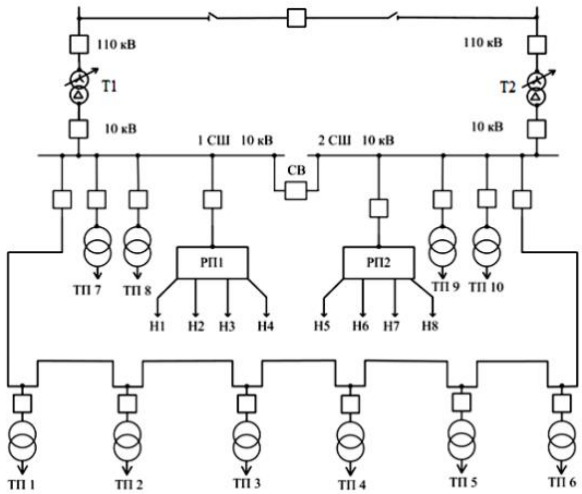

Fig. *1. The example of the site of the electric network*

The considered electric network co-contains both radial branches, and a ring section with six substations, receiving a power supply from two sections of bars of the main lowering substations of 10 kV. Parameters of casual processes of change of loadings of consumers were set as close as possible to parameters of work of industrial electric networks. The result of modeling of electric loads is shown in Fig. 2.

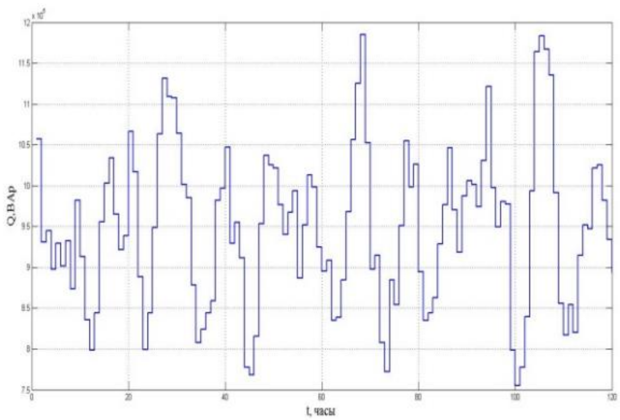

Fig. *2. The model of electric loads*

Features of power supply systems of the oil complex enterprises are large capacities of technological installations, specific character of loading of numerous electric receivers and their big territorial dispersion. At the same time, besides the enterprises of the oil complex there are other objects with their specific features, on which the problem of the quality of the electric power is manifested. For example, socially important objects, features of power supply systems of socially important objects are asymmetry of load, territorial concentration, sensitivity to the quality of electric energy. Electric complexes of oil industry enterprises and socially significant objects are considered as the objects of research, as examples of diverse enterprises. Distinctive features of the mentioned enterprises are presented below:

- for electrical complexes of oil industry enterprises: a large share of nonlinear load (about 90% of the installed capacity of the enterprise), a large length of transmission lines, a uniform schedule of consumption of electric energy, the remoteness of the source of electric energy, a long distance to the source of electric energy, powerful consumers, at the start of which there is a voltage failure;
- for electrical complexes of socially important objects: small length of power lines, large non-linearity coefficient, relatively small installed capacity.

Only one thing is obvious – at different enterprises the amount of losses will be determined differently by different indicators of electric energy quality. Further we will consider the basic indicators of quality of electric energy, influencing losses of energy in an electro technical complex of the enterprise, namely, in a part of system of its electrical supply.

On the basis of the conducted analysis the following indicators of quality of electric energy mostly influence on losses of electric energy:

- non-sinusoidal current or voltage curve;
- load power factor.

Let's consider each of them separately.

3 NON-SINUSOIDAL CURRENT

Non-sinusoidal current or voltage curves cause loads with nonlinear voltamper characteristics. These loads draw current from the mains, which turns out to be non-sinusoidal, characterized by the presence of higher harmonic currents. This results in nonlinear distortion of the mains voltage curve. Fig. 3 shows an example of the presence of harmonic distortions in the voltage curve. Using the Fourier transform, the curve can be broken down (in this case) into two components: the main or first harmonic and the fifth harmonic.

