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ACCURATE DETECTION OF HARMONICS DUE TO NONLINEAR LOADS IN POWER SYSTEM NETWORK USING FFT ANALYSES

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ABSTRACT

The main aim of this paper is to reduce the harmonic disturbances created by nonlinear loads; it has been a significant problem to maintain power quality. It is very essential to analyze power signal and find different harmonics. To finding the harmonic parts of some specific system currents and voltage references. Some harmonics are harmful to sensitive equipments and also cause power losses. In this paper, tries to finding the supply harmonics is downstream with relevance the nodes caused due to linear and nonlinear load. Here study the effectiveness of the concept with change in position of loads at corresponding nodes. The Fast Fourier Transform (FFT) is introduced with a new structure, capable of harmonic detection and type of load in single and three-phase systems. An analysis of the convergence of the FFT based on a linear and non-linear load under firing angles is presented. This algorithm is developed based on a design to find out the harmonics for combination of suspicious nodes. Systems with a more number of suspicious nodes, the system may divide into sub-system and the certain algorithm is applied to each sub-system to identify the harmonics. Simulations are carried out on performance analysis and to support the theoretical development. The decomposition of an input signal in its harmonic components using the Fast Fourier theory is based on previous knowledge of the signal fundamental frequency, which cannot be easily implemented with input signals with varying frequencies. In this scenario, the main contribution of this paper is the association of a FFT under the results showed the node combinations which are represent the harmonic sources yields an estimation error which approaches zero asymptotically.

KEYWORDS: Fast Fourier Transform (FFT), linear load, non-linear load and identification.

INTRODUCTION

The harmonics identification when system connected to different types of loads is complicated task for past several years. But now is very simple to find out harmonics in linear and nonlinear type connected loads, so it has common toll to resolve the downstream is that the harmonic power direction based technique. A harmonic detection algorithm is expected to supply an estimation of the magnitude, frequency and phase angle of each individual harmonic component. The incentive scheme is considered by many as an ideal solution's to control the harmonic generations from disturbing loads.

The purpose of this measurement technique, which could be used iteratively to detect the presence of harmonics system with various types of loads in power system. From this information, the average harmonic power flowing in the circuit load and it can be founded by FFT analysis.

This paper introduces a new application of the Fast Fourier Transform analysis for harmonic identification and type of load. In the present paper, FFT structure is expanded to allow for harmonic detection in single and three-phase systems at different loads. Compared to other methods, the FFT identification of harmonics has the advantage of a fast response and simple implementation different harmonic components. It is shown that if the orders of the harmonics in the signal are known, further simplification is possible. This paper is a collaboration of identification of load and percentage of harmonics at different nodes of system. The harmonic occurrence and identification is simulated in MATLAB environment by using Fast Fourier Transforms algorithm is used for analysis and breakdown the signals into its various voltages. It is suitable for either linear or non-linear load

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detection. The proposed algorithm will get the estimation of fundamental magnitude components accurately, even if the supply voltage is distorted.

Here another challenge is there, when measuring the harmonics of time varying waveform is have accurate measured data is essential in some applications including the design of harmonic filters, stress on power equipment's and solution to power quality problems. Some recent algorithms are based on wavelet packet transform is lose the accuracy under some conditions if no preventive actions are taken.

This method of FFT has rapidity and accuracy. The result analysis for harmonic percentage identification and identification of the type of load (linear or non-linear) at different nodes is done, The Percentage of the harmonic occurrence. In the further work, the identified result can be implemented for custom power and industrial applications.

SYSTEM CONFIGURATION

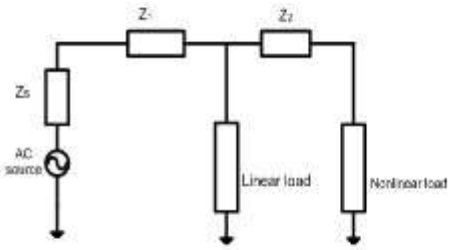

Fig.1: Single line diagram with a Linear and nonlinear load connected to a sinusoidal supply.

