

ALGORITHM AND FLOWCHART: TWIN BROTHERS AS TOOLS FOR OPTIMIZATION

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Abstract:

A step-by-step procedure structured in achieving a defined objective or objectives within a specific time frame is known as an algorithm. Two or more of such steps may repeat (looping) itself once or more in order to achieve the set objective or objectives. Flowcharts are schematic representations of algorithms. Optimization is the scientific method of getting the best considered suitable alternative out of several possible alternatives. Minimization of efforts or costs or maximization of benefits or profits is the central goal of optimization. Algorithm and flowchart can be viewed as tools for optimization. Both can be used to predict the performances of parameters within one or more objective functions when subjected to one or more possible constraints. Minimization of harmonics in a power distribution network through the use of five different filters is used to illustrate the beauty of algorithm and flowchart in an optimization problem in this work. An algorithm is formulated and a flowchart developed. A template that can be adopted by researchers studying the effects of harmonics and how to mitigate such is finally developed.

Keywords: Algorithm, Distribution, Filters, Flowcharts, Harmonics, Mitigation, Network, Optimization, Power.

1.0 Introduction

Algorithm has been extensively used in solving many optimizations related problems [1 – 3]. Many algorithm techniques to solve optimization problems exist in the literature. All are structured step-by-step method aimed in minimizing cost or maximizing benefits. Flowchart in its simplest form is a mere diagrammatic representation in whatever form of a step-by-step processes of achieving an aim or realizing an objective. The aim or objective can be either minimizing cost or maximizing benefits when applied to optimization of a resource, item, good, product or service. Thus, the duo of algorithm and flowchart can be regarded as identical twin brothers that greatly assist in solving an optimization problem.

Electric Power Quality (EPQ) refers to the ability of an electrical network to maintain near sinusoidal waveform of power distribution bus voltages and currents at rated magnitude and frequency. Voltage, current or frequency deviations results in low power quality with its several disadvantages [4].

Harmonics is a major factor in defining power quality. A harmonic is a signal whose frequency is an integral multiple of the frequency of some reference signal and a greater percentage of electric signals contain energy at the fundamental and harmonic frequencies. Harmonics are usually caused by the behavior of nonlinear loads [5 - 12].

The voltage supplied by a distribution network and other loads supplied from a network with induction furnace will be negatively affected if necessary precautions and corrective measures are not taken to control the harmonics generated by the furnace [13 - 19].

There are many disadvantages posed by current harmonics to electrical network. The flow of harmonic currents through the system impedances in turn causes voltage distortion in the distribution system. These harmonic currents stress the electrical network, potentially damage equipment, and disrupt normal operation of devices and increases operating costs. It further causes overheating of electrical equipment and devices such as transformers, motors and cables, thermal tripping of protective devices, logic faults of digital devices, etc. [8]

Harmonic mitigation requires taking action to minimize the presence of harmonics in electrical system to avoid one or more of the disadvantages. Harmonic mitigation is carried out with the aid of electronic filter circuits which perform signal functions, specifically to remove unwanted frequency components from the signal, and to enhance wanted ones or both. Minimization of harmonics in a power distribution network can be carried out through the use of power filter which is an electronic component that effectively reduces electromagnetic interference in power line of any equipment. [13, 15, 19]

Power Filters are broadly classified into three categories. These are passive, active and hybrid filters. A passive filter uses passive components like resistor, inductor and capacitor to generate a signal of a particular band. An active filter is a type of analog circuit implementing an electronic filter using active components such as transistors, op-amps, etc. Active power filters are used to filter out both higher and lower order harmonics in a power system. [20]

While passive filters consume the energy of a signal without power gain the active filters have a power gain. Active filters require an external power supply, while passive filters operate only on the signal input. The passive circuit performs basic filtering action at the dominant harmonic frequencies (e.g., 5th or 7th) whereas the active elements, through precise control, mitigate higher harmonics. This will effectively reduce the overall size and cost of active filtering. [21]

