Angular Velocity's Neural Network Observer of the Electric Drive of TVR - IM Type Implemented in Software Environment LabVIEW

L Kozlova[1], E Bolovin[1] and L Payuk[2]
[1]Assistant, National Research Tomsk Polytechnic University, Tomsk, Russia
[2]Senior Lecturer, National Research Tomsk Polytechnic University, Tomsk, Russia

E-mail: kozlovale@tpu.ru

Abstract. One of the common ways to manage a smooth starting and stopping of asynchronous motors are soft-start system. For this provision is necessary to use a closed speed asynchronous electric drive of tiristor voltage regulator - induction motor (TVR-IM) type. Using real sensors significantly increases the cost of installation and also introduces a number of inconveniences in the operation of the actuator. Observer has clear advantages that are created on artificial neural network. Creating a neural network observer in program graphic programming LabVIEW will allow to evaluate the speed of rotation of the asynchronous electric.

1. Introduction

Using of real sensors in the system of control of asynchronous electric drive of TVR-IM type technically and not economically justified. There are several advantages in the neural network based on which the observer was established: robustness, ease of establishment, there is no need to know the internal drive parameters, and others.

The article proposes to implement the neural network observer of angular velocity in the software environment graphical programming LabVIEW [1]. Currently artificial neural network (ANN) [2] is used in industries such as autonomous control, robotics, computers, and others.

This software product is useful in programming the sensors, graphical representations of various processes et al., created through a broad range of virtual instruments (VI) and functions for collecting, analyzing, displaying, and storing data. LabVIEW can visually identify and correct errors in the code. LabVIEW consists of three main parts: the front panel, block diagrams and subVI. The front panel is the user interface of the virtual instrument. To manage objects that are located on the front panel, using graphical representations of functions placed on the block diagram.

2. Experimental

Neural network observer consists of two main parts: the block of data preprocessing and neural network. The block diagram of such an observer, implemented in the software environment LabVIEW, is shown in figure 1, contains four subVI that act as a block of data preprocessing and a model of the observer. The block diagram contains four oscilloscopes. Block «Wait Until Next ms Multiple Function», with a constant of 0.00005, organize frequency of data collection.
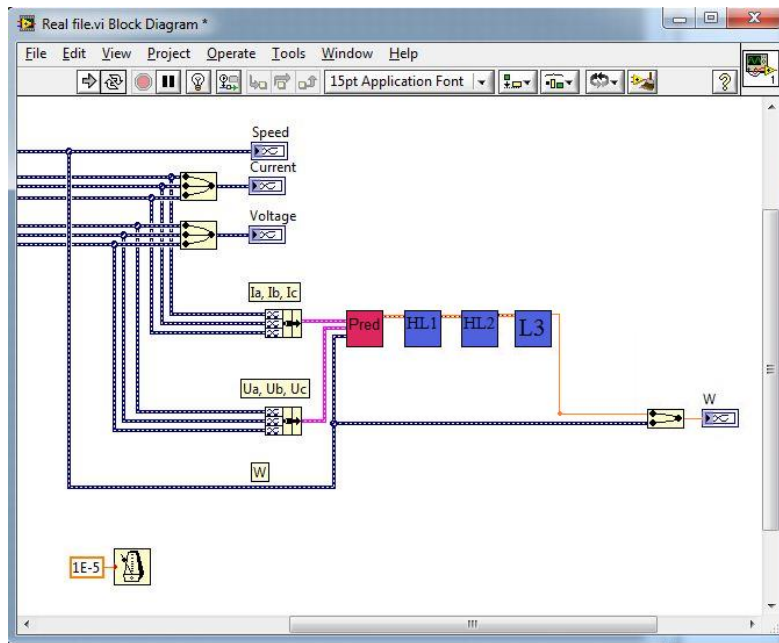
Figure 1. The block diagram of the simulation model.