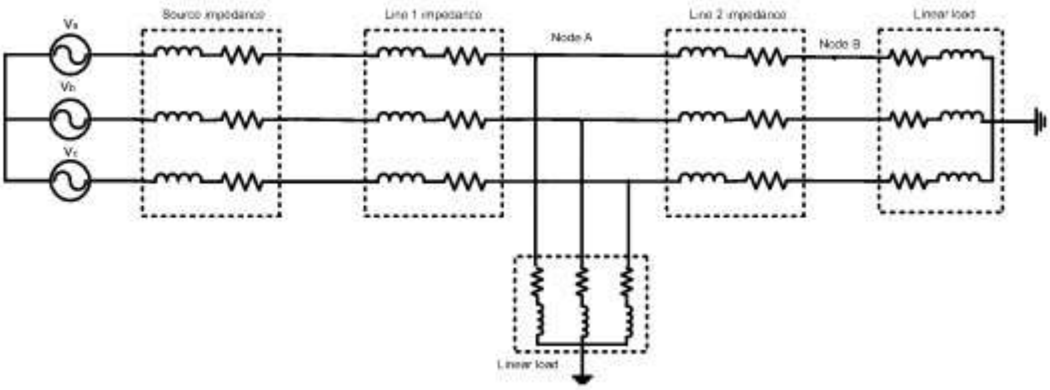

Fig.2: Two Linear loads connected at node A & B

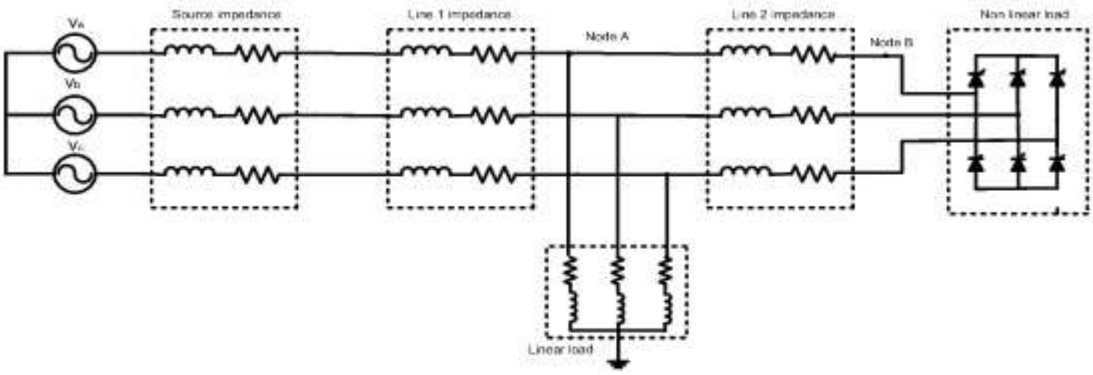

Fig.3. Linear load connected at node A and. Nonlinear connected at node B

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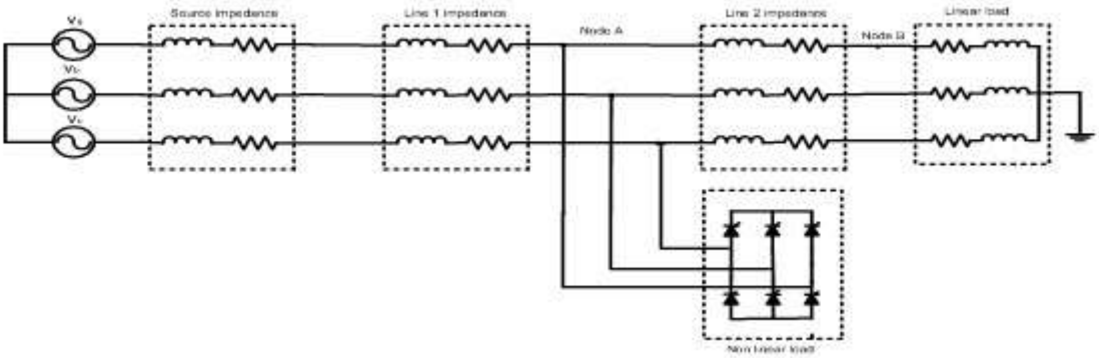

Fig.4. Linear load connected at node A and. Nonlinear connected at node B

From fig.1 a perfect ac source is connected to linear and nonlinear loads through a system impedance or source impedance. The nonlinear load generates harmonics in current waveform that flows within the system affected by distortion in voltage. This voltage distortion depends on each harmonic current and the system electrical phenomena at harmonic frequencies.