The hybrid filters combine a number of passive and/or active filters and their structure may be of series or parallel topology or a combination of the two. They can be

installed in single-phase, three-phase three-wire, and three-phase four-wire distorted systems. [22]

There exist different classifications of active and hybrid filters based on power rating, supply system (e.g., number of wires and phases), topology (e.g., shunt and/or series connection), number of (passive and active) elements, speed of response, power circuit configuration, system parameter(s) to be compensated, control approach, and reference-signal estimation technique. [22]

In this work, the five filters considered are classified on the basis of topology. The intent is to develop a template for the minimization of harmonics in a power distribution network through the application of algorithm and flowchart to different filter topologies.

2.0 A Brief Survey of the Literature on Harmonics

Authors in [23] designed a filter that yield the required level of harmonic distortion in steel plant with induction furnaces by carrying out the simulation of an active filter for the reduction of the voltage total harmonic distortion created by a steel plant. Harmonics analysis obtained shows limitation to industrial furnaces only while other harmonics sources were neglected. Broad categorization of different harmonics mitigation techniques was applied in [24] and [25] to power distribution networks.

Based on viability and economic factors, in [26] Hybrid Harmonic Filters (HHF) was discovered to be much more attractive in harmonic filtering than other pure filters. Specific attention was not paid to high-power applications while light and heavy current scenarios were neglected. This neglect was considered in [27] by using real time method of monitoring the harmonics for both light current and heavy current industries. The study used software to analyze the presence of harmonics in the system. An extensive harmonic measurement of a real distribution system were performed in [27] to prove the usefulness of the indices for harmonic distortion monitoring of power in distribution lines but it failed to give consideration to high harmonic generating equipment.

In the mitigation of harmonics of high-power converters [28], an optimal selective harmonic mitigation method was introduced for cascaded H-bridge converter but it has the shortcoming of not being suitable for fast switching loads such as induction furnace. In addition, IEEE 519 - 1992 Standard was not given consideration.

Harmonic analysis in the time domain was conducted by authors in [29] to accurately represent the system nonlinearity and voltage dependency by using a designed hybrid reactance one-port compensator to reduce the harmonic distortion in practical single-phase and balanced three-phase distribution systems having different types of nonlinear loads. Comparative analysis of the iterative method to other active methods was conducted. The lack in comparative analysis of the iterative method to other active methods resulted in the inability to establish the most superior method. The study was not able to consider frequency domain and the use of fast switching devices such as Insulated Gate Bipolar Transistor, IGBT.

The authors in [30] postulated power system harmonics as one of the important indices to rate power quality. A comparative analysis of original hypothetical signal and reconstructed signal using the new versatile Least Mean Square, LMS algorithm was carried out. A mismatch in phase information which occurred during initialization process is a major limitation to the method.

The use of Multiple Active Power Filter Configuration in [31] proved to be a better detailed procedure for harmonic voltage mitigation in which optimum controller parameters of Active Power Filters (APFs) were calculated. The improvement in the efficiency of the installed APF was achieved by the establishment of additional APF at a proper place of the power system.

In all the above cited literatures and many more that are not cited, the processes, procedures, steps and actions taken to control, minimize or mitigate harmonics can be developed or represented in forms of algorithm and flowcharts. Development of a typical template for the processes, steps and actions involved in the mitigation of harmonics through the use of algorithm and flowcharts is the objective of this presentation.

