A NEW NOVEL METHOD OF HARMONIC ANALYSIS IN POWER DISTRIBUTION NETWORKS USING ARTIFICIAL INTELLIGENCE

Mahdi FAYYAZI
Ardebil Electricity Distribution Company – Iran
mahdifaiazy@yahoo.com

Adel AKBARI MAJD
Mohaghegh University - Iran
akbari@uat.ac.ir

ABSTRACT

This paper presents a new novel method to analyze harmonics in electrical power distribution network by using artificial neural networks. Harmonics are a growing concern in the management of electrical systems today. The increasing application of power electronic facilities and circuitry involves continuous power switching has led to serious concerns about source line pollution and the resulting impacts on system equipment and power distribution systems. Power electronic devices have become abundant today due to their capabilities for precise process control and energy savings benefits. However, they also bring drawbacks to electrical distribution systems: harmonics. Power systems designed to function at the fundamental frequency, which is 50 Hz in the Iran, are prone to unsatisfactory operation in the presence of harmonics and faces the problems of voltage unbalance , sag, swell, momentary or temporary interruptions and ultimately the total shut down or the black out of the system. So the safety, reliability and economic efficiency of the power distribution networks will be affected. In this research Artificial Neural Networks have been used for fast and efficiently predicting the harmonics of a power distribution network. The research highlights the importance of focusing on various power quality parameters specially prevention of harmonics in power distribution networks to achieve sustainable availability of quality supply of electrical power by power utilities for its customers. The outcomes of this research were compared and tested with the field results of a electric distribution network in Ardebil , Iran.

INTRODUCTION

Harmonic problems are not new to electric utility and industrial power systems. In the past, most harmonic-related problems were caused by large nonlinear loads such as arc furnaces. These types of problems have been effectively mitigated. However, due to the widespread proliferation of power electronic controlled devices nowadays, the problems caused by harmonics are of increasing importance. Power electronic loads offer a number of advantages in controlling power flow and in efficiency, but they perform this by chopping, flatting, or shaping sinusoidal voltages and currents. Harmonics are produced in the process. Harmonic currents are caused by nonlinear loads connected to the distribution system. A load is said to be nonlinear when the current it draws does not have the same wave shape as the supply voltage. The flow of harmonic currents through the system impedances in turn causes voltage distortion in the distribution system. Equipments consisting of power electronic circuits are typical nonlinear loads. Such loads are increasingly more abundant in all industrial, commercial, and residential installations and their percentage of the total load is growing steadily.

Thus it becomes essential for power utility engineers to analyze the wave shape of electric current drawn by non linear customer loads.

Power utilities across the board aim to maintain the voltage with constant amplitude and frequency without any distortion. But harmonic currents increase the rms current in electrical systems and deteriorate the supply voltage quality. They stress the electrical network and potentially damage the equipment. They may disrupt normal operation of devices and increase operating costs.

DESCRIPTION OF HARMONICS IN POWER DISTRIBUTION NETWORKS

The non-linear load connected to the power system distribution will generate current and voltage harmonics. The current and voltage have waveforms that are non-sinusoidal, containing distortion, whereby the fundamental waveform has numerous additional waveforms superimposed upon it, creating multiple frequencies within the normal sine wave. Harmonic distortion is found in both the voltage and the current waveforms in power distribution networks and can be given as under :

$$V_{rms} = \sqrt{\sum_{h=1}^{h_{max}} \left(\frac{V_n}{\sqrt{2}}\right)^2} = \frac{1}{\sqrt{2}} \sqrt{\left(V_1{}^2 + V_2{}^2 + \cdots + V_{h_{max}}{}^2\right)} \quad (1)$$

$$I_{rms} = \sqrt{\sum_{h=1}^{h_{max}} \left(\frac{I_n}{\sqrt{2}}\right)^2} = \frac{1}{\sqrt{2}} \sqrt{\left(I_1{}^2 + I_2{}^2 + \cdots + I_{h_{max}}{}^2\right)} \quad (2)$$

Equations (1) and (2) give the root mean square values of voltages and currents for the non-sinusoidal waveforms where Vh and Ih are the amplitude of voltage and current respectively at the harmonic component h.

