Harmonic estimation using radial basis function neural network

G. Keerthi Vijayadhasan[1*], Thanadapani T[2], R. Raghuraman[1], J. Vishnupriyan[1]
[1]*Department of Electrical and Electronics Engineering, Chennai Institute of Technology, Tamil Nadu, India*
[2]*Department of Electronics & Communication Engineering, Chennai Institute of Technology, Tamil Nadu, India*

Abstract

Harmonic estimation is the initial and main process for designing filter for effective harmonic mitigation. A democratic neural network technique of radial basis function neural network (RBFN) is proposed to estimation of harmonics and the outcomes are compared with the established ofBack Propagation Neural Network (BPN). The BPN has the demerits of slow convergence, repeated training required to reduce the error which results in time consuming and also not meeting the performance goal with complex systems with more number of neurons. The simulation results show that the proposed RBFN method is accurately predicting the harmonics at PCC with very less computational time and error when compared with the BPN network.

Keywords- *Artificial Neural Network (ANN), Back Propagation Network (BPN), Fast Fourier Transform (FFT), Mean Squared Error (MSE), Radial Basis Function Neural Network (RBFN), Point of Common Coupling (PCC), Power Quality (PQ).*

I. INTRODUCTION

The continuous power supply for increasing demand of custom power devices is a challenging task for the utilities. The usage of non-linear loads leads to creation of harmonics in the power circuit. Before installing harmonic filters for a particular system, it is essential to estimate or identify the sources of harmonic in that system. Even though there are numerous techniques available to predict harmonics, for faster and accurate prediction of harmonics the ANN plays a vital role. In this paper, the BPN and RBFN show the predicted values of harmonics. Finally the results prove that RBFN is faster and more accurate than BPN in estimating harmonics.

II. FAST FOURIER TRANSFORM (FFT) FOR HARMONIC ANALYSIS

The Fourier block inwards MATLAB executes a Fourier analysis of the input signal throughout a passing window from one or two cycles of the fundamentals frequency signal. Thus Fourier blocks can be constitute programmed to be calculate the amplitude and the phase of DC component, therefore the fundamental or any harmonic component are input signal. The signal *f(t)* can be conveyed by a Fourier series form,

$$f(t) = (a_0/2) + \sum_{n=1}^{\infty} a_n \cos(n\omega t) + b_n \sin(n\omega t) \qquad \ldots\ldots\ldots\ldots \quad (1)$$

Where

n represents the rank of the harmonic current or voltage
(*n* = 1 corresponds to the fundamental component).

The magnitude and the phase of selected harmonicconstituent are calculated by the given way of equations is below.

ISSN: 2233-7857 IJFGCN

$$|Hn| = \sqrt{a_n^2} + \sqrt{b_n^2} \ldots\ldots\ldots\ldots \quad (2)$$

$$_n = atan\ 2(a_n / b_n)\angle H \quad \ldots\ldots\ldots \quad (3)$$

Where,

$$a_n = \frac{2}{\tau} + \int_{\tau-T}^{\tau} f(t)\ \cos(n\omega t)dt \ldots\ldots\ldots (4)$$

$$b_n = \frac{2}{\tau} + \int_{\tau-T}^{\tau} f(t)\ \sin(n\omega t)dt \ldots\ldots\ldots (5)$$

$$T = 1/f_1 \ldots\ldots\ldots \quad (6)$$

f_1=fundamental frequency

This Fourier blocks are applies a running average window of one or two cycles and the simulation has to be completed, before this outputs give to be the correct magnitude and the phase angle.

III. RADIAL BASIS FUNCTION OF NEURAL NETWORK (RBFN)

An Artificial Neural Network (ANN) is makes up information are processing through a system that has to be accepts a certain performance characteristics of similar with the Biological Neural Networks (BNN). Artificial neural networks have been created based on the assumptions that:

1. Neurons are nothing but information processors occurs at many simple elements.
2. Signals are passed between neurons through the connection links.
3. To each connection link has be associated weight and which that multiplies of signal transmitted.

A) Architecture

The radial basis function network (RBFN) uses the most common nonlinearities such as sigmoid and Gaussian kernel functions. Regularization neural networks are using this Gaussian functions. The response of such **a** functions positive for all values of y; the response decreases to0 as $|y| \to 0$. The Gaussian function is generally defined as

