13. Зенкевич О. Метод конечных элементов в механике. – М.: Мир, 1975. – 524 с.
14. Д. Норри, Ж. де Фриз. Введение в метод конечных элементов: Пер. с англ. – М.: Мир, 1981. - 304с.

T. Kwater
University of Rzeszow. Institute of Technology, Rzeszow, Poland

ARTIFICIAL NEURAL NETWORK AS A TOOL OF CYCLOCONVERTER DIAGNOSTIC

1. Introduction

Consideration of identification problem with using artificial neural networks (ANN) allows to receive fast answer about structure of object and values of its components parameters. Such approach in non invading way shorten process of analysis. ANN are modern tool which can be using in diagnostic and identification [7, 8]. Such realization base on analysis of signal containing information about diagnosed object. However it requires appropriate design of net and learning of proper reactions. The learning process can be realized base on results of simulations obtained from mathematical model. Of course models must as faithfully as possible reflect real behavior of object. Moreover continuous signals obtained from mathematical model usually have to be submit for additional processing in order to receive data which can be used in ANN learning. In that paper identification of condenser capacity in cycloconverter by proper chosen neural network is presented. Net was learned using Levenberga-Marquardt'a method. Learning series was obtained by distribution current in orthogonal functions series. The purpose of this paper is presentation of ANN application in identification. Presented problems were part of University Grant, "Applying of artificial neural network to analysis, synthesis and diagnostics in electrical engineering", in 1998. Part of these solved problems were used in Ph. D. thesis. Future work should lead to design and build intelligent monitoring system of such electrical devices.

2. Model of cycloconverter

Model of cycloconvertor requires transformer and semiconductor elements description by mathematical formulas. The simple way to describe thyristors is make assumption that it is short-circuit when is in conduct state and open in non-conduct state. Transformer usually are modeled basing on equations obtained by analysis of electric circuit. Seems, that using theory of electro-magnetic circuits is more convenient. Advantage of such approach are simpler mathematical equations describing device. Mathematical model can be obtained

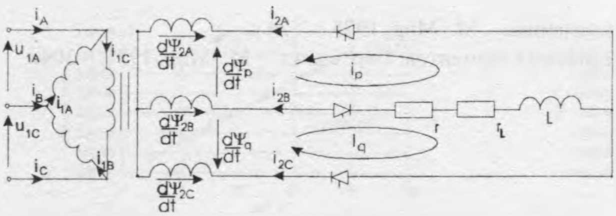

Fig. 1. Scheme of three-phase bridge rectifier in case where phases *CB* and *AB* are working

by writing equations for electric sub-circuit and for magnetic sub-circuit and carrying out analysis of different working states of three-phase rectifier.

The analysis of electric circuits shown on Fig. 1 allows to write down following formulas:

$$\frac{d\Psi_D}{dt} = \frac{d\Psi_D}{dt} + \mathbf{L}\frac{di_{2B}}{dt}, \quad \frac{d\Psi_D}{dt} = -\mathbf{R}_2\mathbf{I}_D,$$

where: $\mathbf{L} = (L, L)^T$.

Using known dependences for three-phase transformer we get:

$$\frac{d\mathbf{X}}{dt} = \mathbf{B}(\mathbf{U} - \mathbf{RI}),$$

where: $\mathbf{X} = (\psi_A, \psi_B, \psi_C, i_p, i_q)^T$ - column matrix of associated flux and eye current of transformer secondary winding; $\mathbf{U} = (u_{1A}, u_{1B}, u_{1C}, 0, 0)^T$ - column matrix of voltage; $\mathbf{I} = (i_{1A}, i_{1B}, i_{1C}, i_p, i_q)^T$ - column matrix of windings current; $\mathbf{R} = \mathrm{diag}(\mathbf{R}_1, \mathbf{R}_D)$ - matrix of resistances;

$$\mathbf{R}_D = \begin{array}{|c|c|}\hline r_{2A}+r_{2B}+r+r_L & r_{2B}+r+r_L \\ \hline r_{2B}+r+r_L & r_{2B}+r_{2C}+r+r_L \\ \hline\end{array}$$