Fig. 1 below shows the fundamental sine waveform and also shows 3rd , 5th and 7rd harmonics and the distorted waveform which is the result of sinusoids of harmonic frequencies with different amplitudes.

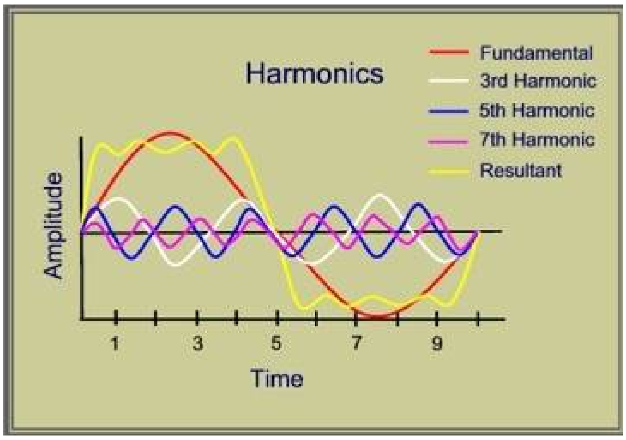

Fig. 1. Waveforms of fundamental, 3rd , 5rd and 7th Harmonic

To quantify the distortion, the term total harmonic distortion (THD) is used. The THD value is the effective value of all the harmonics added together, compared with the value of the fundamental waveform can be expressed as in (3) [1]:

$$THD = \frac{\sqrt{\sum_{h>1}^{h_{max}} (M_h)^2}}{M_1} \qquad (3)$$

where M_h is the root mean square value of harmonic component h of the quantity M.

EFFECTS AND METHODOLOGY FOR ANALYSIS OF HARMONICS

Power systems designed to function at the fundamental frequency are prone to unsatisfactory operation in the presence of harmonics. With the increased usage of modern power electronic equipment the situation has become difficult for power utility engineers to maintain supply of quality power to its customers on sustainable basis. Symptoms of problematic harmonic levels include overheating of transformers, motors and cables, thermal tripping of protective devices, and logic faults of digital devices. In addition, the life span of many devices is reduced by elevated operating temperatures. [2]

Over the years numerous techniques, methods and tools have been employed to measure the harmonic distortion in power distribution network. In recent times the extensive use of non-linear loads especially in modern industry has made it quite difficult to achieve accuracy for the measurement of amount of harmonics generated by customer's equipment. In such a scenario, fast methods for measuring and estimating harmonic signals through artificial intelligence techniques have produced excellent results [3].

Different Researchers have worked on the harmonic detection in electrical power system with the help of neural networks and have proposed active filters to cancel the harmonic current generated from the specific nonlinear load [4-6].

Power Quality Data for voltage unbalance for a power utility of 20 KV substations in Ardebil, Iran has been analysed at 2013. However, the analysis reserved only 10% data for training purposes and harmonic distortion data was not considered.

The current research work is an extension of the previous work and aims to analyze the harmonic distortion for the same power utility by using intelligent algorithms. The PQ instruments at the substation monitor PQ parameters at the 20 kV bus. The values of voltages and currents are measured phase-to-phase. The different PQ parameters have been recorded for a period of 6 month along with power factor of the distribution network.

ARTIFICIAL NEURAL NETWORK BASED ALGORUTHM

The Feed Forward Back Propagation Algorithm is one of the most widely used techniques in ANN. Due to the non convergent behaviour of Multilayer Perceptron for our available Power Quality dataset, the FFBP algorithm is proposed. It is a common method of training artificial neural networks. In this Algorithm supervised techniques are employed.

The training errors for the estimated harmonics are calculated using the "Least Mean Squared (LMSE) technique" [7]. Fig 3 shows the flowchart of proposed Algorithm in this paper.

