ANALYSIS OF GENERATED HARMONICS DUE TO SINGLE PHASE PWM AC DRIVES LOAD ON POWER SYSTEM USING ARTIFICIAL NEURAL NETWORK

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ABSTRACT

Recently harmonic distortion in power systems is attracting significant attention. Traditional methods for harmonic distortion analysis using either FFT or DFT are, however, susceptible to the presence of noise or sub-harmonics in the distorted signals. Harmonic detection by using Fourier transformation requires input data for one cycle of the current waveform and also requires time for the analysis in next coming cycle. In this paper, an alternative method using neural network algorithm has achieved satisfactory results for fast and precise harmonic detection in noisy environments.

In this paper we are identifying the harmonics component in power system generated by a control scheme of single-phase to three-phase PWM converters for low power three-phase induction motor drives. Currently there are number of methods are available for identifying the harmonic components in power system but we use the intelligence system (ANN) for this work.

**Keyword:** Power system, Harmonics, Artificial Neural Network, VFD.

1 INTRODUCTION

The increasing application of power electronic facilities in the industrial environment has led to serious concerns about source line pollution and the resulting impacts on system equipment and power distribution systems. Power systems, in the presence of electronic equipment, can produce harmonics in the power signal waveforms. Power converters, specifically, are responsible for a disproportionate amount of the harmonics troubling power systems today [1]. Converters are used in variable-speed drives, power supplies, and UPS (uninterruptible power supply) systems; the term converter can refer to rectifiers, inverters, and cycloconverters. Arc furnaces are another significant source of harmonics. Harmonics in power systems can be the source of a variety of undesirable effects.
In recent years, neural network has got special attention to the researchers because of its simplicity, learning and generalization ability and it has been applied in the field of engineering such as in harmonic detection [2-6]. In this paper we identify the harmonics component in power system generated by a control scheme of single-phase to three-phase PWM converters for low power three-phase induction motor drives. In low power residential and industrial applications, where only a single-phase utility is available, a single-phase to three-phase power converter system is required to feed the three-phase induction motor drives. Conventionally, a full–bridge diode rectifier plus three-leg PWM inverter has been used. However, the diode rectifier produces harmonic currents to flow into the supply [7]. Traditionally and currently there are different methods are available and in use for identify the harmonic components in power system but we use the intelligence system (ANN) for this work.

2 VARIABLE FREQUENCY DRIVES

INDUCTION motor for many years has been regarded as the workhorse in industrial applications. In the last few decades, the induction motor has evolved from being a constant speed motor to a variable speed, variable torque machine. Its evolution was challenged by the easiness of controlling a DC motor at low power applications. When applications required large amounts of power and torque, the induction motor became more efficient to use. With the invention of variable voltage, variable frequency drives (VVVF), the use of an induction motor has increased. Variable frequency Voltage Source Inverters (VSI's) are widely used to control the speed of 3-phase squirrel cage Induction Motors (IM) over a wide range by varying the stator frequency. In particular the VSI's are widely preferred in industries for individual medium to high power variable speed drive systems, driving a group of motors connected in parallel at economic costs. Most modern variable frequency drives operate by converting a three-phase voltage source to DC using rectifier. After the power flows through the rectifiers it is stored on a dc bus. The dc bus contains capacitors to accept power from the rectifier, stores it, and later deliver that power through the inverter section. The inverter contains transistors that deliver power to the motor. The “Insulated Gate Bipolar Transistor” (IGBT) is a common choice in modern VFDs. The IGBT can switch on and off several thousand times per second and precisely control the power delivered to the motor. The IGBT uses “pulse width modulation” (PWM) technique to simulate a sine wave current at the desired frequency to the motor [8-10].

![Fig(1): Block diagram of variable frequency drive with 3 phase induction motor load input and output signal also show](image-url)
In this paper we use a single-phase to three-phase PWM converters for low power three-phase induction motor drives which is shown in fig(1). In low power residential and industrial applications, where only a single-phase utility is available, a single-phase to three-phase power converter system is required to feed the three-phase induction motor drives. Conventionally, a full-bridge diode rectifier plus three-leg PWM inverter has been used. However, the diode rectifier produces harmonic currents to flow into the supply.

![Circuit diagram of variable frequency drive](image1)

**Fig(2):** Circuit diagram of variable frequency drive

![single-phase to three-phase PWM converters for low power three-phase induction motor drives](image2)

**Fig(3):** single-phase to three-phase PWM converters for low power three-phase induction motor drives

### 3 ARTIFICIAL NEURAL NETWORK

The most popular Artificial Neural Network (ANN) architecture is multilayer Feedforward Network with backpropagation (BP) learning algorithm. This network, as its name indicates is made up of multilayer. Thus architecture of this class besides processing on input, an output layer also have one or more intermediary layers called hidden layers. The computational units of the hidden layer are known as the hidden neurons or hidden units. The hidden layer aids in performing useful intermediary computations before directing the input to the output layer. The input layer neurons are
links are referred to as input hidden layer weights. Again the hidden layer neurons are liked to the output layer neuron and the corresponding weights are referred to as hidden output layer weights.

A two layers network in which one is input layer and other is output layers called single layer feed forward network. In this architecture the input layer receive the input signals and after processing it forwarded to output layer for output the data. The synoptic links carrying the weights connected every input neuron to the output neuron but not vice-versa. Such a network is said to be feed forward in type or acyclic in nature. Despite the two layers, the network is termed single layer since it is the output layer, alone which performs computation [11-13].

![Multilayer Feed-forward Network](image)

**Fig (4): Multilayer Feed-forward Network**

### 4. BACKPROPAGATION LEARNING RULE

There are several different training algorithms for feed-forward networks. All these algorithms use the gradient of the performance function to determine how to adjust the weights to minimize performance. The gradient is determined using a technique called back-propagation.

