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ESTIMATION OF THE CONDUCTOR AND TOWER CHARACTRISTICS USING NEURAL NETWORK

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Abstract. Neural networks are intelligent calculator tools which have the capability of learning and they are considered as a solution and a novel methodology in solving the unknown phenomena in the fields of science and technology. Neural networks learn the dynamic state behavior of a system using its performance or a phenomenon occurrence. Furthermore, they are able to simulate a system model or a complicated phenomenon with non-linear behavior even by using examples with high desperation and turbulence. Using advanced learning algorithms, neural networks will be converged towards the physic of the phenomenon or the system rapidly and accurately. In this survey, after presenting a concise explanation of biologic neurons, artificial neurons will be studied. Then, the structure and relations ruling the artificial neural networks as well as the learning algorithm will be surveyed. Consequently, the particular implementation of neural network in the problem of estimating the attributes of power network and the neural network success will be evaluated in this article by presenting examples.

Keywords: Turbulence, Neural networks, Transition lines

1. INTRODUCTION

Due to the invention of technological neural networks for solving this problem and for acquainting the computer with intellection principles, it is tried for its ruling principle and structure to be designed based on human brain inspirations. Human brain and nervous system is a complicated structure which has the most full-fledged known tool for intelligence and cognition. [Rafiq,et.al, 2001] Artificial neurons and neural networks are mathematical calculation instruments capable of learning. In addition, human has developed them using nervous system, cognition power, and his information about them. [Beatty, 2000] Artificial neural networks are made of a set of artificial neurons juxtaposed next to each other in various arrangements. Neural network mostly used in field of simulation and control in subsets of mechanical engineering is Feed Forward Multilayer Perceptron in which the neurons are arranged in two or three parallel layers. [Sadiku, 2004] The learning process of Feed Forward Multilayer Perception is very similar to the process in which human experience his surrounding environments. This process is called Error Back Propagation which has been developed based on numerous learning algorithms for multi-layer perceptron. [Sanger, 1989]

1.1. Artificial Neural Networks

Neural networks are dealing with some problems for which there are not any determined solutions. However, in classic methods, it is feasible to follow the algorithm step by step and solve the problem. Neural networks are appropriate for some problem in which the real data for the

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surveying system performance is available enough. However, there is not an especial equation to indicate the relations among the variables. [Beatty, 2000]

1.2. Neuron Mathematical Model

The simplest model for a neural network consists of a processor unit (neuron). As shown in figure 1, first in this unit, the relating W weight values are multiplied then, the products will be added to each other and thus, n weight signals will be made. N weight signals are making the **A** output signal using the conversion function of **F**. Furthermore, an extra input signal will be added which causes the movement. Totally, it shows that the output is a particular function of input values which can be shown as the following. In case we have numerous numbers of signals instead of one signal as demonstrated in figure 2, the relations would be as the followings.

$$n=wp+b$$
$$a=F(n)=F(wp+b)$$

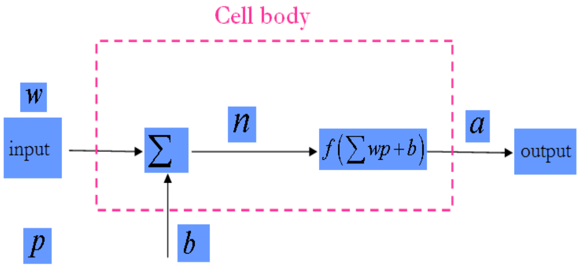

Figure 1. A simple neuron.

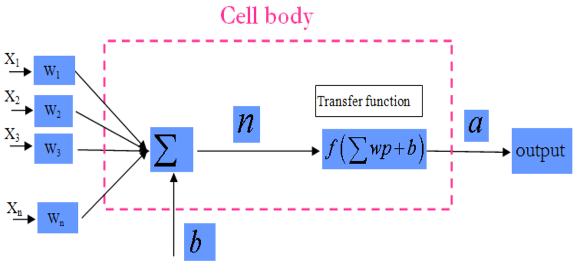

Figure 2. A simple neuron with several inputs.

There are plenty of methods to train neural networks, however; all of them follow two overall patterns.

