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Modeling and Simulation of Resistance Electric Arc Furnace Based on Actual Recorded Data using Artificial Neural Network

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Abstract - *This paper presents Artificial Neural Network (ANN) model of electric arc furnace. ANN has a multilayer feed forward network structure and is trained using a back propagation learning rule. The ANN model is used to predict the arc impedance of EAF. The data for training of ANN model uses the measurement data using power quality analysis at side secondary of transformer furnace. Simulation results show that the proposed method is very effective for modeling of electric arc furnace. The performance of best validation reached at epoch 58 and the error is 0.0011961*

Key Words:electric arc furnace, neural network, back propagation, arc resistance

1. INTRODUCTION

Electric Arc Furnace is part of the steel smelting industry which serves to melt the raw materials such as scrap sponge, limestone and other mixed materials into steel[1]. EAF type used is an alternating current electric arc furnace three-phase, which every phase connected with one the electrode. The electrodes produce an electric arc are used as a source of energy for melting[2]. The melting process, electrodes will move up and down through electrode control system to generate stable electric arc, the electrode control system automatically ordered electrode to move up and down to keep gap between the tip of the electrode and material that serves as a load, so that gap between the tip electrode and the charge remained stable according to the reference impedance that have been determined[3]. The distancebetweenthe tipelectrodeandmaterial asconductorwillaffecttheflowof the electrical currentto the electrodes, whichin turnaffecttheelectricalarc(arc power) generated. So that when theelectric currentin thethreephase electrodesis stable, theelectric arcandthe power generatedis also stable.Normal operationof theEAFcan bedivided intotwostages, called stage of meltdown andrefining.

The datainthis study were obtainedfromthe datasystem inthe steelindustrywithloadsEAFthat seen infigure 1.

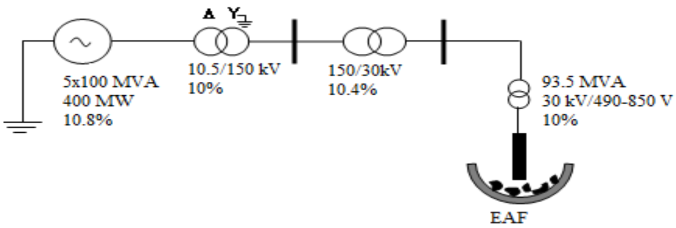

Fig -1: Electrical systemswere observed inthisstudy

In this study, EAF connectedat30kVbusthrough atransformerfurnace with a capacity 30kV/566 V, 93.5 MVA[4]. Charging is the process of inputting of raw materials of steel that have been placed in a bucket into the electric arc furnace. Charging system of raw materials into an electric arc furnace there are two kinds of charge conventional feeding system and charge continuous feeding system.

The EAFs are non-linear load and the operation of EAF caused power quality problems such as unbalanced voltage and current, voltage flicker and odd and even harmonics. The problem that arises in the EAF needs to be repaired. Researcher have published in remedy of power quality in weak grid system and weak grid characteristics[5][6]. Characteristics response time of EAF have an important role in power quality issues[7].

2. ARTIFICIAL NEURAL NETWORK

Artificial Neural networks are information processing paradigm inspired by biological nervous systems, such as our brain[8].

ANN structure is divided into 2 phases:

a. Feed forward, if the current propagates information forward and not members output feedback neural network to network input.
b. Back forward that if it involves network output feedback input to the network and not just responds to input but also responds to network output is fed into the network input.

The main characteristic of the ANN is the ability to learn. Learning the ANN can be defined as a process of adjusting its parameters (weights interconnect). A desired output depends on the price of interconnection weights are owned by each cell. The learning process can be grouped into two types: supervised learning and unsupervised learning. Supervised learning process requires the desired output as the basis for changing the weight. While unsupervised learning process, ANN weights will change by itself, in response to input without reference output.

Basically back propagation consists of three or more layers (multilayer). Architecture for multilayer back propagation network is shown in Figure 2. In this figure the network has one hidden layer (z units). Unit left layer is input layer which is the only unit in the network that receives input from the outside. The middle layer is the hidden layer that connects the input to the output layer. The hidden layer can amount to one or more layers. The right layer is the output layer. Output unit (unit y) and the unit have a hidden bias. Bias on the output unit behaves the same as the weight on the connections to the output is always 1. The right layer is the output layer. Depicted in Figure 2 only feed forward phase direction. Direction on the back propagation learning phase is the signal sent to the opposite direction.

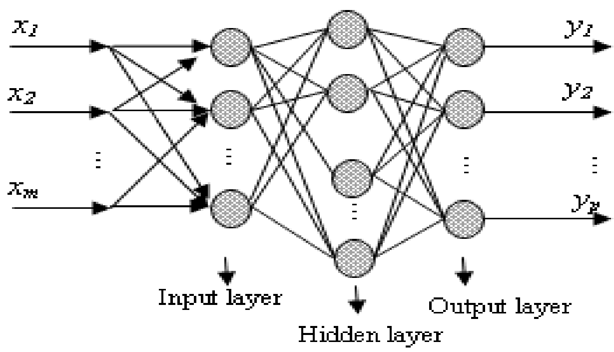

Fig -2:Structure of neural network

3. METHODOLOGY

The data used in this study is actual recorded datafrom plant. Data input are the rms value of current, voltage, and active power. The amount of data used in modeling with the ANN are 15.000 with a composition of 60% data for training, 20% data for testing, and 20% data for validation. The waveform of voltage, current and power like look at Figure 3. The ANN builds using Matlab toolbox.