3.0 Methodology

Step by step approaches to be adopted in achieving the aim of this study are:

- i. Preliminary studies and a comprehensive review of the literature.
- ii. Characterization of different types of harmonic mitigation techniques on the basis of circuits, devices and systems employed in the method of mitigation.
- iii. Development of a single line diagram for the case Study-Distribution Network.
- iv. Designing of the circuit and development of a Simulink Model for a simple nonlinear load.
- v. Designing of the equivalent circuit diagram of the Distribution Network with the simple nonlinear load and the development of a corresponding Simulink Model.
- vi. Establishing if harmonics is introduced into the Distribution Network by the nonlinear load through the waveforms and Fast Fourier Transform analysis from the MATLAB/Simulink Models. If harmonics exists:
- vii. Designing of a Passive and an Active Filter Circuits and the development of their corresponding Simulink Models.
- viii. Designing of the three configuration types of Hybrid Filter Circuits through a combination of the passive and active filter circuits in three different topologies and the development of their corresponding Simulink Models.
- ix. Validating the efficacy and efficiency of each filtering circuits on the Distribution Network.
- x. Designing of equivalent circuit and development of a complete Simulink Model of the Distribution Network with a Steel Plant.
- xi. Establishing the extent of harmonics introduced into the Distribution Network by the steel plant (non-linear load) through the waveforms and Fast Fourier Transform analysis from the MATLAB/Simulink Models.

- xii. Developing and building the prototype of the best power filter among the Hybrid Active Power Filter (HAPF) i.e. the Filter that control best or minimize the presence of harmonics on the Distribution Network.

The above steps simply constitute the “Algorithm”.

A flow chart representation of the Algorithm is as illustrated in Figure 1.

