Performance of Sag Events using Artificial Neural Network

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Abstract- **Voltage sag is one of the Power Quality problems which happen in equipments or even in the transmission line of power system. When lightning strikes, it carries a very high current and may cause the voltage to drop. Hence, there will be an energy lost in the site or building. This energy lost and also the sag score value in every sag events can be calculated but the validity of the calculated data is quite questionable. Thus the objectives of this paper is to compare between the monitored and calculated data and to show the performance of sag score and energy lost in sag events using Artificial Neural Network (ANN)-MATLAB. In order to test the validity of sag score and energy lost, two methods were used; first by calculating sag score and energy lost during sag event from monitored and captured data, second is by feeding the calculated data into the artificial neural network. Results of calculated data will be compared with the results obtained using ANN. It is hoped that the validity of the calculated sag score and energy lost during sag are accurate for monitoring purposes.**

Keywords: Neural Network; Sag Score; Energy Lost.

I. INTRODUCTION

An Artificial Neural Network (ANN) is an information processor which functions to forecast and predict the output of data. ANN received increase attention in the recent years and the techniques are widely used in electronic applications. It works like a brain, ANN is a way to model any input to output relations based on some input output data when nothing is known about the model, and determined by the connections between the processing elements and the elements parameters. ANN learned by example [1]. The data need to be trained to get the convergence result.

A. Neural Networks

Neural network is full with neurons and made of different layers. The first layer which takes input and put into internal layers or hidden layers are known as input layer. The outer layer which takes the output from inner layers and gives it to outer world is known as output layer [2]. The internal layers can be any number of layers as shown in Figure 1.

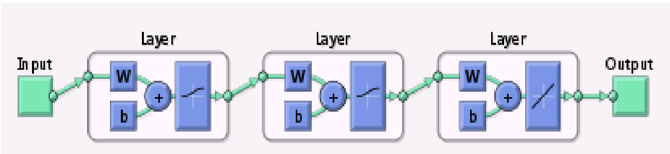

Figure 1: Neural network layer

An ANN is configured for a specific application, such as for pattern recognition, clustering, data classification and system prediction through a learning process. Learning in biological system involves adjustments to the synaptic connections that exist between the neurons. This is true of ANNs as well [1]. The test system is simulated as many times as required to achieve the convergence. Now as each brain needs training, this neural network also needs it. Neural network is trained by using the data generated. For example:

Net = train (net,I,O); (1)

Now as it gets trained, the performance curve is shown in Figure 2.

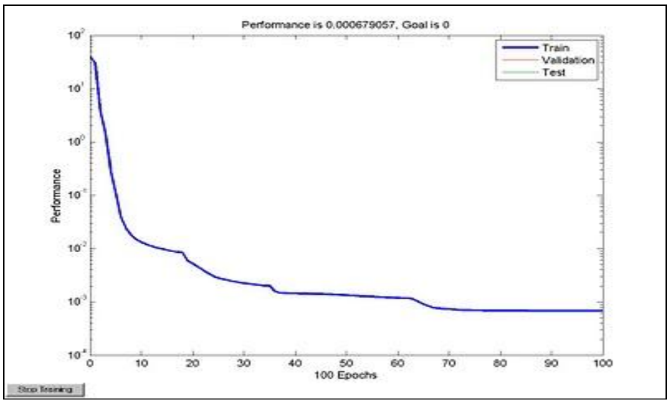

Figure 2: Performance curve of training data

One set data of voltage sag score and their energy lost can be useful to reflect the behavior of a system. The energy supplied during a transient process is very depending on the load and duration of sag occurs. Energy calculations cannot be then based on a deterministic value of the load demand. The main goal of this paper is to validate the energy lost and sag score from manual calculation using formula and ANN solution. The values of phase voltages, V_a, V_b and V_c, their energy lost and number of sag score are detailed in Table 1.

B. Voltage Sag

Sags are transient events caused by faults, transformer energizing, motor starting and sudden load changes; all these phenomena can be classified as low or mid frequency transients [3]. They are also caused by abrupt increases in source impedance, typically caused by a loose connection. Sags are the most common power disturbance. At a typical industrial site, it is not unusual to see several sags per year at the service entrance, and far more at equipment terminals.