A linear load and a nonlinear load are connected to the supply as shown in Fig. 2, 3 & fig.4. Three conditions are studied for this case: first, load 1 is linear while load 2 is linear (condition 1), connected to nodes A & B and then, the locations of the loads are exchanged Fig.3. (Condition2). The linear load is an inductive load having impedance ZL1 at the fundamental frequency is connected at node A. The nonlinear load is an ac voltage regulator with two anti-parallel SCRs, connected to as a load with impedance ZL2 operating at different firing angles of 30o, 60o and 90o, is connected at node B the fundamental power P1 is positive at nodes A, B and decreases from the supply to the load side.

Fig.4. similar construction but loads are exchanged with nodes of Fig.3. Shows the Linear and Non-Linear load connected to the ac supply with interchanging their nodes. It is known that linear load does not draws the harmonics from the source and non-linear load draws the harmonics from the ac supply due its non-linear characteristics present in the thyristor based loads (e.g. electronics devices).

To reduce the load effect on the source, many concepts have been implemented whose concepts suffer from source current harmonics, because of those concepts have inefficient harmonic identification techniques and their slow response. This paper proposes efficient technique to identify the type of load and percentage of harmonics due to the load. For implementation of this process, an analysis and drawback of the conventional concepts is also discussed. In Harmonic detection algorithm the basic function is to detect the current harmonics, the type of load connected and how much percent of harmonics will effects the source currents. Some techniques for detection of harmonics are summarized below.

Fast Fourier transforms (FFT):
In the present paper, its structure is expanded to allow for harmonic detection in single and three-phase systems at different nodes of system. Fourier analysis is used to convert time domain into their frequency components and vice versa. When wave is periodical, the Fourier series can be used to calculate the magnitudes and phases of the fundamental and its harmonic components. The FFT is the DFTs computational efficient implementation Compared to other methods; the FFT has the advantages of a fast response and simple implementation. It is shown that if the orders of the harmonics in the signal are known, further simplification is possible. To achieve the Fourier transform the orthogonal decomposition of power system signal is used. When the FFT algorithm is applied to each supply phase it is possible to obtain the magnitude and phase of each of the frequency components of the supply waveform.