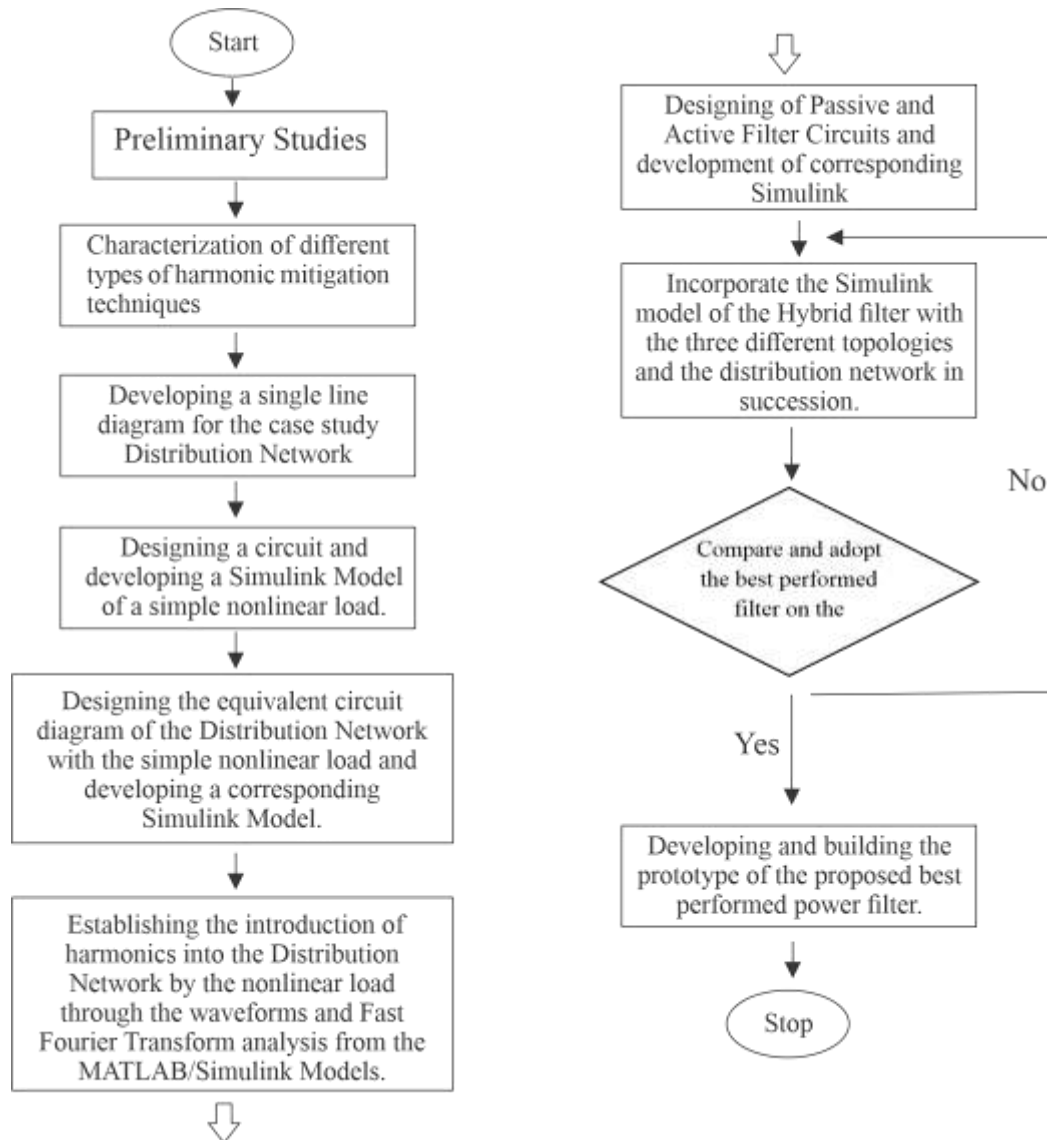


Figure 1: Flowchart of the harmonic mitigation processes of a typical distribution network.

4.0 Validation and Results from a Case Study Distribution Network

The above template was validated on a Distribution Network whose single line diagram is shown in Figure 2 and the Fast Fourier Transform Analysis for the Filters are as in Figures to 8.

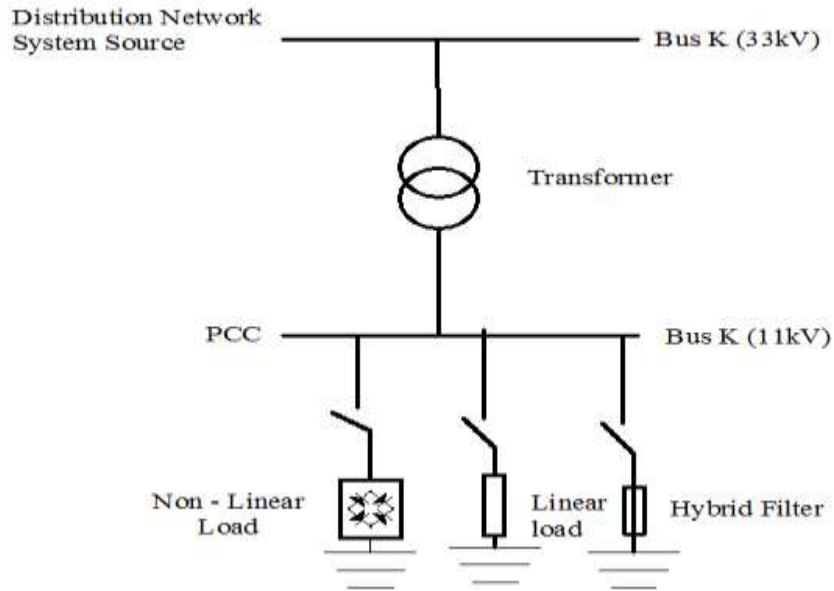


Figure 2: A single line diagram of the case study distribution network.