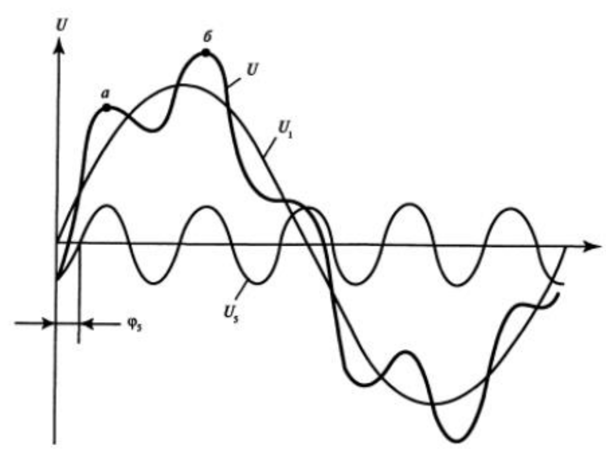

Fig. 3*. Decomposition of the non-sinusoidal curve into sinusoidal components*

Harmonic distortion creates magnetic fields of different sequences. The stress curves in the three-phase system are shifted by 120 degrees relative to each other, unlike the harmonic components of the sequence multiple of three. They form a zero sequence, in the case of a symmetrical load. Non-sinusoidality has a negative impact on consumers and electricity quality control devices. Thus, capacitors with higher harmonics in the network may fail due to current overload, as the capacitor resistance is inversely proportional to the order of the harmonic component. From this it can be concluded that capacitor banks under non-sinusoidal voltage or current conditions are primarily affected by them. In transmission lines, the harmonics cause additional energy losses, since the inductance resistance is directly proportional to the harmonic order:

$$X_{L(n)} = n * X_{L(1)} \quad (2)$$

As can be seen from the graph in Fig. 4, the inductance resistance increases linearly when a current containing harmonic distortion flows through it, and nonsinusoidal voltage and current indirectly affect power losses.

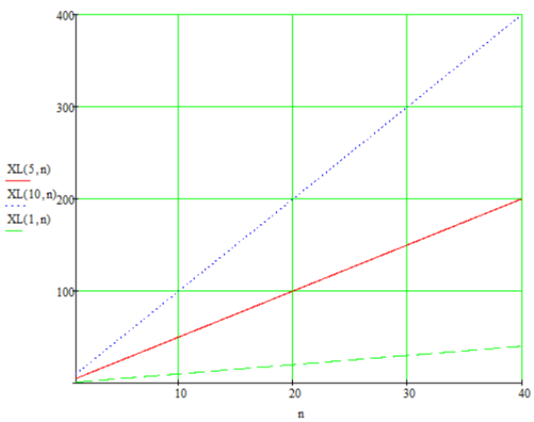

***Fig. 4**. Dependence of inductance resistance on the order of harmonic components at different resistances on the main harmonic*

As can be seen from the graph in Fig. 4, the inductance resistance increases linearly when a current containing harmonic distortion flows through it, and nonsinusoidal voltage and current indirectly affect power losses.

The full current module is defined by an expression:

$$I = \sqrt{\sum I_i^2}, \quad (3)$$

where I_i^2 is the square of the current action value of the i-th harmonics. This expression can be written as a form:

$$I = I_1 \sqrt{(1 + \frac{I_2^2 + I_3^2 + \cdots + I_n^2}{I_1^2})}, \quad (4)$$

where I_1 is the effective value of the first harmonic current. The non-sinusoidality of the curve is characterized by the concept of the total harmonic factor(THD):

$$THD_1 = \sqrt{\frac{I_2^2 + I_3^2 + \cdots + I_n^2}{I_1^2}} \quad (5)$$

Then by combining expressions (4) and (5) we get:

$$I = I_1 \sqrt{(1 + THD_1^2)} \quad (6)$$

It is known that in the general case the losses of active power are determined by expression:

$$\Delta P = 3 * I^2 R, \quad (7)$$

where: I - full current module in the line, R - active line resistance.