; $\mathbf{B} = (\mathbf{D}, \mathbf{A}_2)^T$ - matrix of coefficients; $\mathbf{D} = (\mathbf{G}\boldsymbol{\alpha}_1, \mathbf{GH}_2\boldsymbol{\alpha}_{21})$; $\mathbf{G} = (\boldsymbol{\alpha}'' + \boldsymbol{\alpha}_0\mathbf{Z} + \boldsymbol{\alpha}_1 - \mathbf{H}_2\,\boldsymbol{\alpha}_{22})^{-1}$; $\mathbf{A}_2 = (\boldsymbol{\alpha}_{22}\mathbf{G}\boldsymbol{\alpha}_1, \boldsymbol{\alpha}_{21} + \boldsymbol{\alpha}_{22}\mathbf{GH}_2\boldsymbol{\alpha}_{21})$; $\boldsymbol{\alpha}'' = \mathrm{diag}(\alpha_A'', \alpha_B'', \alpha_C'')$; $\boldsymbol{\alpha}_1 = \mathrm{diag}(\alpha_{1A}, \alpha_{1B}, \alpha_{1C})$; $\boldsymbol{\alpha}_\Phi = \mathrm{diag}(\alpha_{AB}, \alpha_{AC}, \alpha_{BC})$; $\boldsymbol{\alpha}_2 = \mathrm{diag}(\alpha_{2A}, \alpha_{2B}, \alpha_{2C})$; $\boldsymbol{\alpha}_{21} = \mathbf{H}\ \ \boldsymbol{\alpha}_\Phi\mathbf{H}^T$; $\boldsymbol{\alpha}_{22} = \mathbf{H}\boldsymbol{\alpha}_\Phi\mathbf{H}_1$;

$$\mathbf{H} = \begin{array}{|c|c|c|}\hline 1 & -1 & \\ \hline & 1 & 1 \\ \hline\end{array}; \quad \mathbf{H}_1 = \begin{array}{|c|c|c|}\hline -1 & 1 & \\ \hline 1 & & -1 \\ \hline & 1 & -1 \\ \hline\end{array}; \quad \mathbf{H}_2 = \begin{array}{|c|c|}\hline 1 & \\ \hline -1 & -1 \\ \hline & 1 \\ \hline\end{array}; \quad \mathbf{Z} = \begin{array}{|c|c|c|}\hline 1 & 1 & 1 \\ \hline 1 & 1 & 1 \\ \hline 1 & 1 & 1 \\ \hline\end{array}.$$

Magnetic circuit depicted on Fig. 2 can be described by dependence

$$\mathbf{I}_1 = \boldsymbol{\alpha}\,\boldsymbol{\psi} + \alpha_0\mathbf{Z}\boldsymbol{\psi} - \mathbf{H}_2\mathbf{I}_D,$$

where: $\boldsymbol{\psi} = (\psi_A, \psi_B, \psi_C)^T$; $\boldsymbol{\alpha}' = \mathrm{diag}(\alpha_A', \alpha_B', \alpha_C')$.

The presented analysis describes only one of work state of device. Considering remaining six cases and adding second inversely affixed thyristor parallel to existing we can come to final form of formulas describing cycloconverterr with *LC* load.

$$\frac{d\mathbf{X}}{dt} = \mathbf{MY}.$$

where: $\mathbf{X} = (\psi_A, \psi_B, \psi_C, i_p, i_q, u_c)^T$ - column matrix of associated flux and eye current of transformer secondary winding and condenser voltage; $\mathbf{U} = (u_{1A}, u_{1B}, u_{1C}, -u_c, -u_c)$ - column matrix of primary and secondary voltage of transformer; $\mathbf{Y} = (\mathbf{U} - \mathbf{RI}, i_c)$; $\mathbf{I} = (i_{1A}, i_{1B}, i_{1C}, i_p, i_q)$ - column matrix of windings current; $i_c = i_p + i_q - u_c/r$ - condenser current; $\mathbf{M} = \mathrm{diag}(\mathbf{B}, 1/C)$ - matrix of coefficients.

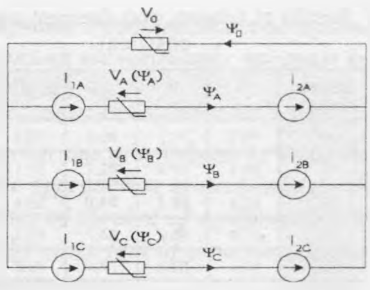

Fig. 2 Scheme of transformer magnetic sub-circuit

3. Data preprocessing

Direct learning of artificial neural network by data obtained from mathematical model is difficult and often practically impossible. It comes from fact that length of input vector is big therefore number of neurons in input layer and network size is also big. Moreover using data directly from model causes dependence on "moment of time" - calculations have to start always in the same moment of period. Application of method which will eliminate such inconvenience is necessary. If period T of analyzed signal is known that the most simple solution seems approximation that signal by orthogonal function system. In such system each of functions bring element which doesn't exist in another function of that system. Most often some first elements of orthogonal system already good enough approximate analyzed signal. Thus in network learning is enough to use parameters describing only these functions. In our investigations Fourier and Walsh series taking first seven harmonics were used. Number of harmonics was chosen after early testing.