PCC: Point of central connection

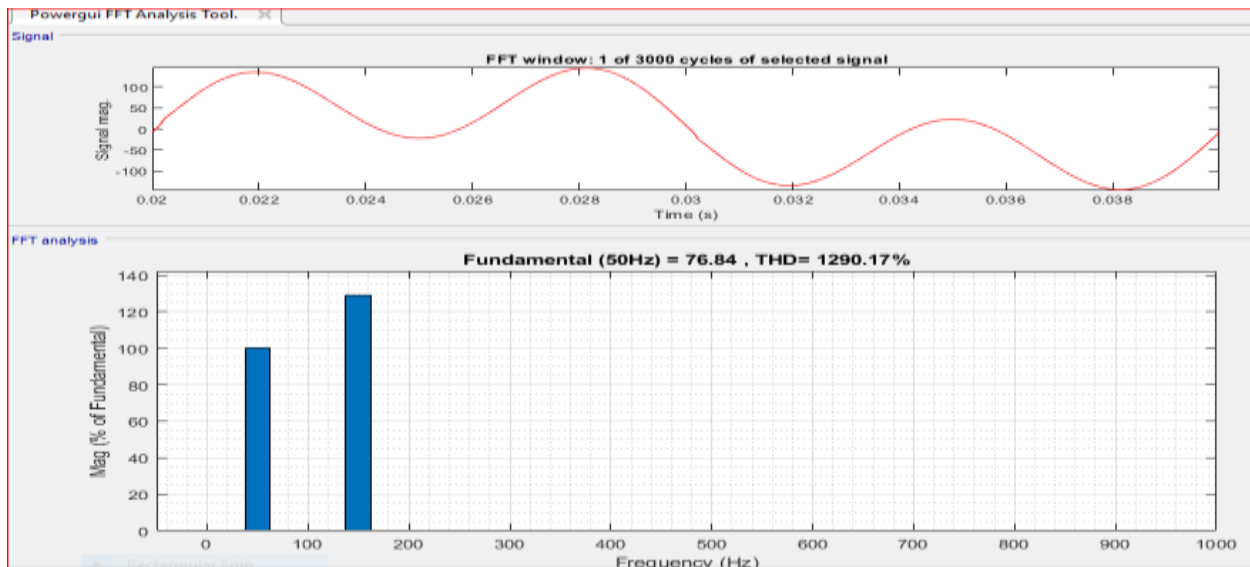


Figure 3: Fast Fourier Transform (FFT) Analysis of Load Current at the PCC without any Filter.