By combining expressions (6) and (7), we obtain an expression for determining power losses, indicating their direct dependence on the non-normalized non-sinusoidal value:

$$\Delta P = 3 * I^2 * (1 + THD_1^2) * R \quad (8)$$

Thus, we can conclude that the non-sinusoidality of the current curve directly affects the active power loss. This follows from expression (7). The non-sinusoidality of the voltage does not directly affect the active power loss, but it can also distort the sinusoidality of the current curve. It is established that losses in the presence of current distortions are determined by expression (8).

4 REACTIVE POWER

The nature of reactive power (reactive energy) is considered in detail in [7]. Reactive power (energy) does not create useful work. The reactive power and power factor are not indicators of the quality of electrical energy. However, a lot of attention is paid to these parameters. As has been said, reactive energy does not do any useful work, in the sense that it cannot turn into thermal or mechanical energy. The power factor is a value that shows what proportion of total power has become active:

$$K_M = \frac{P}{S}, \quad (9)$$

where: P – active power, S – full power.

There is also the notion of a reactive power factor:

$$tg(\varphi) = \frac{Q}{P}, \quad (10)$$

where: Q - reactive power.

It is worth noting that the reactive power factor is more accurate than the power factor for two reasons:

1. The power factor does not take into account the reactive power sign, while the reactive power factor shows the nature of the reactive power, inductive or capacitive in itself;
2. The power factor is not accurate at relatively small reactive power values. The drive of most drilling machines and mechanisms is an asynchronous motor with squirrel-cage rotor.

However, despite these disadvantages, it is the power factor that has spread, because the reactive power factor is only relevant to the main harmonic, while the power factor is applicable even in the presence of higher harmonic distortion of voltage and/or current in the network. If there is reactive power in the network, losses during transmission of electric energy are also determined by expression (7). However, the total current in this case is determined by expression:

$$I = \frac{I_A}{K_M}, \tag{11}$$

where: I_A - active component of current.

Ideally, the power factor is above 1. Obviously, as the reactive power share increases and therefore the power factor decreases, the full current module increases, increasing the amount of loss. In this case the active power losses are determined by expression:

$$\Delta P = 3 * \left(\frac{I_A}{K_M}\right)^2 R, \tag{12}$$

Thus, it is obvious that the reactive power increases the loss of electric power transmission by increasing the full line current. Influence of reactive power is characterized by power factor, at that it is established that losses are directly connected with and determined by expression (12). From the above we concluded that the impact of indicators of electric energy quality on power losses, in cases of their different deviations from the established parameters, is determined differently and should be carried out individually, depending on the type of enterprises with different types of load.

5 OPTIMIZATION METHOD

As a result of the conducted analysis of problems of quality of electric energy at the selected objects it was revealed the necessity of increase of their energy efficiency by means of reduction of total losses of electric energy in their electrical complex. Decrease in the level of total losses is made at the expense of decrease in the total factor of harmonic components of a current and increase in power factor. These factors can be changed in different ways: centrally - to install the appropriate equipment in a substation or distribution point; individually - to install equipment at a separate load; mixed - by combining the first two options. For effective correction of indicators of quality of electric energy in order to bring them into admissible limits, which will reduce losses of electric energy in the electrical complex and, as a consequence, reduce energy costs, it is necessary to use a set of corrective devices. At present, compensators are connected to the substation to which a non-linear load or a load with high reactive power consumption is connected. In this way, the company complies with the regulatory requirements for electrical power quality and reactive power consumption in relation to the grid organization. However, in internal networks the quality of electrical energy remains low and the network capacity is also reduced. In addition, the capacity of the compensating device should be sufficient to compensate for distortions and, in case of load changes, it should be possible to regulate the capacity of the compensating device. Thus, it is necessary to determine the loss of electrical energy as a multifactorial function and to optimize it. As a result of the optimization, we will determine where the compensation devices are installed, as well as their number. We will consider optimal such a set of compensating devices in which the effect of their use will be adequate in relation to the cost of their purchase. Comparative analysis showed that the most rational method for solving the task is neural network optimization for the following reasons: simplicity, low computational load and multiplicity of optimal solutions. According to the results of neural networks the minimum and sufficient set of correcting devices is determined at their maximum impact on the power quality.