On the block preprocessing data receives signals from the current and voltage sensors, which converts the signal and the delays in the polar coordinate system. The delay block uses only three current and three voltage:

$$I_M(t) = \sqrt{I_A(t)^2 + I_B(t)^2 + I_C(t)^2} \, ;$$

$$I_M(t - \Delta t) = \sqrt{I_A(t - \Delta t)^2 + I_B(t - \Delta t)^2 + I_C(t - \Delta t)^2} \, ;$$

$$I_M(t - \Delta 2t) = \sqrt{I_A(t - \Delta 2t)^2 + I_B(t - \Delta 2t)^2 + I_C(t - \Delta 2t)^2} \, ;$$

$$I_M(t - \Delta 3t) = \sqrt{I_A(t - \Delta 3t)^2 + I_B(t - \Delta 3t)^2 + I_C(t - \Delta 3t)^2} \, ;$$

$$U_M(t) = \sqrt{U_A(t)^2 + U_B(t)^2 + U_C(t)^2} \, ;$$

$$U_M(t - \Delta t) = \sqrt{U_A(t - \Delta t)^2 + U_B(t - \Delta t)^2 + U_C(t - \Delta t)^2} \, ;$$

$$U_M(t - \Delta 2t) = \sqrt{U_A(t - \Delta 2t)^2 + U_B(t - \Delta 2t)^2 + U_C(t - \Delta 2t)^2} \, ;$$

$$U_M(t - \Delta 3t) = \sqrt{U_A(t - \Delta 3t)^2 + U_B(t - \Delta 3t)^2 + U_C(t - \Delta 3t)^2} \, ,$$

where $I_A(t)$, $I_B(t)$, $I_C(t)$, $U_A(t)$, $U_B(t)$, $U_C(t)$ - a designation vectors of current and voltage.

Block diagram of the data preprocessing shown in figure 2, consists of such items as [1]:

1. Element «Unbundle Function» designed to separate the data from the block «Claster»;

2. Divided data from current and voltage sensors are supplied to unit «Square Function». This unit produces a function in squared;

3. «Compound Arithmetic Function» - a device designed to sum functions. On the output of this block are summed squares of the currents and voltages;

4. «Square Root Function» - device for finding a square root function;

5. «Feedback Node» - a device designed for organization a delay. To indicate the number of delays is necessary to trigger the properties of function and in the «Delay» indicate the number of delays.
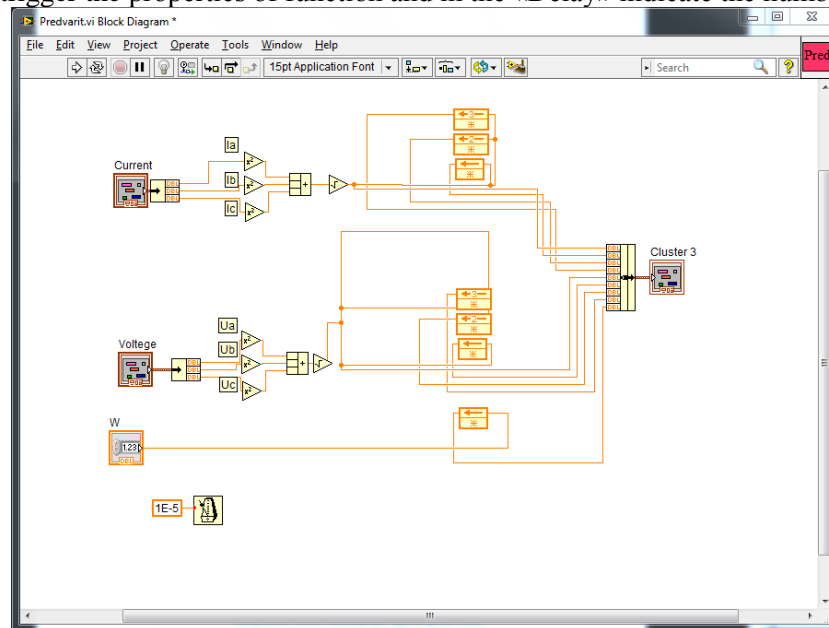

Figure 2. Block diagram of the data preprocessing.