A. Supervised learning
B. Unsupervised learning

There is no especial method to determine the required nodes in each of networks' layers and reaching the desired answer is based on our experience. Normally, three-layer networks are enough to solve the problem. But, in some cases the intermediate layers would be increased for learning to become faster. The size of input layer depends on the nature of the problem and the inputs can be considered based on the number of efficient variables. A ratio can be omitted if it did not have significant changes during synchronization process. Therefore, the network is able to be retrained and if the network could respond to the expectations in this state, it means that the input does not have any significant effects on the output. The size of the output layer depends on the type of the output, the number of output layer nodes would differ for binary and other types of outputs. The intermediate layer is not determined as simple as the input and output layers. It should be considered for the intermediate layer to be as small as possible. It is feasible for the correct and fault method to be utilized for identifying the number of nodes.

1. TRANSMITTING LINES PARAMETERS

The purpose of transmitting network is to transfer electrical energy from production units in various locations to the distribution system which consequently, supplies the electrical loads. In addition to connecting the neighboring installations to each other, transmitting lines not only bring the capability of the economic distribution of power in different regions with normal conditions but also, they provide the power transition in places with abnormal conditions. All of the transition lines in power system show the electrical, resistance, inductance, capacity, and electrical guidance characteristics from themselves. The parameters of $R', L', \ and \ C'$ in flying transition lines are distributed uniformly throughout the line thus, they cannot be considered as fixed elements. Some of them are frequency functions thus, line parameters are used instead of line constants to state these elements. Only the parameters of positive and negative network is required to study the short circuit and power part. These parameters can be furnished from tables in the handbooks or they can be easily obtained by simple formulas. [Papagiannis,et.al., 2005]

1.1. Impedance matrix

It is common to describe the voltage reduction along a transition line in form of nominal differential equations. For instance, for a one-phase line we have the following.

$$-\frac{\partial v}{\partial \chi} = R'i + L'\frac{\partial i}{\partial t} \qquad (1)$$

Parameters of $R'$and L' are not flying lines. They are functions of frequency. In this case, utilization of equation 1 is not appropriate. Instead, voltage decrease should be determined in form of **phase** equations in **Manna state** condition of AC system in a specified frequency.

$$-\begin{bmatrix} \frac{dV_1}{dx} \\ \frac{dV_2}{dx} \\ . \\ . \\ . \\ \frac{dV_{13}}{dx} \end{bmatrix} = \begin{bmatrix} Z'_{11} & Z'_{12} & \cdots & Z'_{1.13} \\ Z'_{21} & Z'_{22} & \cdots & Z'_{2.13} \\ & & \cdots\cdots\cdots & \\ Z'_{13.1} & Z'_{13.2} & & Z'_{13.13} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ . \\ . \\ . \\ I_{13} \end{bmatrix} \qquad (2)$$

In the figure above, V_1 and I_1 are phase voltage measured from **i** conductor to the ground and phase current in **i** conductor, respectively. Thus, we have the following:

$$-\left[\frac{dV}{dx}\right] = \left[Z'\right]\left[I\right] \qquad (3)$$

In which [V] is phase voltage vector measured from conductor to the ground and [I] is the vector of phase currents in conductors.

Equation 3 indicates that the ground is a recursive path which all of the voltages are going toward that.

The $[Z']=[R'(\omega)]+j\omega[L'(\omega)]$ matrix is symmetrical and contains complex numbers known as the impedance matrix. Diagonal element of this matrix, $Z'_{ii}=R'_{ii}+j\omega L'_{ii}$, is self-series impedance in the length unit of **I** conductor in terms of the ground. If no current passes through the I conductor or vice versa, the non-diagonal element of the matrix, $Z'_{ik}=Z'_{ki}=R'_{ki}+j\omega L'_{ki}$, is a series mutual impedance in the length unit between the conductors of **I** and **k**. in addition, it indicates the longitudinal inducted voltage in the **K** conductor. Resistant parts in the mutual coupling are built because of the ground.