$$y_k = \sum_{j=0}^{n-1} w^{jk}\, y_j \qquad (1)$$

Where w is a complex nth root of unity

$$w = e^{-2\pi i}/n$$

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FLOW CHART FOR IDENTIFICATION OF HARMONICS

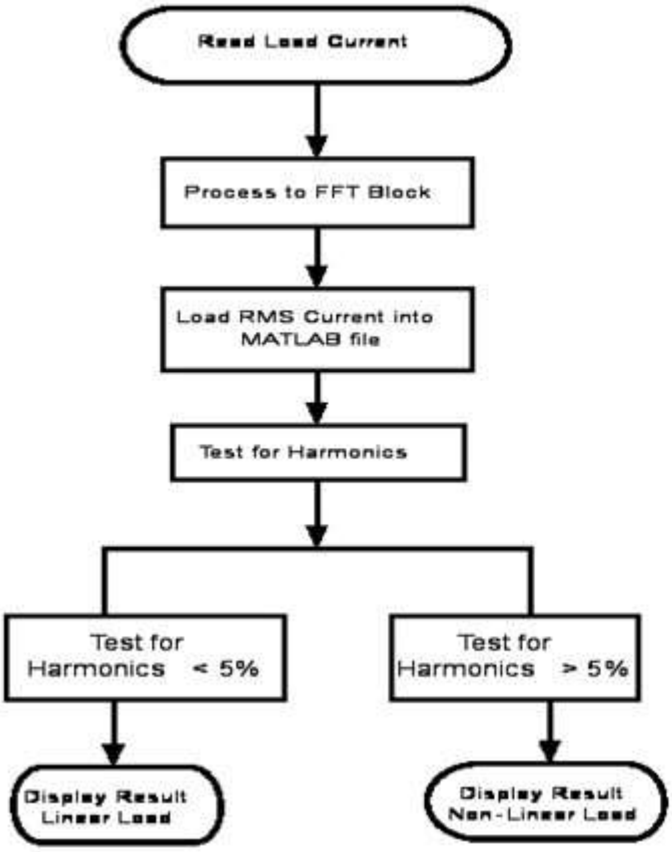

Fig.5. Flow chart for Harmonic Identification using FFT analysis.

Harmonics Detection is essential to describe the accuracy of operation of custom power devices. There are various methods to identify harmonic distortion. The method to detect percentage of harmonics in different types of loads in this paper is Fast Fourier Transform. The FFT plays an important role in analysis, design and implementation of discrete signal processing. FFT algorithms are based on fundamental of discrete Fourier computation. Measuring the harmonic value, harmonic identification exporting the values to Simulating file is discussed in detail in flow chart.

***Read Load Current*:** The harmonic detection process initially starts from the measurement connected to the power system network. This measurement unit connected to each phase individually. Hence it freely identifies the harmonics in the network. The measured signals are given to the further processing of the identification of the Harmonics.

Process to FFT Block: Fourier analysis provides a set of mathematical tools which can be used to break down a signal into its various magnitude components.

An FFT computes the DFT and produces exactly the same result as evaluating the DFT definition; the most important difference is that an FFT is much faster. In the presence of round-off error, many FFT algorithms are also much more accurate than evaluating the DFT definition directly, as discussed below.

$$X[k] = \sum_{n=0}^{N-1} x[n].e_N^{-i2\pi kn} \quad k = 0, 1 \dots N\text{-}1 \qquad (2)$$

The inverse DFT is defined as:

$$x[n] = \frac{1}{N}\sum_{n=0}^{N-1} x[k].e_N^{i2\pi kn} \quad k = 0, 1 \dots N\text{-}1 \qquad (3)$$

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In equations (2) and (3) above, both x [n] and X [k] may be complex. Thus, with complex x [n] and then using equation (2), N complex multiplications and (N-1) complex additions are required to compute each value of the DFT. Consequently, to compute all values of K (0, 1 …N-1), i.e., fundamental frequency have been evaluated accurately with very less span of time.

Load RMS Current into MATLAB file:The identified current harmonics from the FFT block will be given to the Simulating file for evaluation of current harmonics for the given reference signal. In simulink file, multiple conditional operators have been included for identification of harmonic percentage, which identifies the type of load i.e, linear or non-linear load and percentage of harmonic presence.

Test for Harmonics < 5%: In the Simulink file, the identified harmonics have been compared to the specified reference THD value of 5%, with the use of logical operators, if the identified current harmonics is less than the specified THD it will be given for further analysis of identification.

Test for Harmonics > 5%: Else the harmonics have been identified will be > 5% of the specified THD, the signal THD value is sent to the end part of the identification process.

Display Result: The end of the identification process is displaying the results of the percentages of THD. These results will show as linear load if the THD is less than 5% else it will be displayed as non-linear load. This efficient and accurate FFT identification process helps to reduce harmonics on source with very less time by using custom power devices.

MATLAB/SIMULINK ANALYSIS

Case 1: Result of FFT analysis Linear Load exists at node A & node B

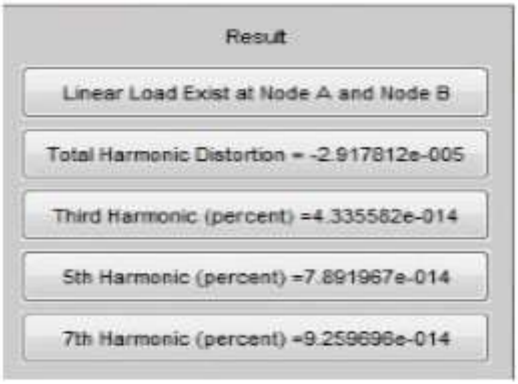

Fig.6. Simulated Result obtained from matlab two nodes connected to linear Loads.