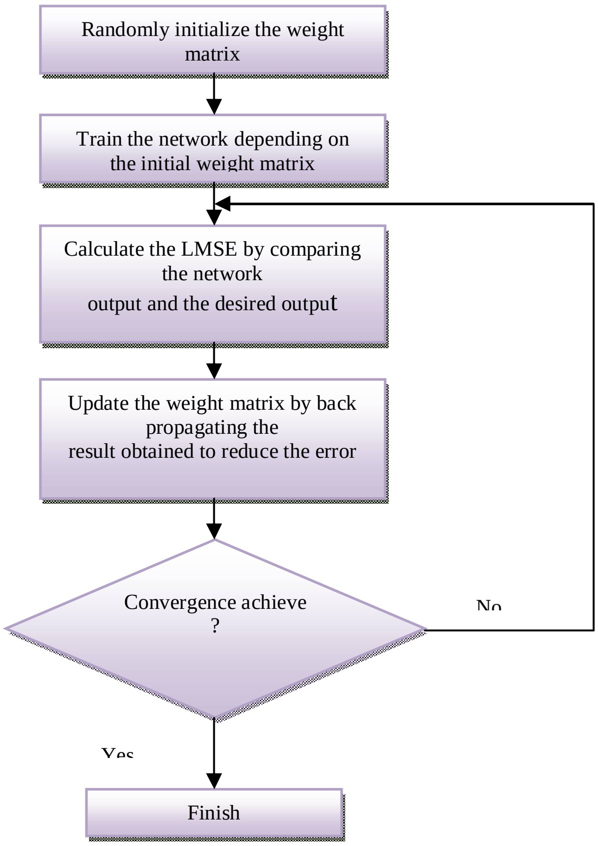

Fig2. The flowchart of used Algorithm

RESULTS AND DISCUSSION

In this research, Artificial Neural Networks are used to efficiently predict harmonics on the three phases of the power distribution network. The experimental results obtained in this research are discussed below :

A. *The Power Quality Data*

The Power Quality data of a power distribution network used in this research has been taken from an electrical distribution company in Ardebil, Iran. It consists of 30 attributes to estimate the harmonics in power distribution network. Each attribute contains 3890 datasets. The raw average values of PQ data were used. The Power Quality data consists of average values of different parameters of power distribution network for consecutive 4320 hours.

B. *Feed Forward Back Propagation Algorithm*

Twenty percent of the available data was reserved for testing purpose where as the remaining 80% data was used to train the neural network. A two layer neural network is used with tan sigmoid in the hidden layer and log sigmoid in the output layer. The output layer estimates the harmonic values on the three phases of the power distribution network. The estimated and actual values of harmonics for phase A are listed in Table I, whereas for phase B and phase C these values are listed in Table II and Table III respectively.

TABLE I . PREDICTED VALUES OF PHASE A

Predicted Values	Actual Values	Difference
6.3498	6.264564	0.08523614
6.5241	6.491537	0.03256314
6.8512	6.798885	0.05231481
7.1205	7.056959	0.0635412
7.1322	7.108548	0.02365214

TABLE I . PREDICTED VALUES OF PHASE B

Predicted Values	Actual Values	Difference
6.476796	6.943381	-0.46659
6.654582	7.193052	-0.53847
7.62351	7.531135	0.092375
7.9253	7.815016	0.110284
7.274844	7.871764	-0.59692

TABLE I . PREDICTED VALUES OF PHASE C

Predicted Values	Actual Values	Difference
7.20363	7.179581	0.024049
6.8952	7.12536	-0.23016
7.49989	7.767335	-0.26744
8.0836	8.051216	0.032384
7.151224	7.03625	0.114974

On the average 96.2 % of accuracy was achieved for predicting the harmonic values of the distribution network. This can help the power utility to attain some precautionary measures against high values of harmonics. The training, testing and cross validation error curves are shown in Fig. 3, 4 and 5 respectively. The harmonics on Phase A achieved convergence in 57 epochs. The harmonics on Phase B achieved convergence in 20 epochs while on Phase C, the convergence was achieved in 28 epochs.

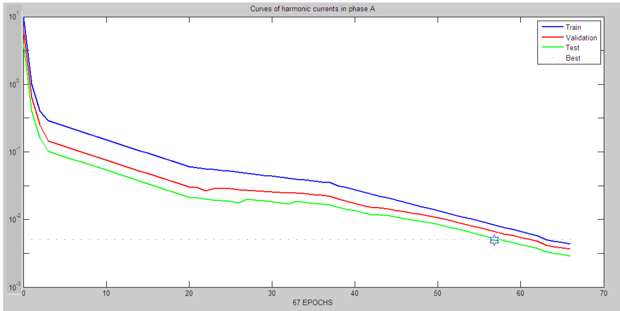

Fig. 4. The training, cross validation and testing error curves for harmonic currents in Phase A.