1.2. Internal impedance and skin effect

Using the computations of side ruler, the internal reactance $X'_{reactance}$ and external reactance $\omega\mu_0/2\pi\ln 2h/r$ are normally in form of a mixable relation if the ground is not subsided. [8] For magnetic field to be considered, **r** radius will be replaced with GMR (Geometrical Mean Radius).

$$\omega\frac{\mu_0}{2\pi}\ln\frac{2h}{r}+X'_{internal}=\omega\frac{\mu_0}{2\pi}\ln\frac{2h}{GMR} \qquad (4)$$

Usually, GMR value can be found in conductor tables. North America handbooks, not only states the GMR but also they represent reactance in the distance of 1 foot called X'_A. This reactance is proportional with GMR.

$$X'_A=\omega\frac{\mu_0}{2\pi}\ln\frac{1(foot)}{GMR(feet)} \qquad (5)$$

In this formula, GMR is in terms of feet (or it is in terms of meter if X'_A reactance is placed in distance of 1 meter.)

1.3. Shunt capacitance matrix

Phase voltages for the N conductor in terms of ground are functions of line charges.

$$\begin{bmatrix} v_1 \\ v_2 \\ . \\ . \\ . \\ v_n \end{bmatrix} = \begin{bmatrix} P'_{11} & P'_{12} & \dots & P'_{1,n} \\ P'_{21} & P'_{22} & \dots & P'_{2,n} \\ \dots & & & \\ \dots & & & \\ \dots & & & \\ P'_{n,1} & P'_{n,2} & \dots & P'_{n,n} \end{bmatrix} \begin{bmatrix} q_1 \\ q_2 \\ . \\ . \\ . \\ q_n \end{bmatrix} \qquad (6)$$

q_i in this matrix is the charge in conductors' length unit that can be briefed in the following form.

$$[v]=[P'][q] \qquad (7)$$

Maxwell potential coefficient matrix $[P']$ is symmetric and real. Its elements can be simply calculated through geometry of the tower shape and conductor shape in the case the following assumption are considered.

1. The space is considered without wastes and the ground is uniformly placed in the zero potential.
2. The conductor radius is smaller than the distance between the conductors for at least one degree.

Both the assumption seems logical for the flying line therefore, the diagonal element is:

$$P'_{ii} = \frac{1}{2\pi\varepsilon_0} \ln \frac{2h_i}{r_i} \tag{8}$$

And the non-diagonal element is:

$$P'_{ki} = P'_{ik} = \frac{1}{2\pi\varepsilon_0} \ln \frac{D_{ik}}{d_{ik}} \tag{9}$$

In which ε_0 is the electrical permeability of free space. In these equations, the factor of $1/(2\pi\varepsilon_0)$ is $c^2.\mu_0/2\pi$ where **c** is the light velocity and it is equal to 2997922 km/s. $\mu_0/2\pi = 0.0002$ and $1/(2\pi\varepsilon_0) = 17975109$ which is in terms of km/f. The shunt capacitor matrix will be furnished by reversing the equation 7.

$$[q] = [C'][v] \;;\; [C'] = [P']^{-1}$$

The lines limitation method implements a Gauss-Jordan process in which symmetry is used to reverse a matrix. [9, 10]

For AC durable states, charges vector (as phase values) depends on the $\left[-\frac{dI}{dx}\right]$ leakage vector.

In this case

$$[Q] = -\frac{1}{j\omega}\left[\frac{dI}{dx}\right] \tag{10}$$

Thus, the second system is a differential equation and if it is compared with equation2, the behavior of AC durable state will be described from one line with several conductors. G' inductances in equation 11 are not considered since their effect in flying lines is negligible. However, it should be considered that this negligence is valid as long as we do not enter the range of frequencies which get close to DC state. It is where the line behaviors of R' and G' are determined because $\omega L'$ and $\omega C'$ are very little. Considering the G', complete model can be defined as follows.

$$-\left[\frac{dI}{dx}\right] = [Y'][v] \tag{12}$$

While

$$\left[Y'\right]=\left[G'\right]+j\omega\left[C'\right] \tag{13}$$

In very high frequencies, Shunt capacitors are influenced by the ground guiding effect. In addition, correction ratios should be added to the equations of 8 and 9. However, usually, the ground control effect in frequencies of lower than 100 kHz or below 1 MHz is negligible. In this state, the capacitors are fixed while series resistant and inductances follow the frequency. [uribe,et.al., 2004]