Voltage sags can also arrive from the utility. However, in most cases, the majority of sags are actually generated inside a building. For example, in residential wiring, the most common cause of voltage sags is the starting current drawn by refrigerator and air conditioning motors. Voltage sag severity depends on the location and the duration of the fault. Some electronic equipment lacks sufficient internal energy storage and therefore, cannot ride through sags in the supply voltage. Equipment may be able to ride through very brief, deep sags, or it may be able to ride through longer but shallower sags.

II. METHODOLOGY

a. Sag Score and Energy Lost

Each of qualifying voltage sag has three phase voltages; V_a, V_b and V_c. One of the three phase voltages is the lowest voltage of all the qualifying sags measured in a 15-minutes interval at each location. The other two phase voltages are the values of voltage on the other phases at the time of that minimum. The same power quality monitor that recorded the lowest voltage also recorded the other phases [4]. Detroit Edison's uses a "sag score" to administer its voltage sag contracts with its automotive customers. Sag score is the average per unit voltage lost. Spatial and temporal aggregation sag agreements only consider the worst sag each 15-minute period per location. Voltage sag score can be calculated from:

$$Sag\ Score = 1 - \frac{Va+Vb+Vc}{3} \tag{2}$$

Lost energy in sag event, W is calculated from:

$$W = (1 - V_{pu})^{3.14} \times t \tag{3}$$

Where

V_{pu} is per unit voltage during the sag event, and

t is the sag duration

b. Data Training

To start this process, some or all historical data for input and output variables can be chosen randomly. Then, the training or learning process can be initiated. This data training process must be repeated until its training performance converges.

c. Data Testing

Once the training performance of the network achieved the convergence level, the black box is ready to be tested to ensure whether the neural network has successfully being trained or not. For this project, data for both input and output variables of voltage sag score and energy lost are chosen at random, and then the testing process can be run. This process is to ensure that the performance of the trained neural network is functioning accordingly and specifically to compare the targeted output and the actual output.

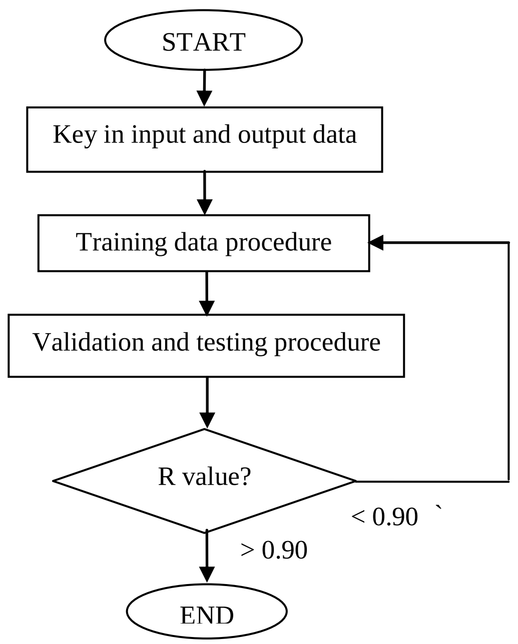

Figure 3: Flow chart of neural network process

Figure 3 shows the flow chart of neural network process. First, the input and output data must be key in editor part. Next, training data procedure is run to get the result of testing performance curve, line gradient and regression line value. If the data plotted is not achieving convergence, training and testing procedure is repeated by changing its learning rate or momentum value. For testing procedure, the data is run to get the graph of output versus target and their regression line value. The learning methods in neural network are classified into three basic types:

1. Supervised Learning
2. Unsupervised Learning
3. Reinforced Learning

In this project, the learning algorithm used is Levenberg-Marquardt back propagation optimization, which is a network training function that updates weight and bias values. This learning algorithm is often the fastest backpropagation algorithm in the toolbox, and is highly recommended as a first-choice supervised algorithm, although it does require more memory than other algorithms. This learning algorithm also can train any network as long as its weight, net input, and transfer functions have derivative functions.

If the output is correct, then no adjustment of weights is done. i.e:

$$W_{ij}^{K+1} = W_{ij}^{K} \qquad (4)$$

If the output is 1 but should have been 0, then the weights are decreased on the active input link. i.e:

$$W_{ij}^{K+1} = W_{ij}^{K} - \alpha . x_i \qquad (5)$$

If the output is zero but should have been 1, then the weights are increased on the active input link. i.e:

$$W_{ij}^{K+1} = W_{ij}^{K} + \alpha . x_i \qquad (6)$$

Where

W_{ij}^{K+1} is the new adjustment weight, W_{ij}^{K} is the old weight

x_i is the output and

α is the learning rate parameter

If the value of α is small, it leads to slow learning and when α is large, it leads to fast learning.