Fig.6. illustrates the Result after FFT analysis; the harmonic distortion in the source current is showed when two nodes (A & B) are connected with linear loads. It has percentage of total harmonic distortion.

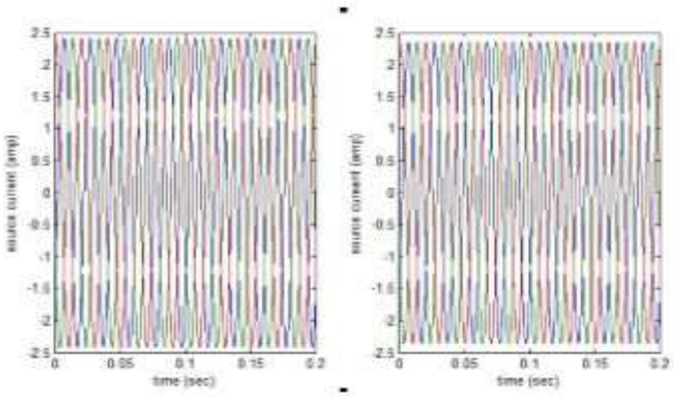

Fig.7. Simulated wave form of Source Current at two linear loads connected nodes A &B.

Fig.7. Shows that source current is sinusoidal under two nodes connected with Linear Load. Here each phase was showed.

Case 2: when linear load connected at node A & Non- Linear Load connected at node B (α= 0^0)

Fig.8. Result obtained from Matlab linear load connected at node A & Non-Linear Load at node B (α= 0^0).

Fig.8. shows the harmonics exists at node B which is connected to non linear load and linear load is connected at node A. it shows total harmonic distortion with 9.80% , and from total THD 5th harmonic component has major contribution with 8.90%

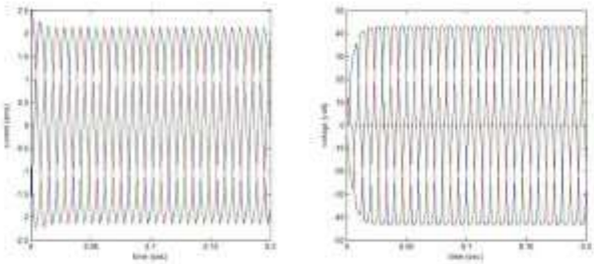

Fig.9. simulated waveform of linear load connected at node A & Non-Linear Load at node B (α= 0^0).

Fig.9.Shows voltage and current is Non-Sinusoidal because the 3-ph ac source is tethered with Non-Linear Load (α= 0^0) at node B. Here the harmonics in source current wave form are presented which are affect the wave form is showed

Case 3: when linear load connected at node A & Non- Linear Load connected at node B (α= 30^0)

Fig.10. Result obtained from Matlab linear load connected at node A & Non-Linear Load at node B (α= 30^0).

Fig.10. Depicts the harmonics at non-linear load connected at node B and linear load connected at node A. The source currents with harmonics, at a Firing angle of α= 30o is identified from FFT analysis that Total Harmonic Distortion is 14.90%. From total THD, 5th harmonic component has major contribution with 13.32% and 3rd harmonic component is almost negligible.

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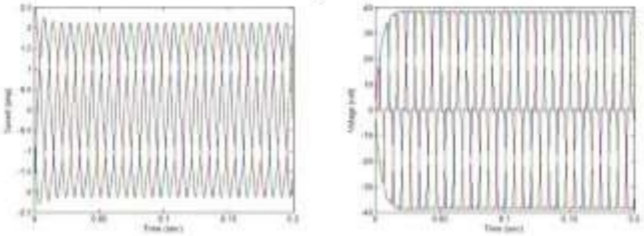

Fig.11. simulated waveform of linear load connected at node A & Non-Linear Load at node B (α= 30⁰).

Fig.11.Shows voltage and current is Non-Sinusoidal because the 3-ph ac source is tethered with Non-Linear Load (α= 30^0) at node B. Here the harmonics in source current wave form are presented which are affect the wave form is showed.