3. SIMULATION RESULTS

Using the outputs of PQS in this part, the way that line parameters and impedance are in relation is estimated by neural network. The input of the neural network is line impedance and the duty of the designed neural network is finding the transition line in relation with this impedance. Line impedance consists of resistant, inductance, and lines capacitors which is the network input. The network outputs are the characteristics of transition lines composed of the following parts:

- The number of wires
- The number of bundles
- The inner diameter of the conductor
- The outer diameter of the conductor
- Bundle diameter
- Earth resistance
- The horizontal distance among the conductors with assumption that they are arranged horizontally.
- The altitude of conductor from the ground
- Direct current resistance

Various tests are done to find the number of neural network layers, each layer neurons, and the type of enabler function for each layer. Furthermore, different tests are carried out to find the most suitable neural network topology in order to decide whether 9 networks can be used to obtain 9 outputs or whether it is possible to gain the desired answer by appropriate training. Amongst all the available data, 80% is used for training and 20% is utilized for validation. The validation part is to avoid the network over training. Later, the effect of each of the factors above on the output of the network will be surveyed. Overall, 3600 states were studied to find the test fault. We should be able to model the neural network using at most two layers. Demonstrated in figure 3, is the network fault in two states of one-layer and two-layer. As it is expected, the fault has a positive correlation value and a little value of **p** parameter which makes the correlation significant. Thus, it can be seen that one-layer neural network has better responds in both parts of validation and test. Consequently, one-layer neural networks have less faults rather than two-layer ones for modeling the relations among the parameters of transition lines and lines impedance. As a result, one layer is enough to model this problem.

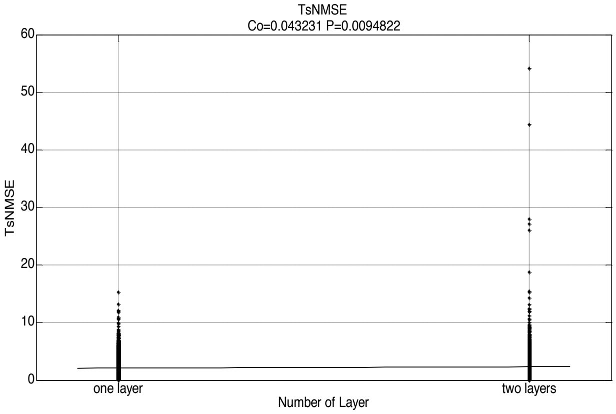

Figure 3. The analysis of the network number of layers on the test fault.

3.1. The output of the best neural network

In this part, the responds of the best neural network have been compared with the real values. The surveying network has 9 outputs which are the characteristics of the transition lines. These attributes were pointed at the first of this part. Subsequently, the comparison of real values and the network outputs are brought. As it can be distinguished through the figures 4 to 12, test outputs of this network are reasonably adapted to the real values.

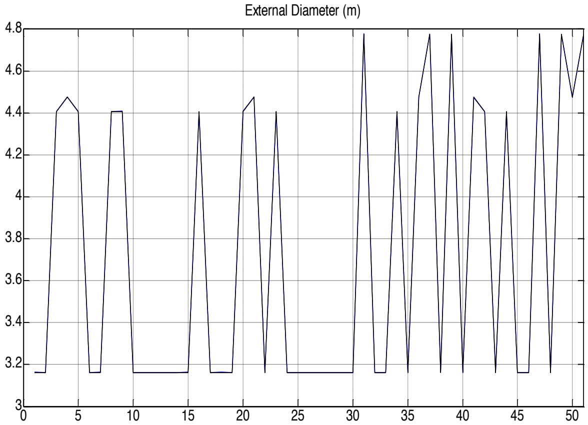

Figure 4. The comparison of real values and the output of neural network for conductor external diameter.