After processing the data arrives at ANN, consisting of a set strictly ordered "elementary particles", which acts as a neuron. The network of neurons emulates the human brain. The mathematical model of a neuron can be described as follows [1, 3 – 14]:

$$S = \sum_{k=1}^{K} X_k \cdot W_k + b; \; Y = F(S),$$

where $X_1, X_2,...,X_K$ – input signals of the neuron; $W_1,W_2,...,W_K$ – synoptic weights of neurons; b – shift; $F(S)$ – activation function; Y – output signal neuron.

The developed neural network (figure 3) consists of a single input, two hidden layers and one output. The input layer consists of nine neurons, a first hidden layer – 7, the second – 27, output layer – from one neuron. Activation function of input layer is linear, hidden layers – tangential activation function and output layer – linear activation function.
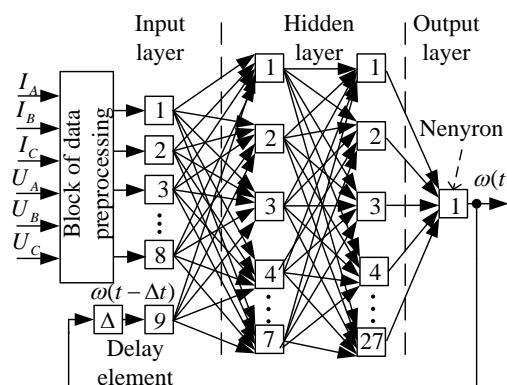
Figure 3. Block diagram of neural network observer of the angular velocity of the rotor.

The input layer of the neural network designed and implemented in LabVIEW software environment is shown in figure 4. Each subVI is the work of a single neuron with its synoptic weights and shifts. Block diagram of the neuron is shown in figure 5.
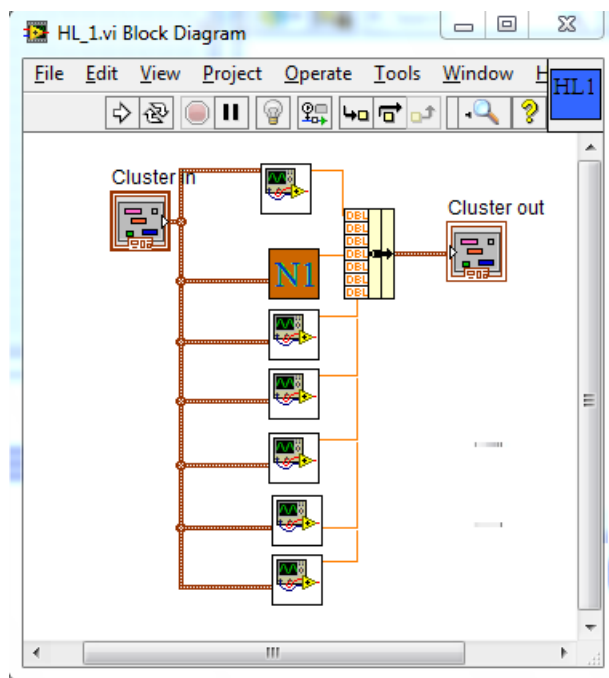