To begin with, it is necessary to rank quality indicators by their impact on energy costs. Obviously, the cost of electricity is a multifactorial function, which depends on:

- time of year;
- the connected load;
- modes of operation of the enterprise;
- technical condition of the electrical complex;
- levels of distortion of electric energy quality.

Since it is impossible to cover the whole range of problems in the dissertation work, let us limit ourselves to the last point.

The level of distortion of electrical energy quality indicators is also a multifactor function, depending on:

- the composition of the electric load;
- electrical power of receivers, which distort the quality of electrical energy;
- modes of operation of the electrical complex;
- the spatial location of consumers within the electrical complex, i.e. the topology of the distribution network;
- the spatial location of the electrical complex in relation to the electric energy source.

Since the above factors are caused by the technological features of a particular enterprise, it is impossible to radically change them. On the basis of the above, the loss of electrical energy as a multifactorial function can be represented as follows:

$$\Delta P = f(P, L, Quality), \tag{13}$$

Where P - the electric power of receivers, which distort the quality of electricity; L - the spatial location of the electrical complex relative to the source of electric energy, i.e. the factor that takes into account the topology of the distribution network Quality - the indicators of the quality of electric energy, affecting the losses. To determine the place of connection of the compensating device it is necessary to determine the significant parameters of consumers and to rank them by their influence on the total losses of active power in the electrical complex of industrial enterprises. As a criterion for evaluation of the efficiency of the electrical complex of the industrial enterprise in the work the value of total losses of active power of the electrical complex in the distribution of electrical energy is accepted. Let's consider the size of total losses of active power as a system on which many factors influence and carry out the system analysis. System analysis is a sequence of actions to establish structural relationships between variables or constants of the system under study. Having carried out the system analysis it is obvious that the active power loss in the transmission line is a multi-factor function, depending on it: non-linearity of load, which is characterized by the concept of harmonic total; full load power - S, which includes active, reactive and distortion power; the active resistance of the transmission line - R, which in turn depends on the length of the transmission line - l, ambient temperature - t, the material of the transmission line - ρ, and the cross section of the transmission line wires. We rank consumers by their influence on the value of active power losses in the electrical complex. Definition of active power losses, applying all possible parameters, is inexpedient and irrational in terms of the volume of calculations and the need to store a large amount of data, not to mention the fact that it is often impossible to obtain some of the data due to their absence. To do this, it is necessary to identify the factors that have a greater influence on the amount of loss, while neglecting the other factors. The result is a Z function that shows which consumer is contributing more to the active power loss (14). Thus the task is reduced to the search of dependence:

$$Z_i = \frac{\left(S_i^2 - P_i^2\right) t_i^2 \rho l_i U^2 \sin(\varphi) d}{U^2 \sin(\varphi) d (S_s^2 - P_s^2) t_s^2 \rho l_s}, \qquad (14)$$

To rank consumers in terms of their contribution to active power losses, it is necessary to understand that the losses are ultimately affected by the current in the transmission line. Therefore, to reduce losses it is necessary to reduce the current. Current is directly proportional to full power, and full power includes active and reactive components. The active component cannot be reduced. The reactive component, however, can be reduced to zero by increasing the power factor. Thus, when determining the contribution of consumers to active power losses, it is necessary to take into account the active power of the consumer and its power factor. In view of the above, a number of assumptions have been adopted for further investigation, namely:

- specific resistance of power line wires is the same;
- cross sections of transmission line conductors at one enterprise are adopted equal to each other;
- distortion power is not taken into account;
- voltage in the electrical complex of the enterprise is the same at all its points.