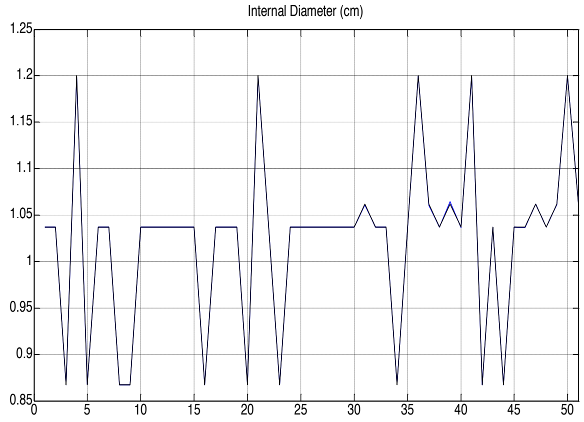

Figure 5. The comparison of real values and the output of neural network for conductor internal diameter.

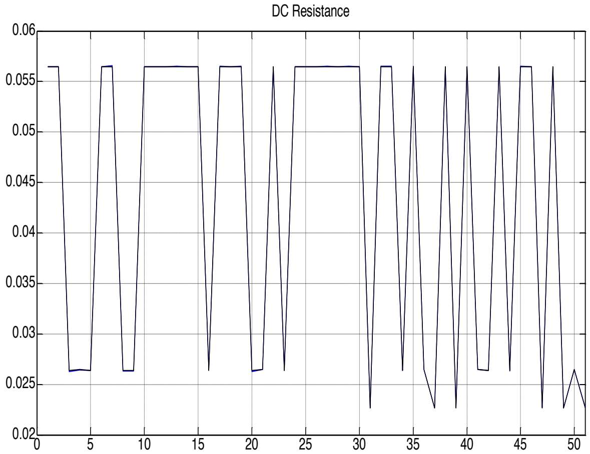

Figure 6. The comparison of real values and the output of neural network for DC resistance.

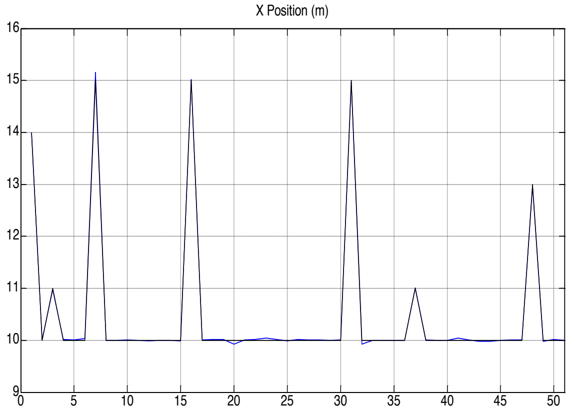

Figure 7. The comparison of real values and the output of neural network for the line horizontal situation.

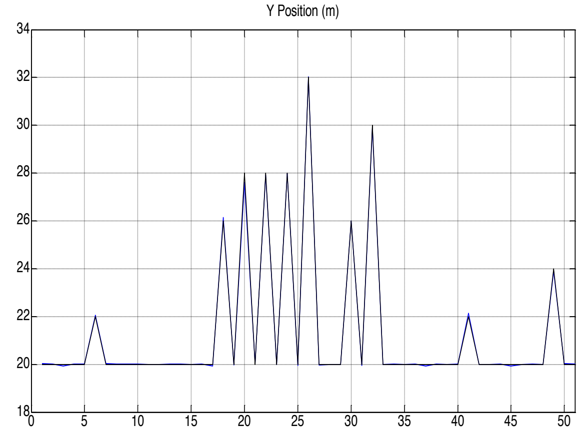

Figure 8. The comparison of real values and the output of neural network for the line vertical situation.