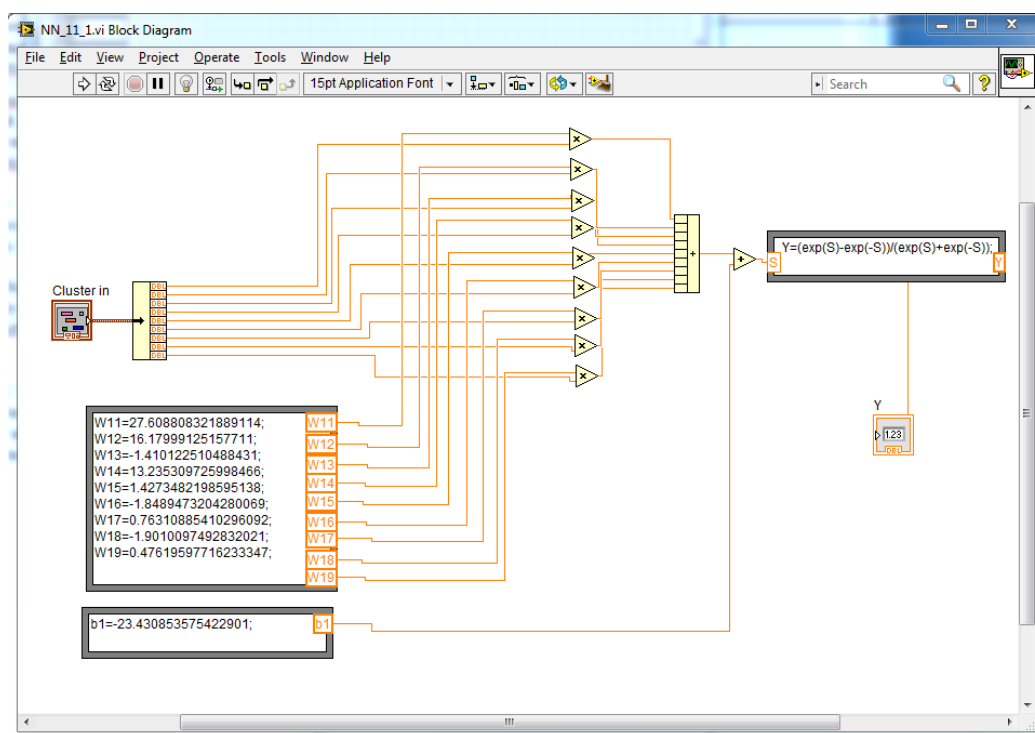**Figure 4**. Block diagram of the first hidden layer.

Figure 5. Block diagram of first neurons of the first hidden layer.

For the organization, neuron was used element «Formula Node» for writing formulas. With using this block the weights W, shifts b and tangential activation function can be arranged. In this way was organized each neuron of each layer of the neural network.

Have been obtained four waveforms to assess speed, voltage, current and comparative waveforms between the rotational speed of the motor shaft and its estimate implemented in the LabVIEW using oscilloscopes «Waveform Graph» (figure 6).
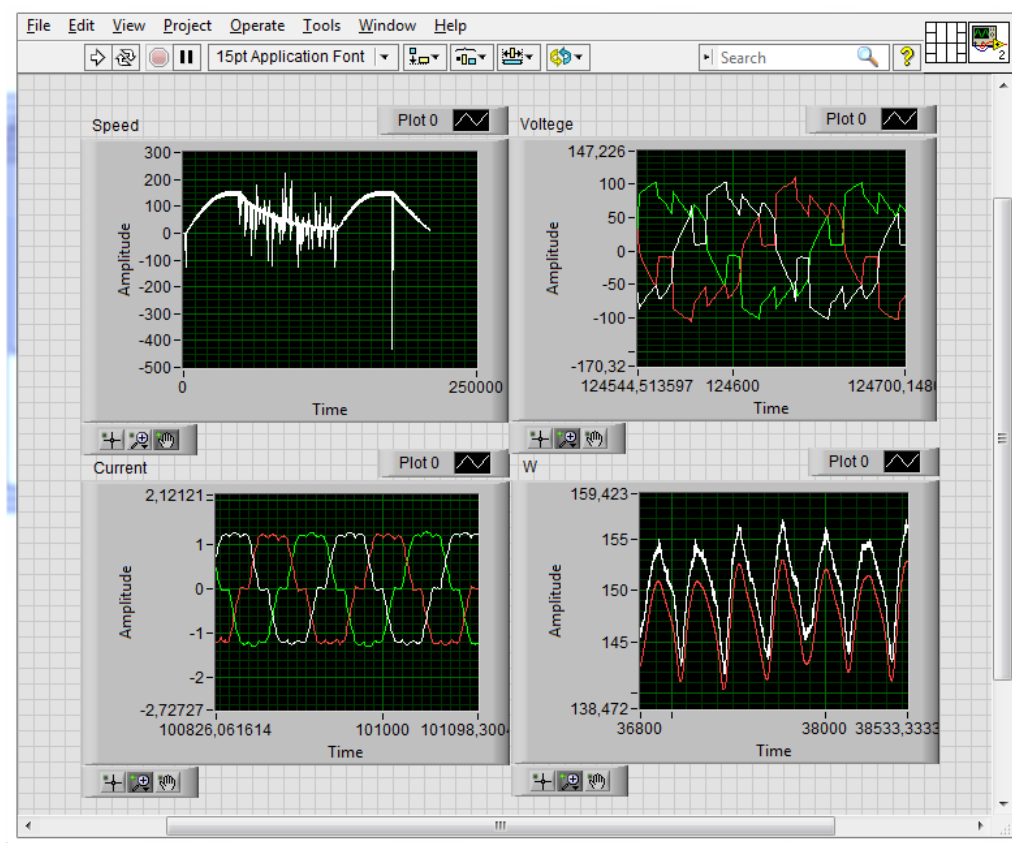
Figure 6. The front panel of the simulation model of neural network observer.

