An ANN system to on-line detection of sag, swell and transient voltages

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1. Brief introduction

The analysis of power quality in electrical power systems includes the study of transient disturbances as frequency variations, sags, swells, flicker or interruptions, [1-3]. In this paper, a measurement system of some transient disturbances based on Artificial Neural Networks will be presented. A feedforward Artificial Neural Network (ANN) has been off-line trained to detect the initial time, the final time and the magnitude of voltage sags and swells. Besides, the designed system will be applied to detect transient voltage in electrical power systems. The performance of the designed measure method will be tested trough a simulation platform designed in ®Matlab/Simulink through the analysis of some practical cases.

Keywords: Electrical power quality, transient disturbances, measurement, artificial neural networks, feedforward

2. Neural network architecture

The artificial neural networks had been applied successfully in several topics of the Electrical Engineering, including the detection of some voltage disturbances [3,4]. The speed and the parallelism of the calculations are the main advantages of these techniques. In this work, a feedforward ANN has been designed for transient voltage disturbance measurements.

The ANNs include a large number of strongly connected elements: the artificial neurons, a biological neuron abstraction. The model of an artificial neuron in a schematic configuration is shown in figure 1.

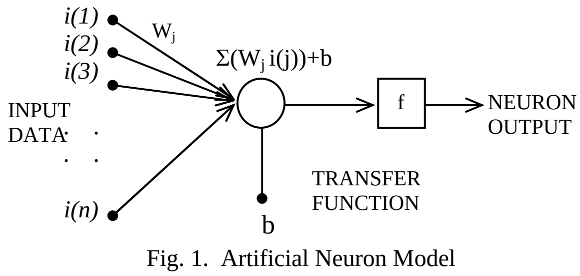

Fig. 1. Artificial Neuron Model

The input data *i(1), i(2), i(3), …, i(n)* flow through the synapses weights W_j. These weights amplify or attenuate the inputs signals before the addition at the node represented by a circle. The summed data flows to the output through a transfer function, f. The neurons are interconnected creating different layers. The feedforward architecture is the most commonly adopted. The scheme is shown in figure 2.

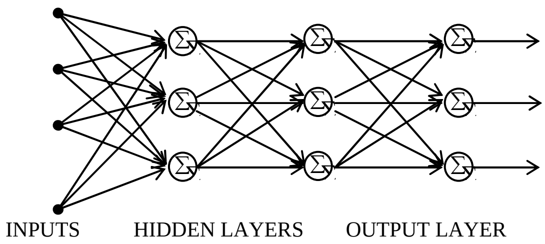

Fig. 2. Feedforward Neural Network Architecture

This network can be trained to give a desired pattern at the output, when the corresponding input data set is applied. This training process is carried out with a large number of input and output target data. These data can be obtained using a simulation platform or an experimental system. The training method most commonly used is the backpropagation algorithm. The initial output pattern is compared with the desired output pattern and the weights are adjusted by the algorithm to minimize the error. The iterative process finishes when the error becomes near null.

In this work, the neural network has been designed with three inputs, corresponding to the voltage at three consecutive time instants $v(t)$, $v(t-\Delta t)$ and $v(t-2\Delta t)$, two hidden layers of 20 and 12 neurons with sigmoid transfer function, and an output layer with only one neuron with pure linear transfer function.

3. Simulation model

To simulate the proposed measurement system, including the ANN off-line training process and its on-line performance, a Matlab/Simulink platform has been designed.

To carry out the network training process, a set of input and output voltage disturbances with different length and depth was generated in Matlab/Simulink platform. The per unit voltage amplitude was considered as desired network output. The training process of the neural network was carried out helped by the Neural Network Matlab toolbox. The error evolution during the training process is presented in figure 3. The maximum error was minor than 0.032%.

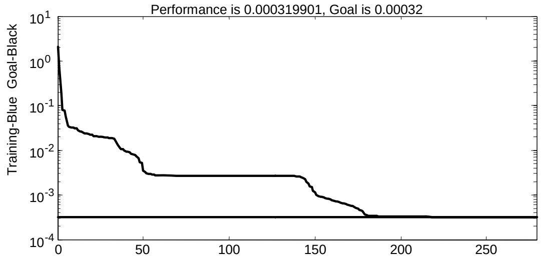

Fig. 3. Error evolution during the training process

After this training process, a Simulink block with a *sim* function is used to issue the designed measurement system.