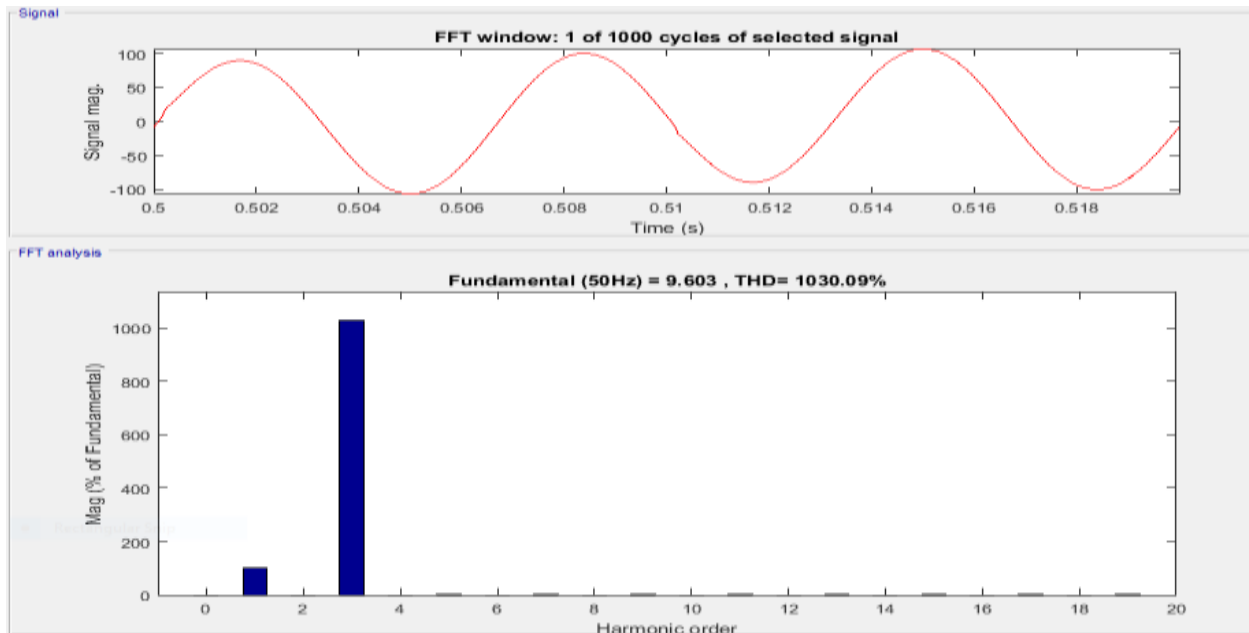


Figure 4: Fast Fourier Transform (FFT) Analysis of Load Current with the introduction of Passive Filter.

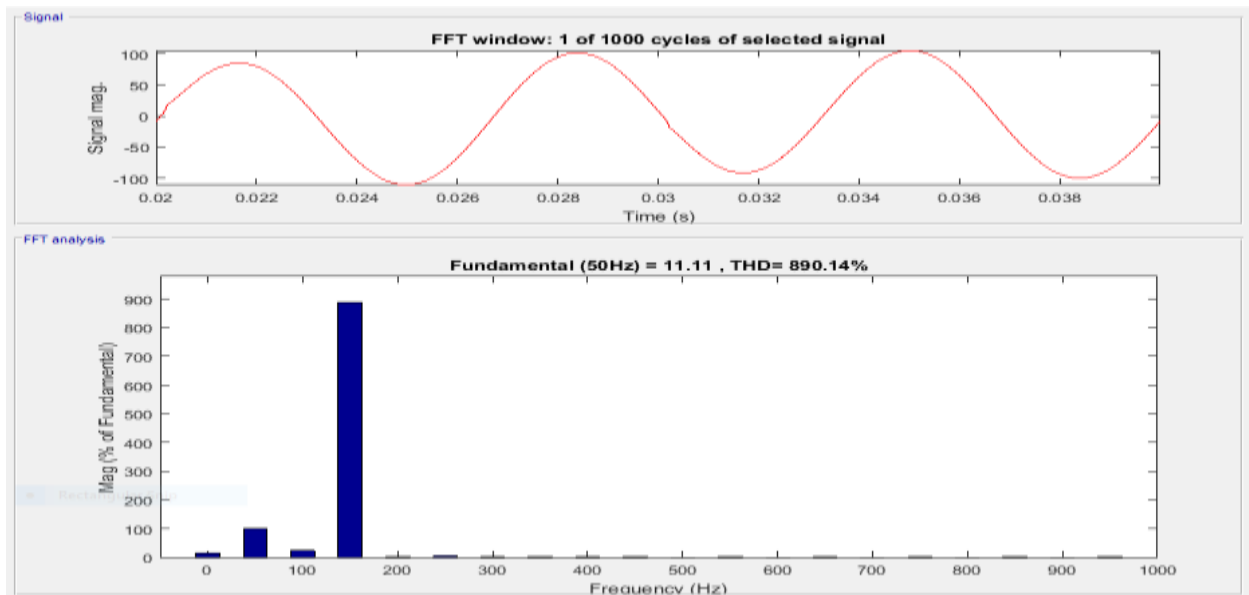


Figure 5: Fast Fourier Transform (FFT) Analysis of Load Current with the introduction of Shunt Active Power Filter.