Case 4: when linear load connected at node A & Non- Linear Load connected at node B (α= 60^0)

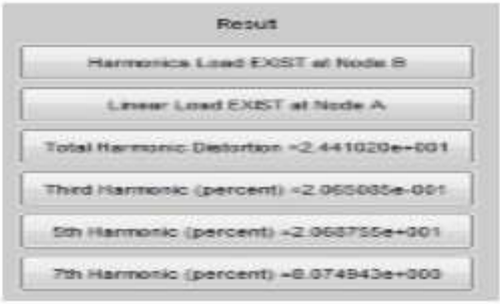

Fig.12. Result obtained from Matlab linear load connected at node A & Non-Linear Load at node B (α= 60^0).

Fig.12. Shows that non-linear load affects the voltage and currents with harmonics at a firing angle of α= $60^{o.}$ it is identified from FFT analysis that Total Harmonic Distortion = 24.41%. From total THD 5^{th} order harmonic component has a major contribution with 20.074%.

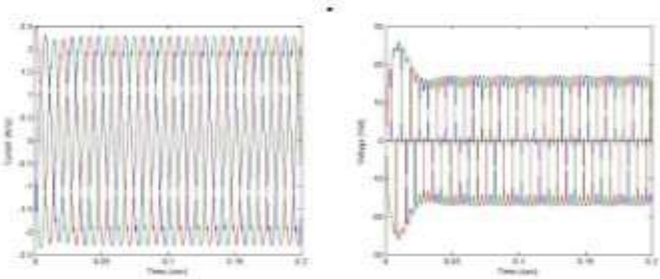

Fig.13. Simulated waveform of linear load connected at node A & Non-Linear Load at node B (α= 60^0).

Fig.13.Shows voltage and current waveform with Non-Linear Load is connected at α= 60. Here high amount of THD and distortion is presented when compared to α= 30.

Case 5: when linear load connected at node A & Non- Linear Load connected at node B (α= 90^0)

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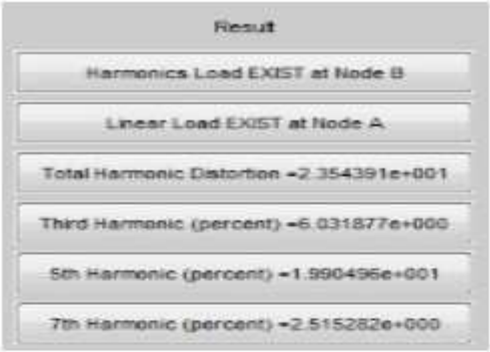

Fig.14. Result obtained from Matlab linear load connected at node A & Non-Linear Load at node B at (α= 90^0).

Fig.14. Shows that non-linear load affects the voltage and currents with harmonics at node B, linear load could not affect at node A it is identified from FFT analysis. The Total

Harmonic Distortion = 23.54%. The 5th order harmonic component has major contribution with 19.90%.

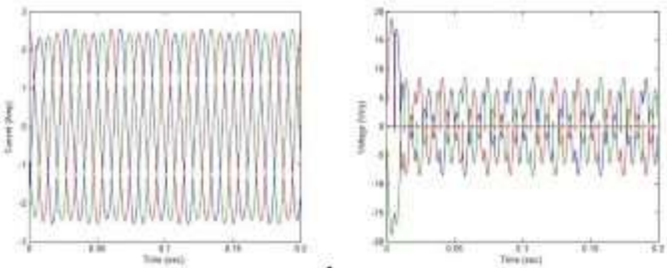

Fig.15. simulated wave form of linear load connected at node A & Non-Linear Load at node B (α= 90^0).

Fig.15.Shows current is Non-Sinusoidal with Non-Linear Load at α= 90. With a high amount of THD presented in current the wave form is highly distorted.