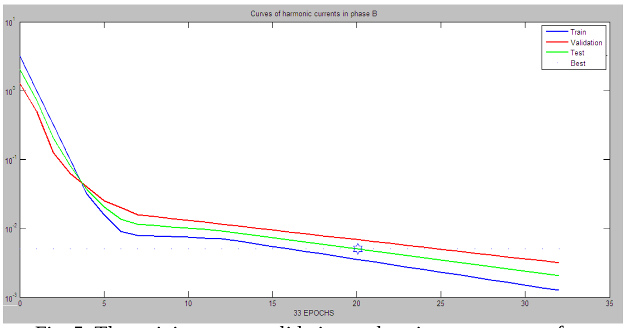

Fig. 5. The training, cross validation and testing error curves for harmonic currents in Phase B.

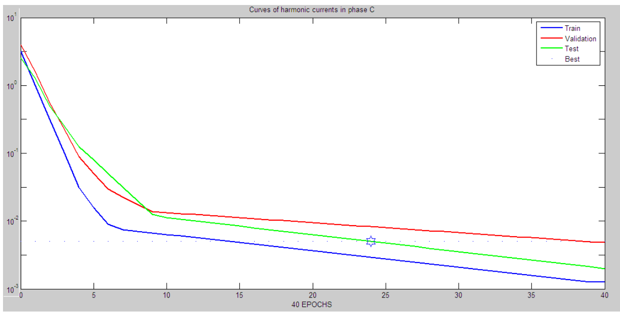

Fig. 6. The training, cross validation and testing error curves for harmonic currents in Phase C.

CONCLUSION

Problems related to harmonics faced by power utilities can be avoided by efficiently estimating/predicting the harmonics using artificial intelligence techniques. This research efficiently predicts the harmonic values on the three phases of a distribution network with an accuracy of 96.2%. This means that artificial intelligence techniques can be used to predict and estimate the undesirable harmonic values with high accuracy. Hence ANN techniques can be used for efficient estimation of harmonics in power distribution networks and precautionary measures can be taken in advance by power utilities for proper protection, reliability, and economical efficiency of the power distribution network.

REFERENCES

[1] R. C. Dugan, S. Santoso, M. F. McGranaghan and H. Beaty, *Electrical Power Systems Quality*, McGraw Hill, November, 2002.

[2] Marty Martin, P.E., "Two Modern Power Quality Issues-Harmonics and Grounding", Available online, http://www.copper.org/applications/electrical/pq/issue, Last Accessed, March 10, 2009

[3] Boguslaw Swiatek, Marek Rogoz and Zbigeniew Hanzelka , "Power System Harmonic Estimation Using Neural Networks", *9th International Conference, Electric Power Quality and Utilization, Barcelona*, 9-11,October2007.

[4] F. Temurtas , R. Gunturkun , N. Yumusak , H. Temurtas "Harmonic detection using feed forward and recurrent neural networks for active filters", *Journal Electric Power Systems Research* vol. 72,pp.33-40. , 2004

[5] A. Hikihara, T. Hirane, Y. Oku, K. Nakamura, O. Tada, S.; Mizuki, K. Ogihara, Y "Suppression of harmonic voltage distortion by neural network controlled active filter", *Industry Applications Society Annual Meeting, 1992., Conference Record of the 1992 IEEE*, 4-9 Oct. 1992, pp.754 – 761, vol.1

[6] B.S. Lathika and S.A. Koya," Active Power Line Filter using Artificial Neural Network and Fuzzy Control", in *Proc. International Conference on Power and Energy Systems 2005*, pp.1-5.

[7] Shafayat Abrar, Azzedine Zerguine and Maamar Bettayeb, "Recursive Least-Squares Backpropagation Algorithm for Stop and Go Decision-Directed Blind Equalization", *IEEE Trans. on Neural Network*, vol.13, no.6, pp. 1472-1481, November 2002