$$f(y) = e^{-y2} \quad \ldots\ldots\ldots\ldots (7)$$

The derivative of this function is given by,

$$f'(y) = -2yf(y) \quad \ldots\ldots\ldots\ldots \ (8)$$

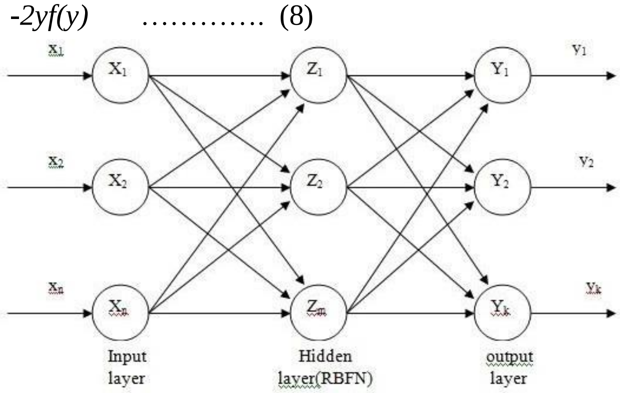


Figure 1: RBFN architecture

ISSN: 2233-7857 IJFGCN

IV. METHODOLOGY

A. Simulation of a non-linear load

The non-linear loads are the major causes for the power system harmonics. So here the three phases AC Drive is connected with a three phase source. Before that, the universal bridge has three arms consisting of six diodes for rectification. The converted (DC to AC) voltage feeds the AC machine. The FFT Analysis is used to measure the Input current and Voltage harmonics.

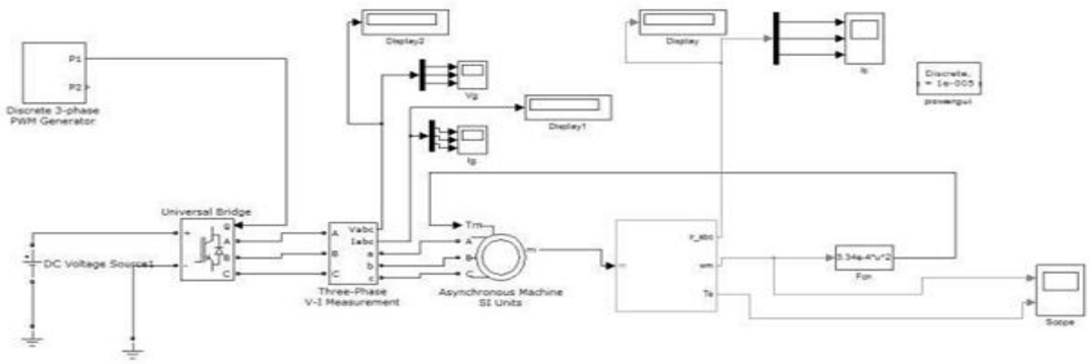
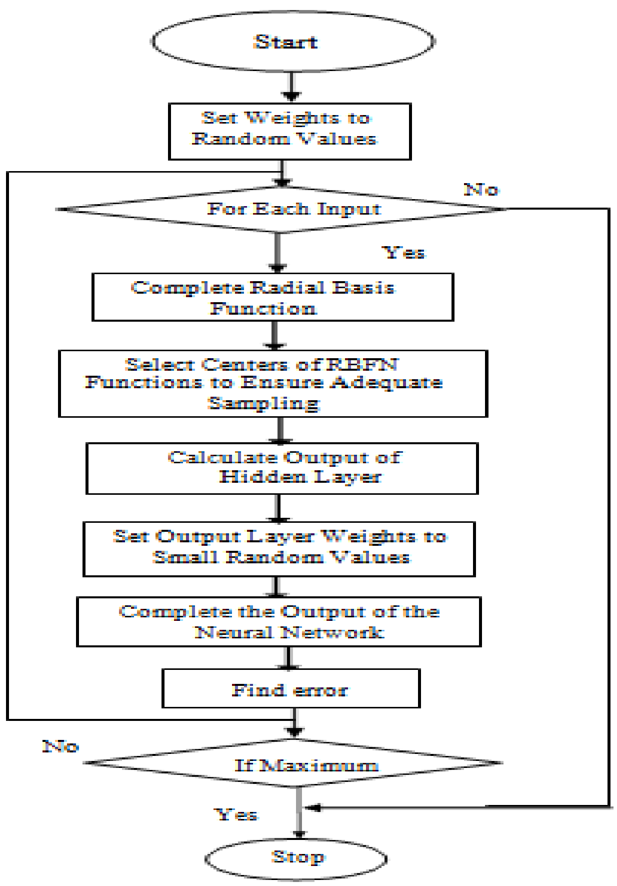


Figure 2: Three phase AC machine connected to a source



ISSN: 2233-7857 IJFGCN

Table 1: Specification of an AC Drive

SI. No	Specifications	Rating
1	Rated voltage	400 volts
2	Rated power	5.4 hp
3	Rotor type	Squirrel-cage

For a real time case, the poor power factor will absolutely affect the nominal frequency (50 Hz) of the power system. Taking this into consideration, varying the fundamental frequency from 49.5 Hz, 49.6 Hz, and 49.7 Hz...50 Hz,50.3 Hz, to 50.5 Hz. For each frequency the AC drive current samples, voltage samples, harmonic amplitude, phase angle and total harmonic distortion is obtained using FFT analysis. So here there are 11 samples were taken for each phase i.e., A, B and C. Each sample represents the varying frequency (49.5 Hz to 50.5 Hz). The actual values of harmonic amplitude and phase angle were obtained from FFT analysis. The current samples are the input and the harmonic magnitude and phase angle forms the target in the neural network training. The simulated results are the predicted values of harmonic amplitude and phase angle. The differences between among the actual and predicted values are error. In this paper, the results are compared between the BPN and RBFN. Finally RBFN shows faster and more accurate prediction of harmonics than BPN.