After determining the numerical values of the Z function for each consumer it is necessary to rank them in descending order of the found values. In order to validate the results, a simulation was carried out, the results of which prove the validity of the expression. The power loss reduction graph represents a multitude of solutions from which the most rational one can be selected.

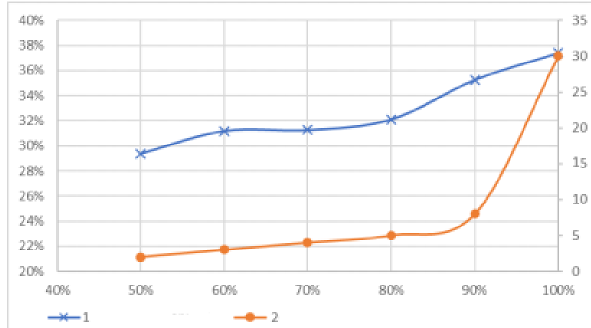

***Fig. 5**. Dependence of total power loss*

The analysis of the charts in Fig. 5 shows that compensation for distortions created by 80 % of consumers allows to reduce losses of electric energy by 32 %, and at compensation of distortions from all consumers only by 37,4 %. At the same time, the cost of compensating devices with 80% compensation is much lower than with all distortions. The results of the simulation showed that expression (14) with low computational power consumption allows to determine the points of connection of compensating devices as well as their number.

The algorithm of connection points selection of compensating devices is formed and the program allowing to define connection points of compensating devices is written. The algorithm includes the following steps:

1. bring the circuit to one voltage level;
2. to determine the number of consumers under consideration;
3. measure the active power, the power factor, the total factor of harmonic components and the length of the transmission line to of the consumer;
4. enter the initial data into the program;
5. the program determines the connection points of the compensation devices on the basis of the entered data.

As a result of the calculations, the program will determine the necessary and sufficient number of compensating devices and their installation location. Equipment required for data acquisition: fixed or portable power quality analyser, or a functioning data acquisition system (provided that the specified parameters can be measured). After receiving the data, the calculation must be carried out according to expression (14). The calculation is done automatically in the developed program. It should be noted that the data entered in the program should correspond to the maximum active power. After performing the calculation, the developed program ranks the obtained values by their reduction and displays the result as a histogram. Further, the resulting histogram is overlaid with the curve of accumulated percentage . Setting the level of accumulated percentage (usually 80%) determines the area of priority measures, consumers who are in this area make the greatest contribution to the total power loss and distortion, which they create, are subject to priority compensation. When algorithmizing the capacitors' operation it is necessary to take into account possible emergency situations affecting the consumer's operation and, in case of the consumer's failure or change in the mode of its operation, the capacitors' control algorithm should not allow overcompensation of reactive power and react to these changes accordingly. It follows from the foregoing that continuous measurement of power factor and/or total harmonic factor of current components and maintenance of these parameters at a given level are necessary in the process of capacitors operation. When measuring the electrical energy quality, the power factor, in the presence of current curve distortions, should be calculated according to [8]. The scheme of calculation is shown in Fig. 6.