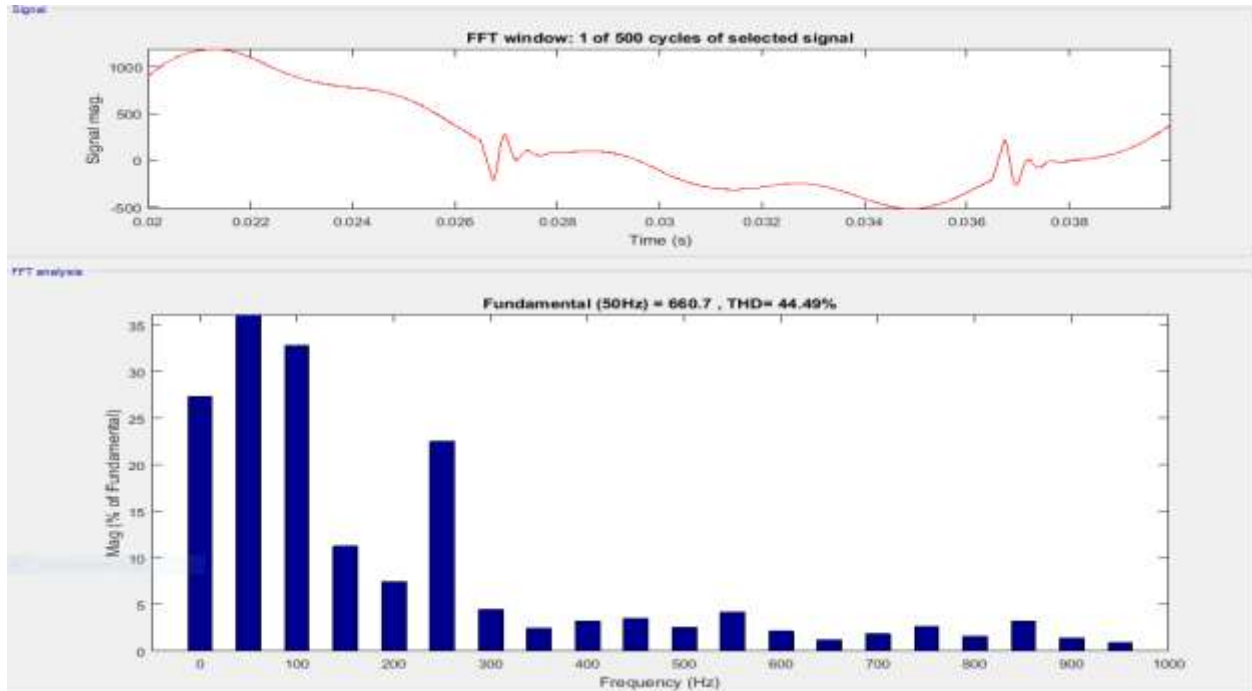


Figure 6: FFT analysis of Load Current with the introduction of Hybrid Filter Type I (Combination of a shunt active and shunt passive filter).