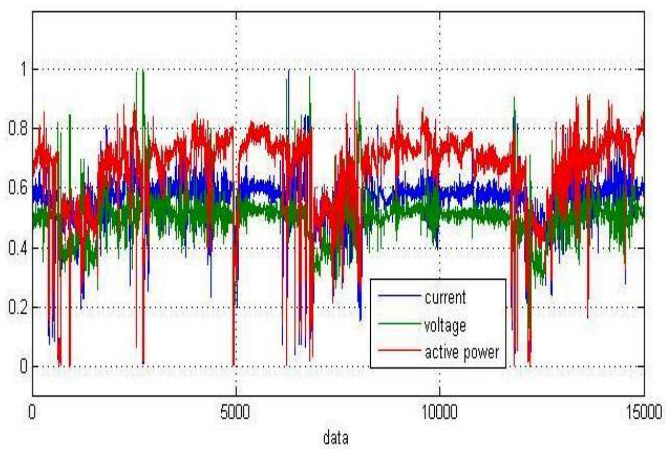

Fig -3:Waveform of neural networkinput

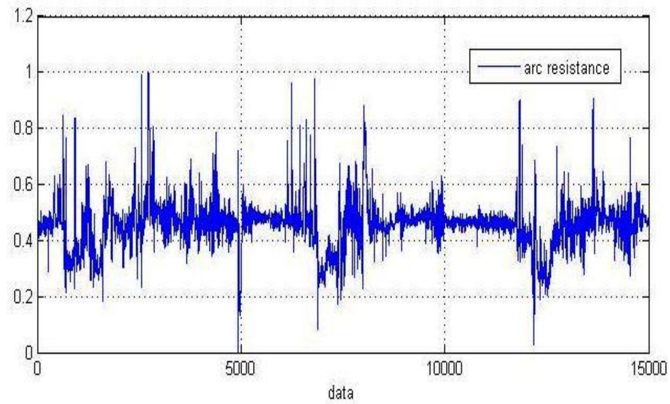

Fig -4:Waveform of neural network target

The data are already in the form of matrix, file names are then given to them for input and target patterns desired. The data are executed in the program back propagation. The data obtained are in the raw form which is still used in the learning process. The datamustbe in thesame rangeof theactivation function, which isusually locatedbetween0and1.Therefore, itis necessaryto process theraw databy:

$$d_n = \frac{d_x - d_{min}}{d_{max} - d_{min}} \quad (1)$$

Where d_n is the data have been normalized, d_x is raw data, d_{max} is maximum value of the raw data, and d_{min} Minimum value of the raw data

Figure 5 shown the configuration which used for modeled of EAF, 3 unit inputs, 1 unit of hidden layer with 10 neurons, 1 unit output. The ANN consist of 2 layers i.e. layer 1 and layer 2