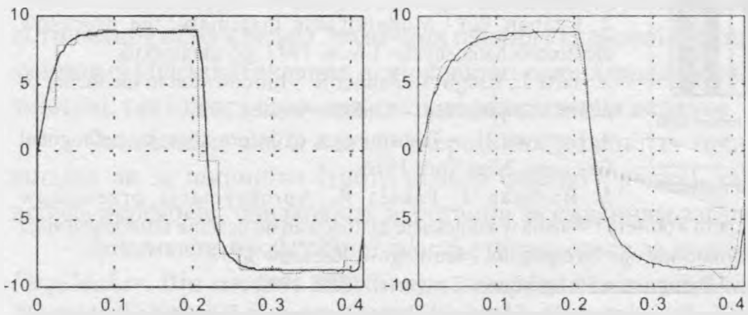

Fig. 3. Example distribution of analyzed current in Walsh and Fourier series

3. Artificial neural network

Feedforward nets with one hidden layer learning backpropagation method were used in our investigations. Input layer consist of 15 neurons (number of elements in input vector) and output layer has 1 neuron because network recognized capacity of filtering condenser. ANN with 10, 15, 20, 25 and 30 neurons in hidden layer were tested. Neurons in hidden layer has tangent transfer function.

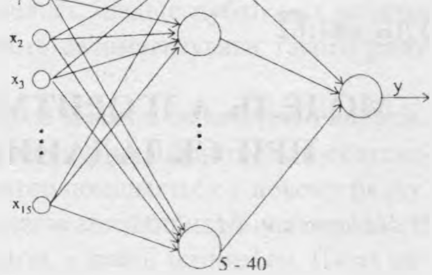

Fig. 4. Scheme of ANN designed to condenser capacity identification

4. Results of experiments

Proper identification of condenser capacity in range from 10-5 to 9 10-3 F is the task for artificial network. An assumption that net properly recognizes

Results of network work (percent of proper answers)

SSE\no. neron?w	10	15	20	25	30
10^{-5}	73,2	77,7	88,5	73,3	38,2
10^{-6}	81,1	87,3	**92,7**	87,1	40,4
10^{-7}	82,9	**92,3**	**94,0**	88,4	42,2
10^{-8}	72,9	85,2	84,7	83,4	41,9
10^{-9}	67,5	83,1	77,4	73,2	38,8
10^{-10}	62,0	80,5	75,7	67,4	34,0

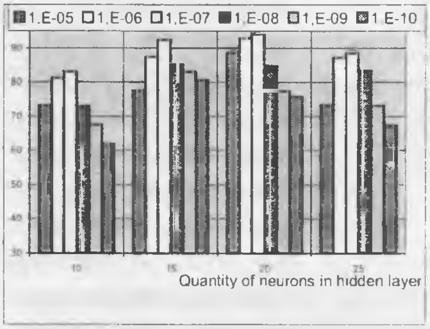

Fig. 5. Efficiency of artificial neural network

capacity when difference between real value and value from net is less than 0.01. Because ANN were learned only in some points therefore that task required from net ability to interpolation of condenser capacity values base on current course. In table 1 results of network work are shown.

Efficiency of ANN reaches 95% for 15-20 neurons in hidden layer. It is worth noting that short term learning and long term learning leads to worsening of condenser capacity identification.

1. Bartman J. - Wplyw wybranych parametrow sztucznych sieci neuronowych na dokladnosc identyfikacji elementow urzadzen energoelektronicznych - rozprawa doktorska AGH Krakow 1999.
2. Czaban W. - Modelowanie matematyczne procesow elektromechanicznych - Lwow 1997 (po ukrainsku).
3. Hertz J., Krogh A., Palmer R. - Introduction to the theory of neural computatiom - Addison-Wesley 1991.
4. Hermuth H. - Transmission of information by orthogonal functions. New York 1970.
5. Bartman J. Pekala R. Aproksymacja przebiegow przejsciowych ortogonalnymi funkcjami Fouriera i Walsha w kontekscie zastosowan do uczenia sztucznych sieci neuronowych - Materialy V Miedzynarodowego Sympozjum Metrologow. Rzeszow 1997.
6. Neft Ch. Schauder C. - Theory and Design of a 30-hp Matrix Converter. IEEE 1992
7. Kwater. T, Tejchman M., Szostek Z., Kwiatkowski B., "Artificial Neural Network In Diagnostic Problem Of Rectifier System". Proceedings of 4th IMACS Symposium on Mathematical Modelling, Vienna, Austria, 2003.
8. Nalecz M., Biocybernetic and biomedic engineering, Volume 6, Neural network, AOW "Exit", Warsaw, 2000.

М. Назаркевич
Національний університет "Львівська політехніка"

УДК 681:62

МОДЕЛЬ АЛГОРИТМУ АВТОМАТИЗАЦІЇ ОПЕРАЦІЙ ПРИ СКЛАДАННІ ТЕЛЕВІЗІЙНИХ ПРОГРАМ

Розглядається питання автоматизованого верстання програм телебачення шляхом побудови математичних моделей алгоритмів та їх апробації. Моделі