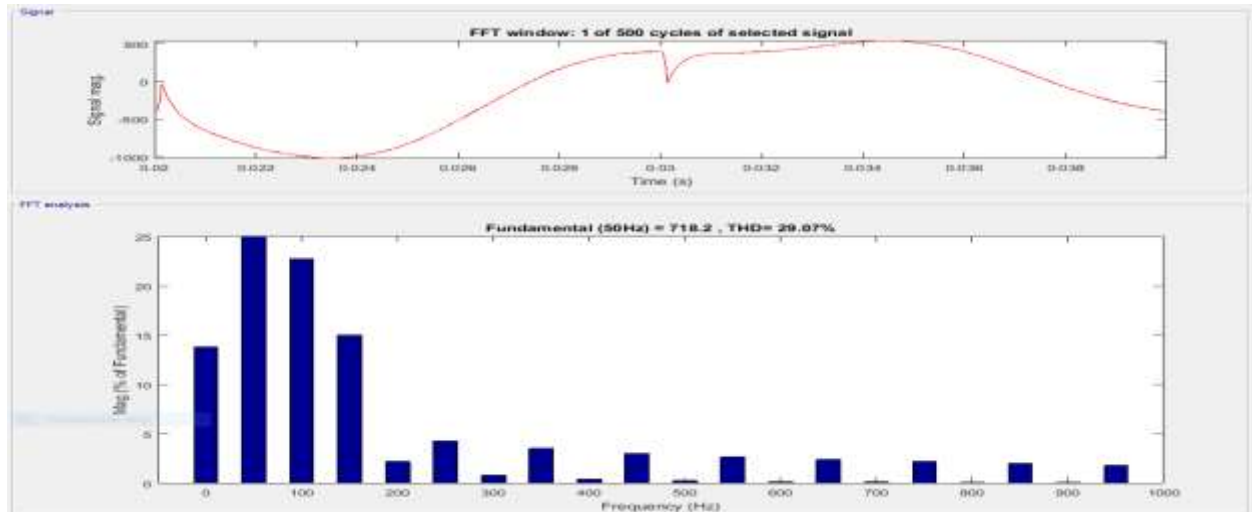


Figure 7: FFT of the distribution network after introducing Hybrid Filter Type II (Combination of a shunt active and series passive filter)

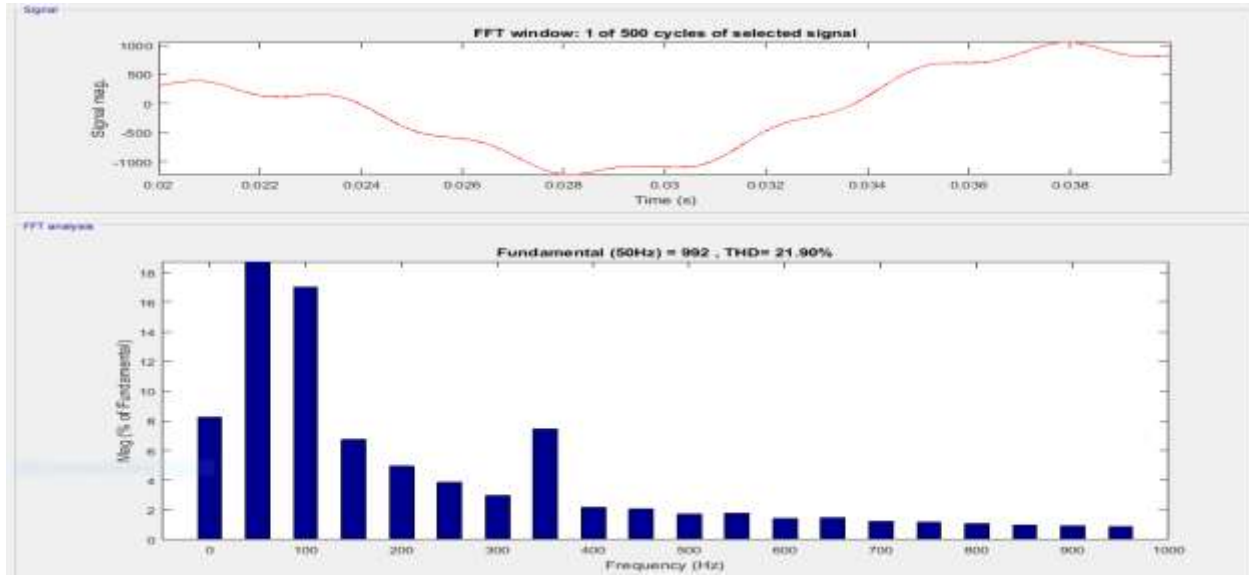


Figure 8: FFT analysis of Load Current with the introduction of Hybrid Filter Type III (Active filter is in series with passive filter).

5.0 Conclusion

A template was developed for the minimization of harmonics in this work. Using different filter configurations, the template was validated on a distribution network. The FFT analyses indicated the Total Current Harmonics Distortion (THDI) as: 1030.09%, 890.14%, 44.49%, 29.07% and 21.90% for passive, active, hybrid type I, hybrid type II and hybrid type III respectively. Thus, the hybrid filter type III performs better than others.

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