Case 6: when linear load connected at node B & Non- Linear Load connected at node A (α=0^0)

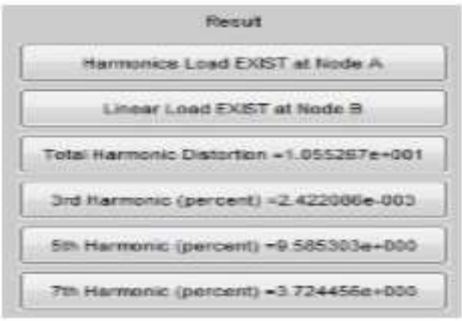

Fig.16. Result obtained from Matlab linear load connected at node B & Non-Linear Load at node A at (α= 0^0).

Fig.16. Shows that non-linear load affects the voltage and currents with harmonics at node A. linear load could not affect at node B it is identified from FFT analysis. The Total Harmonic Distortion = 10.55% at α= 0^0. The 5th order harmonic component has major contribution with 9.58%.

Fig.16. Shows that non-linear load affects the voltage and currents with harmonics at node A. linear load could not affect at node B it is identified from FFT analysis. The Total Harmonic Distortion = 10.55% at α= 0^0. The 5th order harmonic component has major contribution with 9.58%.

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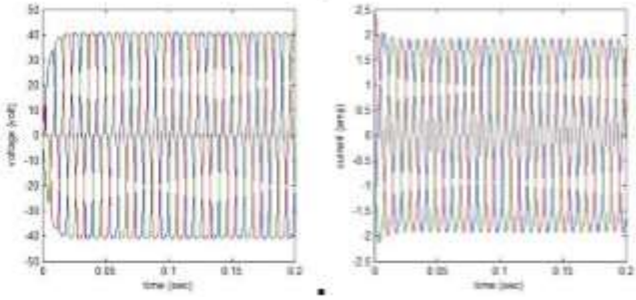

Fig.17. simulated wave form of linear load connected at node B & Non-Linear Load at node A (α= 0^0)

Fig.17.Shows voltage and current waveform with Non-Linear Load is connected at α= 0^0. Here less amount of THD and distortion is presented.

Case 7: when linear load connected at node B & Non- Linear Load connected at node A (α=30^0)

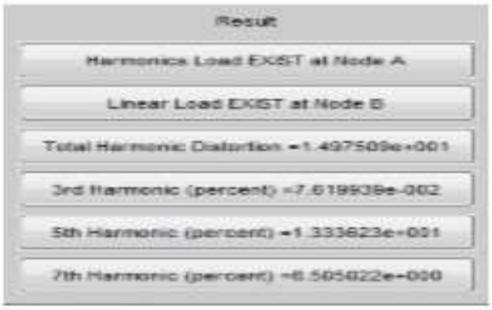

Fig.18. Result obtained from Matlab linear load connected at node B & Non-Linear Load at node A at (α= 30^0).

Fig.18. Shows that non-linear load affects the voltage and currents with harmonics at node A, linear load could not affect at node B it is identified from FFT analysis. The Total Harmonic Distortion = 14.9%. The 5^{th} order harmonic component has major contribution with 13.33%.

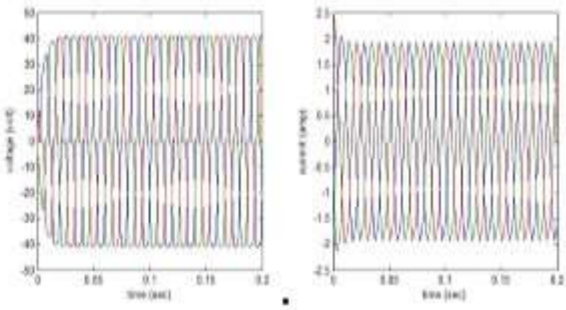

Fig.19. simulated wave form of linear load connected at node B & Non-Linear Load at node A (α= 30^0)

Fig.19. Shows voltage and current waveform with Non-Linear Load is connected at α= 30^0. Here medium amount of THD and distortion is presented.

Case 8: when linear load connected at node B & Non- Linear Load connected at node A (α=60^0)

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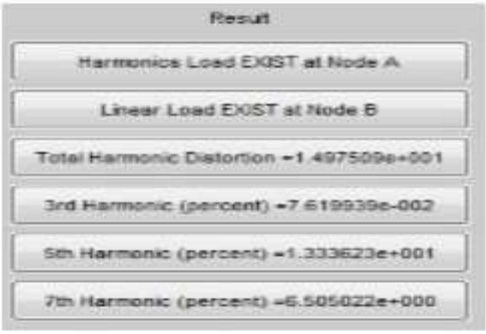

Fig.20. Result obtained from Matlab linear load connected at node B & Non-Linear Load at node A at (α= 60⁰).