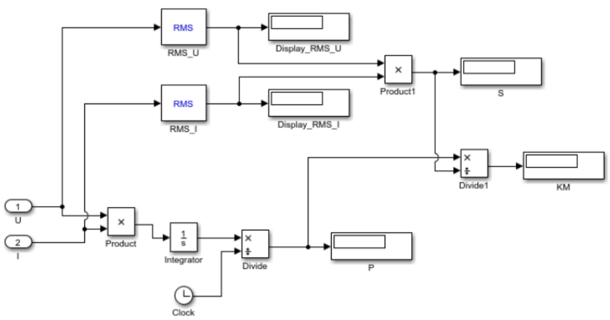

***Fig. 6**. Power factor measurement*

6 LOAD PREDICTION

Currently, the following are taken into account when making the short-term forecast of electric loads of the energy system: graph of electric loads of the current day and the corresponding day of the previous year; weather forecast (average outdoor temperature for the coming day; duration of the light day, i.e. time of sunset and sunrise; possibility of atmospheric precipitation or cloudiness); proposals of energy systems to provide electricity to consumers; operation mode of the largest consumers. Additional factors taken into account when forecasting the load for the next day include: the day in question is included in the day of the heating season or not, and the clock hands are one hour forward or backward. The main disadvantage of the existing load forecasting methods is the need to build a load model. To avoid this, the neural network forecasting technology is used. Neural network construction is solved in two stages: selection of neural network type (architecture) and selection of weights (training) of the neural network. In [9] it is noted that the variety of factors influencing the value of electric loads in combination with high nonlinearity of the investigated dependences essentially complicates the use of classical methods of mathematics for the solution of this problem. Existing methods of forecasting of electric loads based on application of statistical methods cannot provide necessary quality of forecasts in modern conditions and do not satisfy to a number of requirements among which accuracy of the forecast, stability to errors, simplicity of use, possibility of realization as a part of the automated systems of the account of electric power are the most significant. The reason of such discrepancy lies, first of all, in the fact that for the studied dependencies, due to their nature, the limitations imposed by statistical methods on empirical data are not quite fulfilled. This is an artificially introduced assumption about the stationarity of the process and the consequent requirements for the dispersion stability, etc. In addition, the high degree of nonlinearity of the trend does not allow accurate approximation by using polynomial or exponential models. One of the most promising alternatives of regression analysis is the use of artificial neural networks.

The use of prediction methods based on the application of neural networks provides a number of advantages over traditional methods of statistics, among which the most important, in relation to this task are:

- the ability to obtain accurate representations based on empirical data without human intervention;
- the possibility of automatic adaptation of the model to changes in the parameters of electrical installation and environmental conditions;
- low sensitivity to inaccuracies in initial information. The inaccuracies in the initial data are smoothed out and have minimal impact on the final result;
- ability to function with incomplete input data. A specially trained neural network can fill gaps in the data set;
- high reliability. Neural networks are able to function correctly even if some neurons are damaged due to redundancy of information.

In [10] developed methods and models of forecasting electric load of power systems are compared. The analysis of developed methods of forecasting has shown that their practical application is connected with certain difficulties. Some methods lead to significant errors in the estimation of predicted values, others due to the complexity of the mathematical apparatus have not received wide application for the solution of practical problems of electric power industry. That is why the problem of development of load forecasting methods is very actual. Among the previously developed methods of forecasting the following approaches can be distinguished:

- autoregression. The following form of autoregressive model can be applied:

$$L(t,d) = \sum_{k=1}^{n} a_k L_k(t,d), \tag{15}$$

where: a_k - linear weights providing the optimal combination of four separate forecasts; $L_k(t,d)$- forecast based on the first order autoregressive model with a delay of 1 hour;

RMS errors of daily forecasting of electric load on the basis of this approach, according to the data do not exceed 4%.

- generalized exponential smoothing. The generalized exponential smoothing method can be used to predict total hourly workloads:

$$L(t) = a^T f(t) + \varepsilon(t), \tag{16}$$

where: a^T - is a transposed vector of exponentially smoothed weights; $f(t)$ - is a vector of smoothing functions.