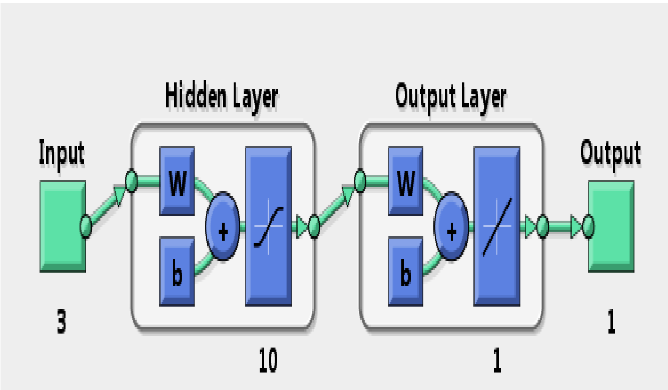

Fig -5: Configuration of neural network for eaf model

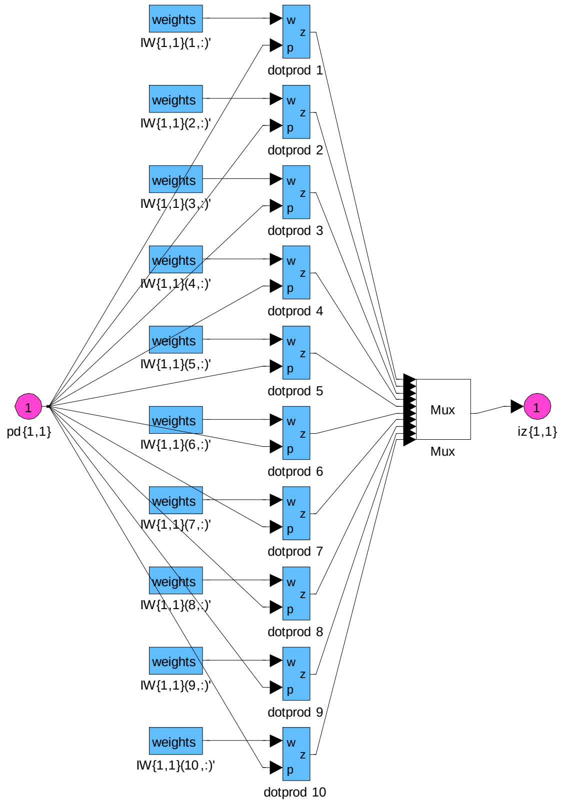

Fig -6: The node of hiddenlayer

4. RESULT AND DISCUSSION

Simulations performed using Matlab 7.6 was applied to the system to provide performance of modeling electric arc furnace. Training network using Levenberg-Marqurdtbackprogation and the result shown in table 1.

Table -1: Result of training network

	Sample of data	MSE	R
Training	9000	1.13371e-3	9.26985e-1
Testing	3000	1.23860e-3	9.23115e-1
Validation	3000	1.22798e-3	9.26985e-1

Mean sqared error (mse) is the average square different between output and target.Lower values of mse are better, mse close to zero that mean no error. Regression (R) shows the correlation between the output and the target. Value of R close to one that mean a close relationship between output and target.From table 1, the network output and target for the data training were analyzed with linear regression. The correlation coefficient of this model is worth 0.926985 (close to 1) shows good results for the target and network output.Datatestingand data validation were analyzed with linear regression too. The correlation coefficient at this model by using the data testing is worth 0.923115and data validation is 0.926985 shows good results for the target and network output.

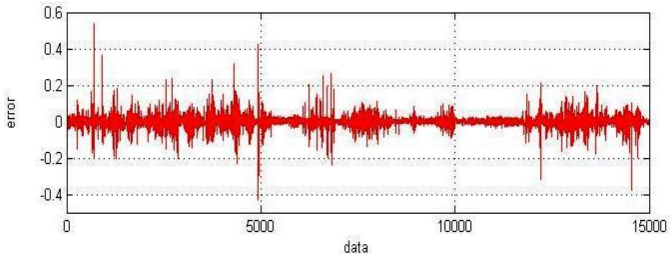

Fig -8: total error

Arc resistance modeling simulation result using artificial neural networks obtained total error (training, testing and validation) as shown in figure 8.

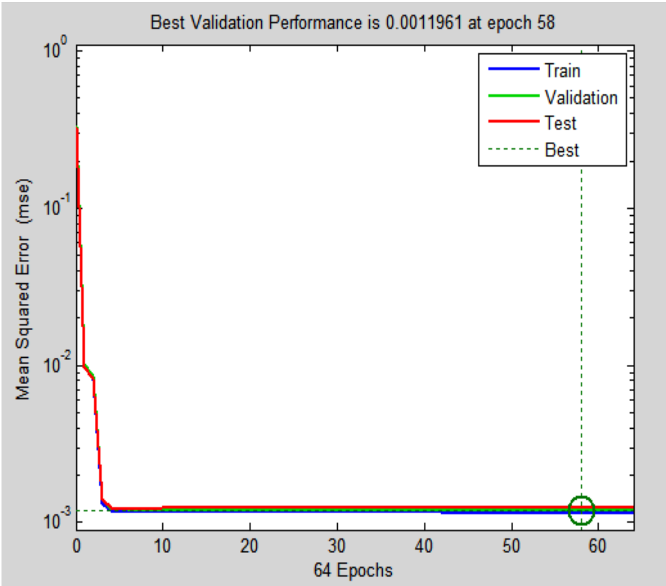

Fig -9: Performance of Epoch

Figure 9shows the performance of error for the proposed artificial neural network. The model of arc resistance reaches the best validation at epoch 58.

The final result of arc resistance of EAF is illustrated in Figure 10.

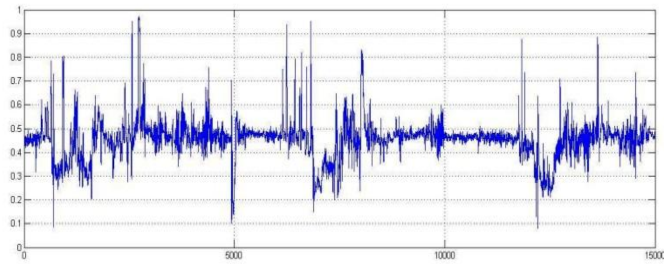

Fig -10: Simulation output of arc resistance

It can be seen that the simulation output of arc resistance obtained for artificial neural network is very similar to the target, as show in figure 4.

5. CONCLUSIONS

Data measurement of EAF could be simulating using Neural Network with 10 hidden layers. Best validation reach is0.0011961 and at epoch 58. Suggestions of this research are conducted further research using another artificial to get a better performance.

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BIOGRAPHIES

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