III. RESULT AND DISCUSSION

Table 1 shows the detailed set of data for sag occurs in one site. In this project, the duration and value of three phase voltages are the input data, while energy lost and sag score are the output data. Total energy energy lost is the summation of energy lost values for all sag events.

TABLE I. INPUT AND OUTPUT DATA

Duration (s)	Va (pu)	Vb (pu)	Vc (pu)	Energy lost (pu*ms)	Sag score
0.099	0.89	0.72	0.9	1.99	0.1633
0.952	0.85	0.85	0.86	6.91	0.1467
0.067	0.87	0.67	0.84	2.38	0.2067
0.167	0.85	0.89	0.73	3.33	0.1767
0.082	0.94	0.75	0.71	2.75	0.2000
0.1	0.92	0.7	0.68	5.11	0.2333
0.067	0.96	0.85	0.86	0.32	0.11
0.3	0.73	0.72	0.76	13.82	0.2633
0.082	0.96	0.72	0.71	3.19	0.2033
1.417	0.63	0.62	0.65	129.01	0.3667
0.116	0.82	0.87	0.66	4.64	0.2167
0.485	0.96	0.81	0.78	6.83	0.15
0.45	0.96	0.82	0.75	7.87	0.1567
2.67	0.81	0.74	0.96	20.03	0.1633
0.249	0.87	0.92	0.8	2.09	0.1367
0.067	0.97	0.86	0.84	0.35	0.11
0.301	0.84	0.64	0.57	34.39	0.3167
0.084	0.86	0.67	0.85	2.98	0.2067
0.2	9.73	0.29	0.7	76.07	-2.5733
0.286	0.83	0.82	0.93	2.48	0.14
1.064	0.67	0.71	0.66	85.07	0.32
0.133	0.87	0.79	0.82	1.82	0.1733
3.983	0.75	0.76	0.75	37.06	0.2467
0.3	0.82	0.74	0.77	8.71	0.2233
0.165	0.88	0.59	0.58	21.08	0.3167
0.1	0.78	0.64	0.98	4.91	0.2
0.066	0.81	0.82	0.82	0.96	0.1833
0.067	0.96	0.82	0.71	1.68	0.17
2.008	0.72	0.7	0.7	63.99	0.2933
0.033	0.98	1	0.82	4.59	0.0667
0.083	0.93	0.96	0.38	18.52	0.2433
0.484	0.97	0.84	0.98	1.54	0.07
0.05	0.89	0.81	0.93	0.33	0.1233
0.015	0.98	1	0.81	0.08	0.07

Resource : [5]

Training procedure is done to create a black box for the artificial neural network. The artificial neural network needs to be trained until it is converge. As a result of performing training procedure, the blue line in Figure 4 shows the performance curve of the input and output data. The data is said to be converges if the blue line approaches the dash line. In this figure, the line is converged at 13th iterations, which shows its best training performance. By getting converge line, it means that the output from obtained by running the data almost similar to the data plotted.

The regression line of training data is shown in Figure 5, the line regression almost fit with the data plotted, which is almost equal to 1. The dotted line shows the targeted output while the blue line indicates the regression line after run training procedure.

For testing procedure, the output versus target line is obtained as shown in Figure 6. Testing procedure will be run when if the training procedure obtains the convergence result. The regression line value is shown by the red line. The dash line indicates targeted output of the data. When the red line and dash line is almost overlapping with each other, the R value is close to 1. In this figure, the R value is 0.92029, which is almost near to value 1. Therefore, the black box has achieved the targeted performance.