V.RESULTS AND DISCUSSIONS

Table 2: Comparison of aggregate error in harmonic amplitude

Phase	Back propagation network	Radial basis function network
A	0.012195	0
B	0.044536	0
C	0.004163	0

Table 3: Comparison of aggregate error in harmonic phase angle

Phase	Back propagation network	Radial basis function network
A	0.000241	0
B	0.024493	0
C	0.329604	0

ISSN: 2233-7857 IJFGCN

Table 4: Comparison of computational time in sec- harmonic amplitude

Phase	Back propagation network	Radial basis function network
A	106.574217 sec	1.301326 sec
B	182.190788 sec	1.295748 sec
C	14.512707 sec	1.156586 sec

Table 5: Comparison of computational time in sec-harmonic phase angle

Phase	Back propagation network	Radial basis function network
A	13.652542 sec	1.292473 sec
B	14.678676 sec	1.308226 sec
C	22.210274 sec	1.292727 sec

From the Tables no 2 & 3 is to be noted that radial basis function neural network contributes are very less error, when compare with the Back Propagation Neural Network (BNN). Tables 4 & 5 show the comparison of computational speed of the BPN and RBFN. From the tables 4 and 5 RBFN has very lesser computational time to converge when compared to the BPN. Unlike BPN, RBFNN has the advantage of predicting its own hidden layer neurons for training corresponding to the complexity of the problem. But in BPN it is user's wish in allocation of neurons for the hidden layer. Afterwards, this result is chaos in a choosing number of neurons to be a reducing the computational time and to get accurate output.

VI. CONCLUSION

Problems related to be associated with the harmonics confronted by power utility can be voided by efficiently expeditiously the estimating figuring/predicting of harmonics using Artificial Intelligence Techniques (ANN). The results show that the BPN may have a minimum error in predicting the amplitude and phase angles. But besides that, BPN undergoes chaos in choosing appropriate number of neurons for hidden layer. In some cases MSE value also increases according to our number of neurons chosen and it requires several number of training to reduce the MSE values. Then it also met with slow convergence for complex input and target values. To overcome all these disadvantages, the radial basis function network (RBFN) is implemented. In this work the results show that the RBFN gives faster convergence, lesser MSE (nearer to zero) , lesser iterations and accurate estimation of harmonics when compared to BPN.

ISSN: 2233-7857 IJFGCN

REFERENCES

[1] Claudionor Francisco Nascimento, Azauri Albano Oliveira Jr., Alessandro Goedtel, Alvaro Batista Dietrich,"Harmonic distortion monitoring for nonlinear loads using neural-network-method", Elsevier,Applied Soft Computing,Vol. 13, pp: 475–482, 2013.

[2] Zahir J. Paracha, Akhtar Kalam, and Rubbiya Ali, "A Novel Approach of Harmonic Analysis in Power Distribution Networks using Artificial Intelligence", IEEE Conference 2009.

[3] S.Ghodratollah Seifossadat, Morteza Razzaz, Mahmood Moghaddasian, Mehdi Monadi, "Harmonic Estimation in Power Systems Using Adaptive Perceptrons Based on a Genetic Algorithm", WSEAS Transaction on Power systems, vol.2, issue.11, pp:239-244, 2007.

[4] Hsiung Cheng Lin, "Intelligent Neural Network-Based Fast Power System Harmonic Detection", IEEE Transactions on Industrial electronics, Vol.54, No.1, pp: 43-52, 2007.

[5] Mario Oleskovicz, Marcelo A. A. Lima, Etienne Biasotto, and Denis V. Coury, "Estimation of Harmonic Currents Injected by Nonlinear Loads for a Distorted Power Supply Scenario Using Artificial Neural Networks", *IEEE conference*, pp:457-462, 2012.

[6] B.Vasumathi, S.Moorthi, "Implementation of hybrid ANN–PSO algorithm on FPGA for harmonic estimation", Elsevier, Engineering Applications of Artificial Intelligence Vol. 25, pp:476–483, 2012.

[7] Joorabian M, Mortazavi SS, Khayyami AA, "Harmonics estimation in a power system using a novel-hybrid Least Square–Adaline algorithm". Electric Power System Research, Vol.79(1), pp:107–116, 2009.

[8] C. Demoulias, D. Goutzamanis, K. Gouramanis, "Analysis of the voltage harmonic distortion at buses feeding office loads", *IET Sci. Meas. Technol.*, Vol. 3, Issue. 4, pp. 286–301, 2009.

[9] Howard Demuth, Mark Beale, "Neural Network Toolbox-For Use with MATLAB", User's guide, Version 4, The MathWorks.

[10] Roger C.Dugan, Mark F. McGranaghan, Surya Santoso and H.WayneBeaty, "Electrical Power System Quality", McGraw –Hill.

ISSN: 2233-7857 IJFGCN