Back-propagation is a systematic method of training multilayer Artificial Neural Networks. It is built on high mathematical foundation and has very good application potential. Even though it has its own limitations, it is applied to a wide range of practical problems and has successfully demonstrated its power.

The Back-propagation learning algorithm approach to be followed is basically a gradient descent along the error surface to arrive at the optimum set of weights. The error is defined as the squared difference between the desired output and the actual output obtained at the output layer of the network due to application of an input pattern from the given input-output pattern pair. The output is calculated using the current setting of the weights in all the layers. The optimum weight may be obtained if the weight are adjusted in such a way that the gradient descent is made along the total error surface [13].

### 5 ANN DESIGNING PROCESS

ANN designing process involves five steps: gathering input data, normalizing the data, selecting the ANN architecture, and Training the Network, Validation-testing the network [14].
5.1 Gathering Input Data

The configuration of the experimental system and experimental system block diagram is shown below in Experimental –setup

In the above block diagram set-up, a transformer is connected with power supply. A linear or non-linear load is connected with this transformer. Due to transformer and other loads are generated harmonics in power system. Due to this power supply waveform is distorted. A data acquisition card is connected at power common connection to collect the distorted current/voltage waveform or data. These collected waveform/data transmitted to PC through RS-485 for ANN input which is designed in MATLAB. Collected data is shown in waveform in fig (7).
Fig(7): Supply current waveform when Variable frequency drive loaded with three phase induction motor

5.2 Normalization of input and output data sets

Normalization of data is a process of scaling the numbers in a data set to improve the accuracy of the subsequent numeric computation and is an important stage for training of the ANN. Normalization also helps in shaping the activation function. For this reason [-1, 1] normalization function has been used.

Fig(8): Normalised current waveform of collecting waveform/data
5.3 Selecting the ANN Architecture

The numbers of layers and the number of processing element per layer are essential decision for selecting the ANN architecture. Choosing these parameters to a feed forward backpropagation topology is the art of the ANN designer. In this paper the ANN configuration has 32 input neurons receiving 32 sampled points of the distorted waveform and 32 output neurons producing the magnitude of harmonic components up to the 33th odd harmonics. The hidden layer has 65 neurons to bridge input layer with output layer. For a set of input there is a corresponding set up of output “target” values already stored in a data array. ANN Toolbox in MATLAB is used for this work. The designed network is shown in fig(10)
5.4 Training of the ANN Model

The ANN model used is executed by a structured computer program that can update neurons almost simultaneously. Before the start of training, the initial weight were randomized to value between -0.5 and +0.5. These input and target outputs were “shown” to the ANN in a sequential manner so that the weights were updated step by step according to the backpropagation learning algorithm. The error between the actual output and the target was evaluated after every update. The backpropagation learning algorithm employed [15] works toward reduction of the RMS error, and the training ceases as the total sum of square error reaches just below the error critia initially set. The weights are then supposed to have converged enough that they should represent the non-linear transfer functions between inputs and outputs of the ANN model accurately.

Fig(11): Training of designed ANN

It was observed that during the initial stage of training the rate of convergence in weights update was fast at a learning rate of 0.05. This was seen in the rapid steady drop in total sum of square. Subsequently training yielded a slower convergence rate. The learning rate was constantly reduced whenever the total sum of square value changed too slowly. It was also reduced when the total sum of square value oscillated for a prolonged period of training epochs due to entrapment in local minima.

5.5 Testing

To test the generalizing capabilities of the magnitude networks the distorted waveforms that contained harmonics up to the 33rd odd harmonic with no noise added were considered for the training process.

After the training and testing, the ANN used for unfamiliar input which is collected from experimental set-up for the identification of the harmonic component.

6 RESULT AND DISCUSSION

Fig (12) and fig (13) shows the output of ANN for input voltage and current which is collected from the experimental set-up. From the graph of ANN output we observe that odd harmonics generated in power system due to the single-phase to three-phase PWM converters for low power three-phase induction motor drives load.
Fig(12): ANN Output for odd harmonicst

Fig(13): 1st node ANN Output for dc component

Fig(14): 2nd node ANN Output for fundamental frequency
Fig(15): 3rd node ANN Output for 3rd harmonics

Fig(16): 4th node ANN output for 5th harmonics

Fig(17): 5th node ANN output for 7th harmonics
Fig(18): 7\textsuperscript{th} node ANN output for 11\textsuperscript{th} harmonics

Fig(19): 8\textsuperscript{th} node ANN output for 13\textsuperscript{th} harmonics

Fig(20): ANN output for phase angle for harmonics
7 CONCLUSION

An artificial neural network model is developed and implemented for measuring harmonics component in power system. This model is tested offline under different condition. The result outcome from offline test indicate that the ANN model has providing very high accuracy in harmonic component measurement. The proposed ANN model is implemented on pc with MATLAB software using a data acquisition card. It was tested off-line under different conditions. The result of the off-line test indicates that the ANN model has very high power system harmonics component measurement accuracy. The developed ANN model was implemented on a PC with MATLAB Software (with ANN Toolbox) using a data acquisition card. The ANN model was able to measure the harmonic components of voltage and current at various levels. The data is collected at Machine lab in Dr.C.V.Raman University where the system is available. The output of the ANN shows that due to the single-phase to three-phase PWM converters for low power three-phase induction motor drives odd current harmonics that is 3rd, 5th, 7th, 9th, 11th, 13th, 15th, 17th etc are generated in power system. So proper filter is required for elimination harmonics from load to supply.

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9 REFERENCES


BIOGRAPHIES

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