Smoothing functions are decomposition in the Fourier series over a period of one week. However, in addition to the above-mentioned load forecasting methods, a new approach based on fuzzy logic and neural networks is now being applied, which has absorbed the properties inherent in these directions. The functions performed by neural networks include approximation, classification, prediction and estimation. Their preference to traditional models is caused by that it is not required construction of model of object, working capacity at the incomplete input information is not lost. However neural networks nevertheless possess lacks. It is known that neural networks can automatically acquire, accumulate knowledge. But process of their training occurs slowly enough, and the subsequent analysis of already trained neural networks is difficult. Many of these drawbacks can be solved by using systems with fuzzy logic. The random, probabilistic nature of changes in the power system load is one of the essential features of the process. Due to the presence of a random component, natural growth of the load and the influence of various factors, there is no strict periodicity in the load diagrams. Previously proposed numerous methods of predicting the electrical load in practice face certain difficulties. As a result, new methods for forecasting the load appear: neural networks and fuzzy neural networks. These new approaches deserve some attention. Moreover, from the practical point of view, the issues of accuracy of forecasting the proposed methods on the basis of minimum learning error, learning time and minimum forecasting error are important. The best neural network was chosen, which was created with the help of the function of creating a type of multilayer neural network with the reverse propagation of the error and the logistic activation function. The proposed neural network is optimal for predicting electrical load both on workdays and weekends. Fuzzy neural network is a type of artificial intelligence systems, which combines the basic properties inherent in neural networks and systems with fuzzy logic. Practical realisation of fuzzy neural networks for the decision of a problem of daily forecasting of electric loading is carried out in package Simulink of system MATLAB[2].

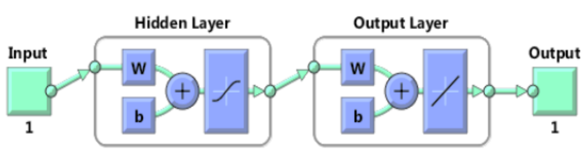

Fig. 7. *Network structure for forecasting electrical loads*

It was found out that the method based on fuzzy neural network is the best from the point of view of forecasting accuracy. The average forecast error of this method was 2.5% for working days and 1.5% for weekends. The regression analysis has the highest forecast error among the compared methods - 3.5% for working days and 3.0% for weekends. For the neural network, the average forecast error was 2.9% for working days and 2.1% for weekends. Based on the above, the optimal tool for forecasting electrical loads by mistake is a forward propagation neural network (multilayer perseptron) or a fuzzy neural network.

7 RESULT AND DISCUSSION

The knowledge of load diagrams allows to determine the size of cross sections of wires and cores of cables, to estimate voltage losses, to choose power generator capacities of power plants, to calculate power supply systems of designed enterprises, to solve technical and economic issues, etc. A great influence on the energy efficiency of the enterprise is the regulation of the daily schedule of load of the electrical complex of the enterprise. In case of its leveling, there is a reduction in specific fuel consumption for power generation, reduction of required for covering peak loads of installed capacity of power plants, reduction of energy losses in power networks. Energy losses during transmission can be identified in a separate group, which is typical for the vast majority of enterprises. Analysis of load diagrams showed that different enterprises have different consumption and active and reactive power ratio. There are periods when the reactive power at minimum level and to compensate it can be inexpedient from the economic point of view. The neural network under consideration shows sufficient efficiency only if there is sufficient initial data on the electrical loads of the outgoing connections, which can be obtained only at the node. The load change processes at each branch of the ring network are usually unknown. In order to solve the task in these conditions it became necessary to create a neural network allowing to make a forecast of electric loads with a lack of initial information. One of the options for obtaining data for neural network training is to measure loads on the connections under consideration at a discrete rate of 1 hour within several days, with simultaneous recording of data on average loads. Further, only the average loads of the previous period are recorded in the neural network for forecasting. The essence of applying this method to the problem being solved is as follows. At reception of the forecast of consumption of jet load for the next time interval modelling of work of a network with predicted values of capacities of compensating devices is made. Then, the compensation capacity of each compensating device changes in a certain range of values (from 0.8 to 1.3 of the predicted required capacity of compensating devices) and the costs associated with the reactive power are estimated. The optimal capacity of the compensation devices corresponds to the minimum costs in the simulated network. This approach allows all cost components to be taken into account by means of the Simulink package and the optimum reactive power mode to be created in the electrical network from an economic point of view. For comparison of economic effect at introduction of modern methods of optimization of a mode of jet power the modelling of work of an electric network in three cases is made:

1) Operation without compensating devices. Modeling of the given network is necessary first of all as a basis for comparison of efficiency of developed methods of optimization. Besides, this situation is possible for urban substations, many of which do not have compensating devices.
2) Simulation of a network with compensating devices mounted on nodes. When compensation devices are installed on 10 kV buses, the capacity of compensation devices is predicted using an algorithm that assumes complete data for forecasting and further compensation of reactive power.
3) Simulation of the network from compensators installed at the node and substations connected to the ring distribution network. Installation of compensation devices only at the

head sections allows to improve the reactive power mode in the network, while reducing financial costs due to reactive power flows.

However, in many cases this may not be sufficient, because even if an acceptable power factor is reached at the point of separation of the balance of reactive power flows in the ring section of the network, it can cause an increase in costs due to power losses. For this reason, it is advisable to install compensation devices at different points in the network ring section. To solve this problem, a neural network capable of predicting electrical loads at incomplete data was developed and created.

8 CONCLUSION

The analysis of modes of a distribution network of the enterprise with various character of technological process, topology of a distribution network and loading is carried out, deviations of indicators of quality of electric energy from the set level are revealed. The analysis and selection of the effective method of multidimensional optimization for its further use in the optimization on the criterion of minimum power losses of the modes of the distribution network of the enterprise in the presence of various distortions in voltage and current were carried out. Methodological support of search of the decision of a problem on increase of efficiency of use of compensating devices at various functional dependences of power losses on indicators of quality of electric energy is developed. The computer program allowing to define connection points and parameters of compensating devices according to the developed technique is written. A simulation model has been developed, which adequately reflects the obtained analytical results and confirms the correctness of the obtained expressions and results.

REFERENCES

[1] T.N. Barchenko, R.I. Zakirov, Electrical supply of the industrial enterprises. Tomsk: TPI Publishing House, 1989.
[2] V.S. Medvedev, V.G. Potemkin, Neural Networks. MATLAB 6. Moscow: DIALOG MEPHI, 2002.
[3] P.S. Zhdanov, The Problems of Stability of Electric Systems, Moscow: Energia, 1979.
[4] A. Kartbayev, U. Tukeyev, S. Sheremeteva, A. Kalizhanova, B. Kalybek Uuly, Experimental study of neural network-based Word alignment selection model trained with Fourier descriptors. Journal of Theoretical and Applied Information Technology, vol.96, no.13., 2018, pp.4103-4113.
[5] A. Kartbayev, Refining Kazakh Word Alignment Using Simulation Modeling Methods for Statistical Machine Translation. Lecture Notes in Computer Science. Springer, Vol. 9362, 2015, pp. 421-427.
[6] Benn D.V., Farmer E.D. Sravnitelnye modeli prognozirovaniya elektricheskoy nagruzki. Moscow: Energoatomizdat, 1987.
[7] Y.S. Zhelezko. Loss of electricity. Reactive power. Electric power quality: Manual for practical calculations. Moscow: ENAS, 2009.
[8] T.T. Omorov, B.K. Takyrbashev. To the problem of the asymmetric operation modes optimization of the distribution networks. Devices and systems. Management, control, diagnostics, Issue 9, Moscow: Naukhtekhlitizdat Publishing House. 2016, pp.11-15.
[9] T.A. Sadykbek, R.E. Matov. Methods and Technical Tools of Improving the Electric Power Quality. Bulletin of the Kazakh Academy of Transport and Communications named after M. Tynyshpaev, Issue 6 (91). 2014, pp. 149-154.
[10] D. Srinivasan, Evolving artificial neural networks for short term load forecasting. Neuro Computing, Elsevier, Issue 23, 1998, pp.265–276.