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MEASUREMENT OF HARMONICS WITH ADALINE USING HALF-CYCLE DATA

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Abstract - Harmonics are undesirable greater frequencies that are overlaid on the fundamental sinusoidal waveform that resulting in creating a distorted waveform. This distortion forms a non-sinusoidal waveform composed of a set of harmonic frequencies, which is harmful to electrical power supply lines. This paper proposes an ADALINE-based algorithm simulated with MATLAB using half-cycle samples. Widrow and Hoff developed ADALINE, a single-layer neural network. It makes use of the delta rule for training to reduce mean square error. It is mainly used because of its advanced and sophisticated machine learning algorithm. ADALINE is used for the estimation of harmonic components. It has higher functionality to respond without delay due to its learning ability. In earlier papers, one full cycle waveform has been used for harmonic measurement. In the proposed system, only half cycle waveform is used for the estimation of harmonics. This algorithm is simulated using MATLAB.

Key Words: Harmonics, ADALINE, MATLAB, half-cycle

1. INTRODUCTION

Harmonic distortion has increased as a result of the use of non-linear loads in power networks. A positive integer number of harmonics is multiplied by the fundamental frequency signal.Harmonic components in currents and voltages waveforms produce distortion and cause the waveform to become non-sinusoidal, causing power system faults and damage. Because harmonics have detrimental effects on transformers, rotating machinery, capacitor banks, and relays, harmonic analysis is critical in industrial power systems. Harmonic identification is useful for understanding electrical machinery in non-sinusoidal situations and designing compensatory filters.

The goal of ADALINE in this project is to shorten the time it takes to measure harmonics. An adaptive linear neuron is a network that contains just one linear unit. The network was developed in 1960 by Widrow and Hoff. The ADALINE system takes input from several units as well as one unit known as bias. In training, the delta rule is used to reduce the mean squared error between actual and target outcomes. The ADALINE architecture is made up of a number of different trainable weights.The inputs and the weights are either positive or negative. The weights are assigned to some non-zero random value. After comparing the actual result with the desired result and the bias, the ADALINE model changes the weights. ADALINE will be trained to measure the fundamental frequency and its harmonics.

2. Harmonics in Power Systems

Harmonics are commonly found in electric power systems. Harmonics will affect the output waveform, so they must be measured. Even and odd harmonics are the two types of harmonics. The even harmonic is a frequency that is 2, 4, 6, 8,... times the fundamental frequency and its multiplications.

The odd harmonic is a frequency that is 3, 5, 7, 9,... times the fundamental frequency's multiplications.

Power quality problems are often caused by harmonic frequencies in the electrical grid. Increased equipment heating and torque vibrations in motors are examples of such problems. The current flowing through a non-linear load fluctuates according to alternating load resistance, meaning the waveform of the current drawn isn't the same as the voltage provided. Short, abrupt pulses are generated by non-linear loads. Pulses distort current waveforms, which in turn can cause harmonics that affect the equipment and loads attached to the distribution system.

Adding harmonic distortion to an electrical power system compromises the system's ability to perform at optimal levels. Due to the increased power consumption caused by harmonics, equipment operations become inefficient. With increased overall current requirements, installation and utility costs increase, overheating occurs, and profitability decreases.

3. Measurement of Harmonics

Azmi Rizki Lubis et al. [1] proposed an Arduino-based approach for monitoring harmonic content that can be modeled using Proteus software. According to the program contained in the microcontroller, voltage and current will be read and assessed. As a result of this research, the Arduino was able to measure harmonic components and show the results on the LCD.

Ignacio Carugati et al. [2] proposed a DFT-based approach for detecting harmonic components from distorted signals that may be implemented quickly and consistently.

For the measurement of both harmonics and interharmonics, **Chang and Cheng [3]** presented a cascaded, two-stage adaptive element structure. To test the effectiveness of the system for detecting elctrical power signals are built.

Dash et al. [4] created an adaptive linear neuron for estimating harmonic components in power networks. The suggested algorithm will adjust the learning parameters to reduce the error.

Enrang et al. [5] developed a system to identify the dynamic harmonic efficiently and fast in power systems by combining both FFT and wavelet transform.

The research of **Haili Ma et al. [6]** focuses on two issues related to recognizing harmonic sources: selecting the best harmonic meter placements and determining the estimates of harmonic source locations. Kalman filtering is used to tackle these issues. The ideal arrangement of limited harmonic meters is determined by a Kalman filter study of system error covariance combined with a harmonic injection estimate.

4. ADALINE Network

There is a single linear component in the ADALINE network, which stands for Adaptive Linear Neuron. In 1960, Widrow and Hoff came up with the concept. In training, delta rules are used to reduce the mean-squared error between the actual and predicted outputs. The bias and weights can both be adjusted.