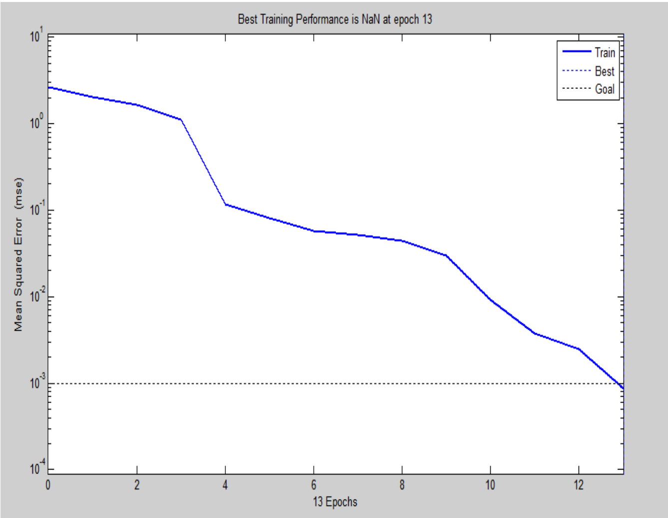

Figure 4: Testing performance curve

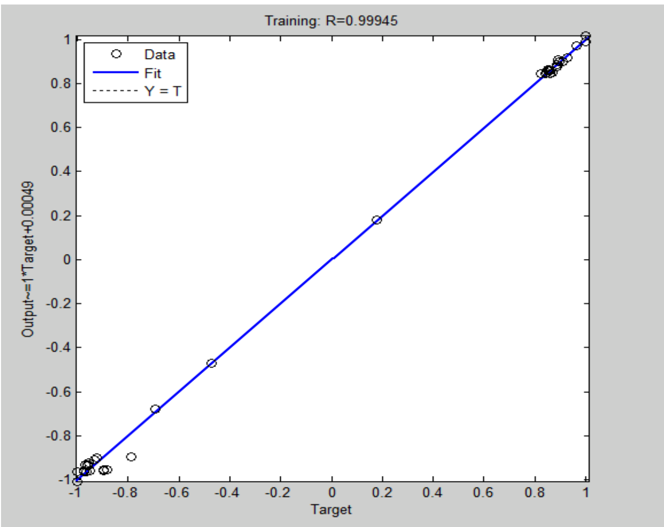

Figure 5: Regression line value

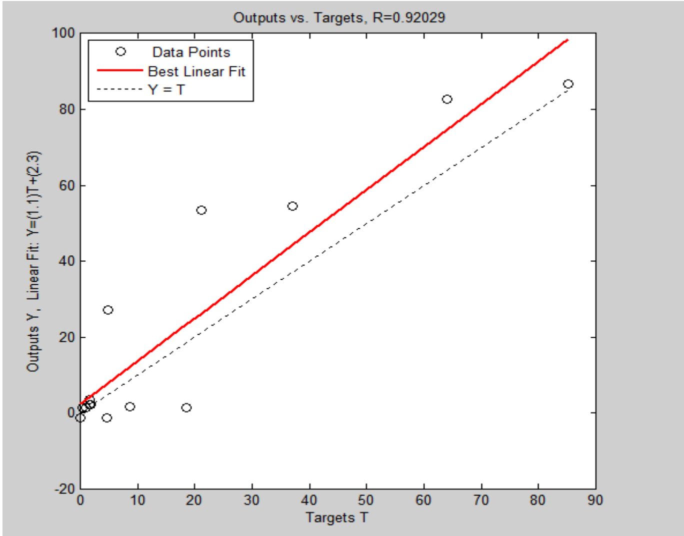

Figure 6: Output versus targets data

TABLE II. TARGETED AND PREDICTED OUTPUT OF ENERGY LOST

Targeted output for energy lost	Predicted output for energy lost
99.7368	85.0700
-45.8310	1.8200
29.0026	37.0600
-46.4955	8.7100
8.5147	21.0800

TABLE III. TARGETED AND PREDICTED OUTPUT OF VOLTAGE SAG SCORE

Targeted output for sag score	Predicted output for sag score
0.3199	0.3200
0.2890	0.1733
0.3033	0.2467
0.2896	0.2233
0.2590	0.3167

IV. CONCLUSION

Voltage sags are one of the most important power quality problems affecting industrial and commercial customers. Industrial processes are particularly sensitive to relatively minor voltage sags. Digital simulation is a very efficient mean for predicting the performance of a network and for testing devices and techniques which could mitigate voltage sag effects. Voltage sag event may produce energy lost in the system and the value of energy lost can be found by using the formula given. This can be validated using ANN, which function to forecast the output and compare it with targeted output. The training and testing procedure will be simulated many times in order to get the convergence of the data. Once the data is converge, so this neural network shows that it is the best method to find solution in order to forecast the future data or output.

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