To assess the quality of the identification of the speed of rotation of the asynchronous electric drive of TVR-IM type integral criterion was used, calculated by the formula [14]

$$I_{\omega} = \frac{\int_{t_{start}}^{t_{stop}}|\omega(t)-\hat{\omega}(t)|dt}{\int_{t_{start}}^{t_{stop}}|\omega(t)|dt}\cdot 100\%$$

where t_{start}, t_{stop} – start and end times of integration, $\omega(t)$ – the angular velocity of rotation of the induction motor, $\hat{\omega}(t)$ - estimate the angular velocity of rotation of the asynchronous motor with different control modes are shown in table 1.

Table 1. The Integral criterion.

I_{ω},%	Modes of operation of the electric drive		
	Start	Increased load	Load-shedding
	3,5	4,9	2,9

3. Summary

Based on table 1, created neyroemulyator of angular speed asynchronous electric drive of TVR-IM type produces adequate assessment despite the presence of noise, non-sinusoidal currents and voltages. The integral error is within 5%.

References

[1]   National Instruments Corporation 2004 *LabVIEW PDA Module User Manual Information* **370624B-01** 30
[2]   Bose B K 2001 *Modern power electronics and AC drive* (Prentice-Hall)
[3]   Braslavskiy I Ya *et al* 2007 *Electrical Engineering* **11** 43–47
[4]   Klepikov V B *et al* 1999 *Electrical engineering* **5** 2-6
[5]   Payuk L A *et al* 2016 *Journal of Physics: Conference Series* **671** **(1)** 012044 DOI:10.1088/1742-6596/671/1/012044
[6]   Kruglov V V *and* Borisov V V 2001 *Artificial neural networks. Theory and practice* (Hot line, Telecom)
[7]   Shepherd G M *and* Koch C 1990 *The Synaptic Organization of the Brain* (Oxford University Press)
[8]   Churchland P S 1986 *Neurophilosophy: Toward a Unified Science of the Mind-Brain* (Cambridge MA: MIT Press)
[9]   Odnokopylov I G *et al* 2015 *Proc. Int. Siberian Conf. on Control and Communications* DOI: 10.1109/SIBCON.2015.7147249
[10]   Bashkirov O A *et al* 1964 *Automation and Remote Control* **25** 629–631
[11]   Lukichev D V *and* Usol'tsev A A 2005 *Scientific and Technical Gazette* **4** 97–102
[12]   Kozlova L E 2015 *Scientific Bulletin NSTU* **1 (58)** 41–50
[13]   Pritulov A M *et al* 2007 *Russian Physics Journal* **50** **(2)** 187–192 http://dx.doi.org/10.1007/s11182-007-0026-3
[14]   Kozlova L E *and* Bolovin E V 2014 *Modern problems of science and education* **3**