4.1. Architecture

An ADALINE has a similar fundamental structure to a perceptron, but it also has an additional feedback loop that allows comparison of the actual results to the targeted output. ADALINE receives information from a variety of different units in addition to the one termed bias. The ADALINE model's weights can be adjusted. Each input can take the values of +1 or -1 and weights can take the positive or negative sign. A random weight is assigned initially. A quantizer transfer function is used to restore the result to a positive or negative value using the calculated net input. ADALINE changes all the weights after comparing the net input to the output value and intended output, as well as the bias. Figure 1. shows the architecture of ADALINE.

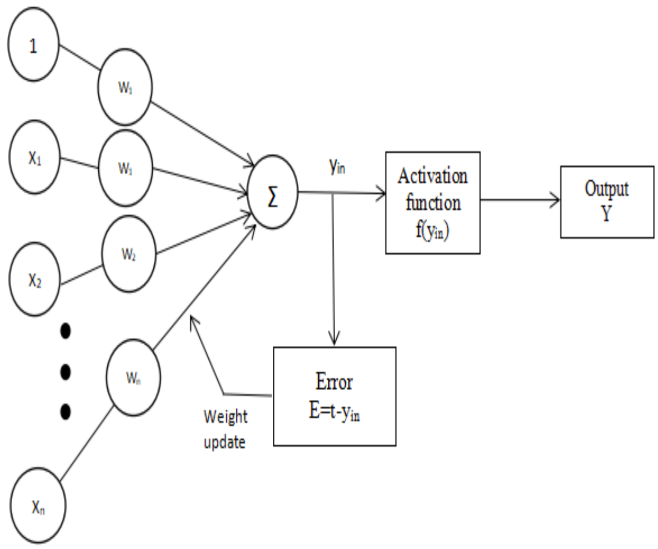

Fig -1: ADALINE architecture

4.2. Training algorithm

ADALINE's algorithm for training networks consists of the following steps:

Step 0: Instead of zero, it is recommended that weights and bias be set to random values.The learning rate parameter should be set to α.

Step 1: When stopping conditions are false, perform steps 2-6.

Step 2: Follow steps 3-5 for each pair of bipolar training.

Step 3: The activations is set up for i=1 to n input units.

Step 4: Calculate the output value from the net input.

Step 5: From i=1 to n, adjust the bias and weights.

Step 6: The training procedure should be stopped if the greatest weight change during training is less than a defined tolerance; otherwise, it should be continued. This method is used to test the halting conditions of a network.

5. ADALINE for Harmonics Measurement

Artificial neural networks (ANNs) are gaining popularity in power system difficulties because of their capacity to learn and handle nonlinear effects and uncertainty. ADALINE networks have been one of the most popular methods for detecting and screening ANNs in electrical networks for nearly a decade. ADALINEs are used to achieve dynamic learning by integrating linear signals with time-dependent data. This type of linear function is quick and accurate. It has been determined that ADALINE is suitable for harmonic compensation.

An ADALINE measured for computing harmonics using data from one complete cycle[4]. One hundred samples were taken from the full cycle waveform. The samples were given as input to the ADALINE architecture and bias is another input with value '1'. The random weight were assigned to the input of the ADALINE network. Then the net input was calculated to the output value using Eq. (1),

$$y_{in} = b + \sum_{i=1}^{n} x_i \omega_i \qquad (1)$$

where , b = bias, n = number of inputs (n = 100), x_i = input vector, ω_i = weights

The net input to output value is subtracted from the target value to calculate the error.

If the error value is maximum then the new weights and bias are updated using Eq. (2) and Eq. (3),

$$\omega_i(new) = \omega_i(old) + \alpha\,(t - y_{in})\,x_i \qquad (2)$$

$$b(new) = b(old) + \alpha(t - y_{in}) \qquad (3)$$

Where, α = learning parameter, t = desired output

Again the above steps are repeated until the error value become minimum. This is based on supervised learning rule. The last updated weights and bias are used for calculating harmonics of different input samples.

6. Measurement of Harmonics using Half-Cycle Data

A complex (non sinusoidal) waveform was generated using MATLAB software. This waveform consists of a fundamental and their harmonics. Figure 2 shows the simulated input waveform for full cycle. ADALINE designed in this project uses only half cycle data for harmonic measurement because the measured signal is in symmetric pattern. In this ADALINE architecture, only 51 samples are used for calculating the order of harmonics and their amplitude. In power system even harmonics are ideally zero; only odd harmonics are present. Even harmonics do not exist because of symmetry between the positive and negative halves of the cycle. This will take less time for harmonic measurement.

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7. Simulation Results

The proposed technique for harmonic measurement is designed and simulated in MATLAB using ADALINE. The order of harmonics and their amplitudes are examined using simply a half-cycle waveform. As a result, the suggested approach outperforms the standard ADALINE algorithm. Figure 3 shows the input, predicted and error waveform and Figure 4 shows order of harmonics and their amplitudes.