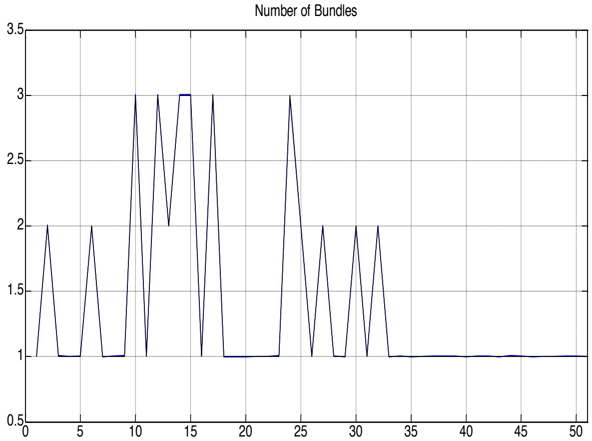

Figure 9. The comparison of real values and the output of neural network for the number of lines bundles.

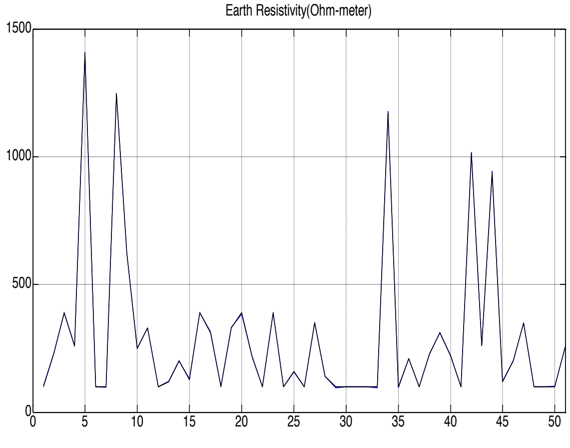

Figure 10. The comparison of real values and the output of neural network for the ground resistance.

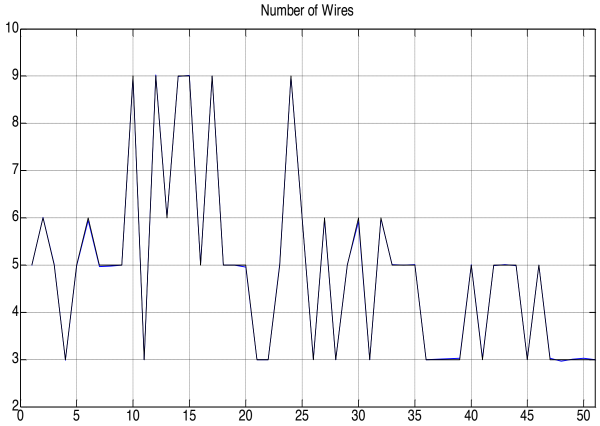

Figure 11. The comparison of real values and the output of neural network for the number of line wires.

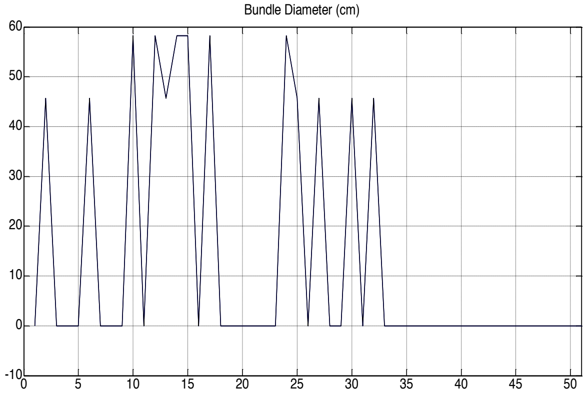

Figure 12. The comparison of real values and the output of neural network for the bundle diameter.

As it can be seen, the findings obtained are completely adapted and they have good correlations thus, the designed neural network is capable of producing the suitable outputs containing the lines characteristics using the line impedance. The surveying neural network is chosen among 3600 neural networks which has less correction faults.

CONCLUSION

In this article, neural networks have been used as a powerful tool for estimating the characteristics of transition lines in the case lines impedances are provided in advance. The number of estimated parameters is 9 and they are accurately estimated by the designed neutral network. According to the works done in this paper, neural network can be utilized as a practical and successful tool to estimate the traits of transition lines. In addition in this paper, the importance of analyzing various networks to find the appropriate structure for the neural networks has been presented in detail. The structure of the neural network highly depends on the problem structure and it is crucial for the problem characteristics to be evaluated first, in order to reach the suitable structure for the network. Results furnished in this article show that neural networks are able to be used in power systems problems.

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