4. Results of practical cases

After the network training process, the measurement system performance was tested in the presence of different ideal voltage sags and swells which happen in different time instants. Figure 4 shows a voltage waveform with a 69% depth sag and the corresponding network output. It can be appreciated that the network works in a suitable form detecting the voltage sag (ANN output = 0.31), including the initial and final instant of the sag.

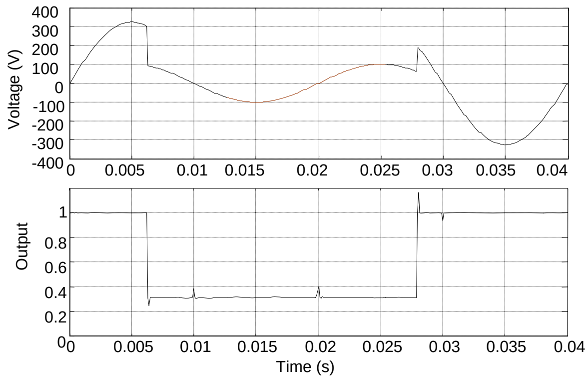

Fig. 4. Voltage waveform and network output with a 69% depth sag

The designed ANN measurement block was applied to detect microsags, swells and transient voltages. As reference, figure 5 shows a transient voltage waveform and the neural network output. It can be detected the initial and final instants of a voltage transient.

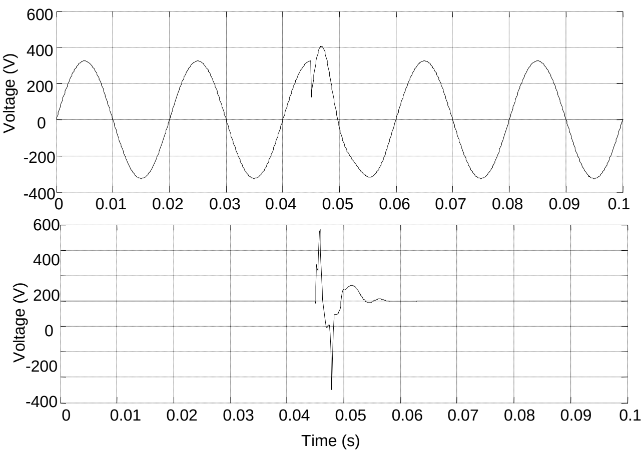

Fig. 5. Voltage and ANN measurement system output during the transient detection

Besides, it was probe to detect voltage disturbances in an electric power system with a fault. The figure 6 shows the simulated Simulink block diagram. The voltage has been measured at point of connection of a load 1. The neural network output is 0.79, and there are small oscillations of the network output caused by the presence of second order transients, figure 7.

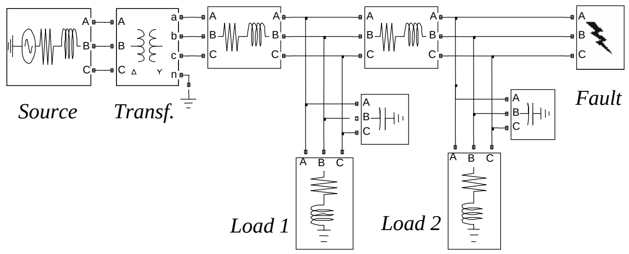

Fig. 6. Simulink block diagram of the electric power system

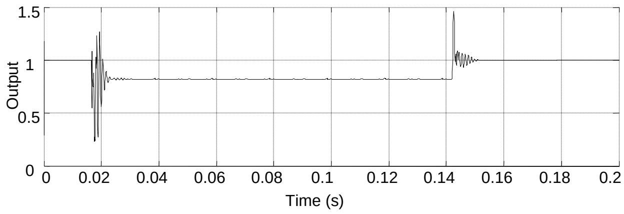

Fig. 7. Neural network output

5. Conclusions

A procedure to measure on-line voltage disturbances using artificial neural networks has been presented. A feedforward neural network has been designed and trained using input/output data supplied with computer simulations. To have an adequate dynamic response of the disturbance detection system, three inputs were considered for the neural network, the voltage at instant *t*, and at two preceding instants, *t-Δt* and *t-2Δt*.

The neural network was satisfactorily tested for the detection and measurement of different voltage sags and swells and for the detection of transient voltages in electrical power systems.

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