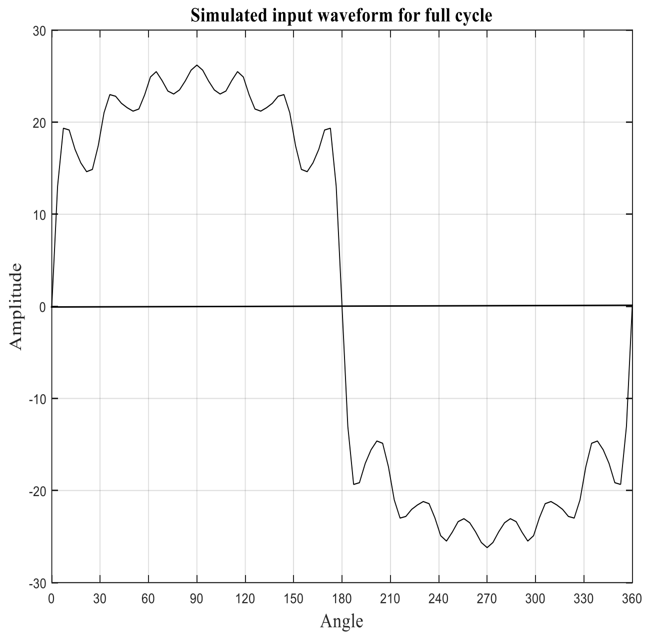

Fig -2: Simulated input waveform for full cycle

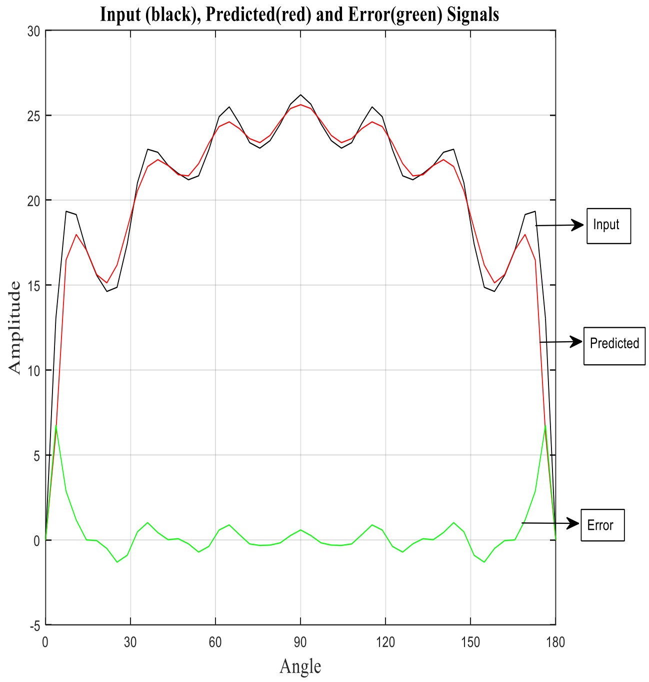

Fig -3: Input, Predicted and Error waveforms for half cycle

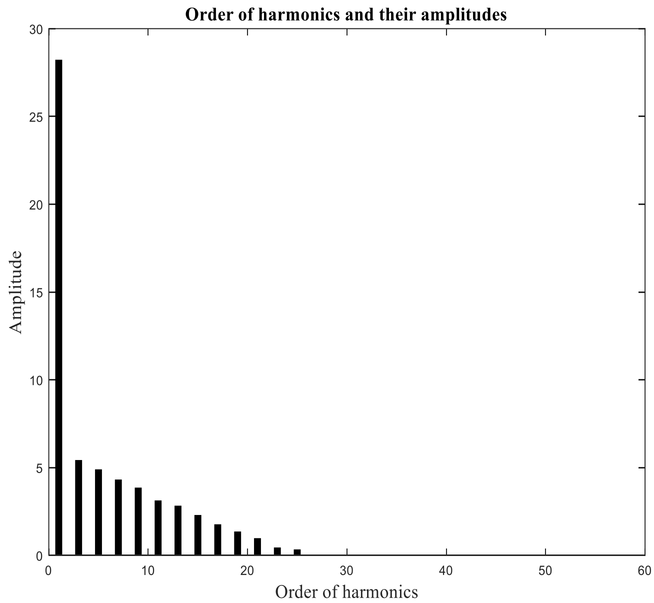

Fig -4: Order of harmonics and their amplitudes as computed by ADALINE

Table -1: Comparison of input amplitudes and predicted amplitudes

8. CONCLUSIONS

The proposed algorithm is utilized to evaluate the order of harmonics and their amplitudes. This method involves changing the weights of input nodes in an ADALINE network using the Least Mean Square methodology. The suggested technique is simulated using MATLAB. Several simulation studies were conducted to estimate harmonics in a power system. As a result, when compared to normal Adaline, the time required for harmonic measurement is less.

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Harmonics order	Input Amplitudes	Predicted Amplitudes	Error %
1	28.6	28.2	1.39
3	5.49	5.40	1.63
5	4.91	4.87	0.81
7	4.32	4.29	0.69
9	3.87	3.83	1.03
11	3.12	3.10	0.64
13	2.83	2.80	1.06
15	2.29	2.27	0.87
17	1.78	1.74	2.24
19	1.36	1.33	2.20
21	0.97	0.95	2.06
23	0.43	0.42	2.32
25	0.32	0.31	3.12

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