Fig.20. Shows that non-linear load affects the voltage and currents with harmonics at node A, linear load could not affect at node B it is identified from FFT analysis. The Total Harmonic Distortion = 14.9%. The 5th order harmonic component has major contribution with 13.33%.

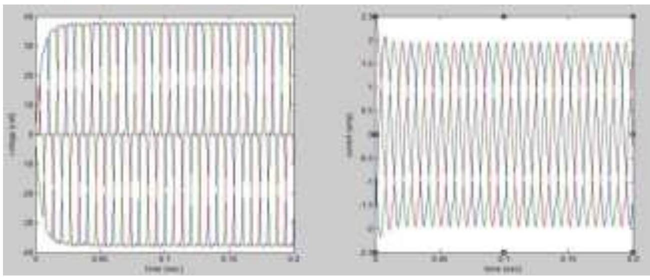

Fig.21. simulated wave form of linear load connected at node B & Non-Linear Load at node A (α= 60⁰)

Fig.21.Shows voltage and current waveform with Non-Linear Load is connected at α= 60⁰. Here the amount of THD presented is high compared with α= 30⁰ case.

Case 9: when linear load connected at node B & Non- Linear Load connected at node A (α=90⁰)

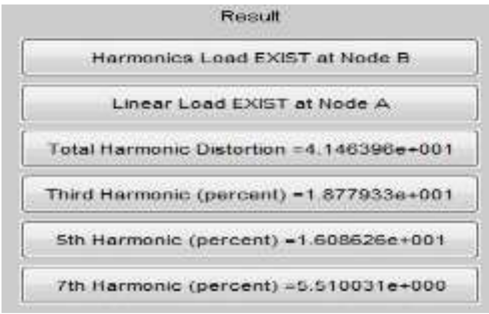

Fig.22. Result obtained from Matlab linear load connected at node B & Non-Linear Load at node A at (α= 90⁰).

Fig.22. Shows that non-linear load affects the voltage and currents with harmonics at node A, linear load could not affect at node B it is identified from FFT analysis. The Total Harmonic Distortion = 41.46%. The 5th order harmonic component has major contribution with 16.0%.

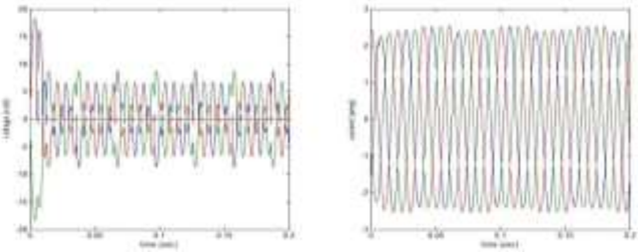

Fig.23. simulated wave form of linear load connected at node B & Non-Linear Load at node A (α= 90^0)

Fig.21.Shows voltage and current waveform with Non-Linear Load is connected at α= 90^0. Here the high amount of THD presented during 0.05 sec to 0.15 sec.

CONCLUSION

Harmonic identification, classification of loads is today's an important task in power system based on its node points. This paper presents harmonics at different conditions of load is connected to system. Causes of harmonic problems and percentage of harmonics in linear and non linear loads at different nodes are discussed. It proposes FFT algorithm for harmonics analysis which is most useful to classify harmonics in odd and there percentage. Paper brief explains the THD calculation using FFT spectrum. It also shows THD varies as per connected type of load at nodes A & B. It has been found that linear load does not have the harmonics from the source and non-linear load draws the harmonics from the ac supply due its non-linear characteristics of thyristors. Depending on the firing angle, harmonic content from the input also varies. Analysis is done for non-linear load at 300, 600 and 900 firing angles by exchanging their nodes. In the further work, the identified result can be implemented for custom power devices for efficient compensation of the harmonics.

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