Research Journal of Engineering Technology and Medical Sciences (ISSN: 2582-6212), Volume 05, Issue 02, June-2022
Available at www.rjetm.in/

Quality Analysis Utilizing UPQC With Sensitive Loads Driven by HDE Based Controllers

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Abstract: *The unified power quality conditioner (UPQC), also known as the universal active filter, is the most comprehensive hybrid filter arrangement. UPQC is a multifunctional energy conditioning which can be used to adjust for a variety of power source voltage fluctuations, correct voltage fluctuations, and prevent harmonics load current from entering the power source. Modifying the UPQC controls and studying the reaction under various loading scenarios were the main goals of the study. The system was created in the MATLAB/SIMULINK environment, and the suggested harmonic elimination differentiated iterative method was implemented using Algorithm.*

Keywords: Power system, power quality, UPQC, Differential Algorithm

I. Introduction

The energy system is a network that consists of three components: generating, distribution, and transmission. It turns the form of energy (such as coal and diesel) into electric power. The power grid contains components such as the synchronous generator, motors, transformers, circuit breaker, conductor, and others, as shown in Figure 1. The six essential components of the electricity system are the power source [1], transformers, transmission line, sub - stations, distribution line, and distribution transformer. The power station creates power that is step-up or step-down for transmitting thru the transformers [2].

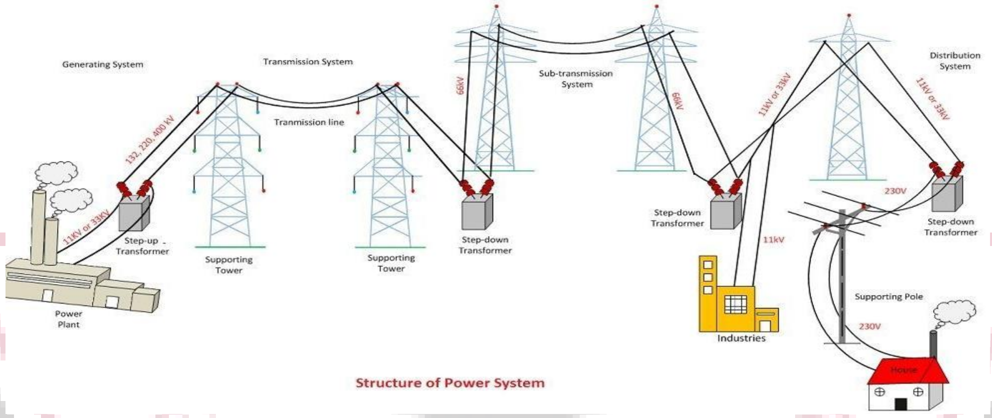

Figure 1: Structure of Power System

The supply of electricity of consistent magnitude and frequency – sinusoidal voltage waveform – to consumer electronics is determined by power quality. The synchronization of voltage, frequency, and phase allows electrical system is functioning as planned without sacrificing consumer device performance or life. A system . Energy Quality [3] indicates how closely a realistic supply system resembles an ideal power supply. The phrase refers to the electrical energy that powers an external charge as well as the load's ability to operate correctly.

The phrase "power quality" refers to the ability to maintain a distortion-free sinusoidal waveform of voltage magnitude at the rated voltage and frequency. The primary goal of most power utility [4] businesses is to offer their customers with a constant-amplitude, uninterrupted sinusoidal waveform. Many power conversion stages and equipment are used in power systems for these purposes, all of which are designed to work on a perfect sinusoidal waveforms. Many of these gadgets, however, alter the waveforms[5]. These distortions may cause problems throughout the electricity systems, as well as quasi current to flow. The harmonic and reactive power component of current are drawn from the ac mains by nonlinear loads. They may also produce imbalances and draw excessively neutrality current flow in three-phase systems[6]. Low system efficiency and poor power factor are caused by injection harmonics and reactive power burden unbalance, as well as excessively neutrality currents[7]. As a result, other customers get irritated, causing interference around the communication system.

The unified power quality conditioner (UPQC), also known as the universal active filter, is the most comprehensive hybrid filter arrangement [8]. UPQC [9] is a multifunctional energy conditioning which can be used to adjust for a variety of power source voltage fluctuations, correct voltage fluctuations, and prevent harmonics load current from entering the power source[10]. It's a specialized energy gadget made to reduce the effects of disturbance on sensitivity and/or critical loads' performances[11].

A UPQC (Unified Power Quality Compensator) is a device that is built similarly to a UPFC (Unified Power Flow Compensator) (UPFC). In a transmission line, a UPQC is used to do both shunt and series compensating at the very same time[12]. Unbalance, distortions, and even dc component can all be found in a power distribution network[13]. As a result, a UPQC performs better than a UPFC in all of these areas to provide shunt or series compensating[14].

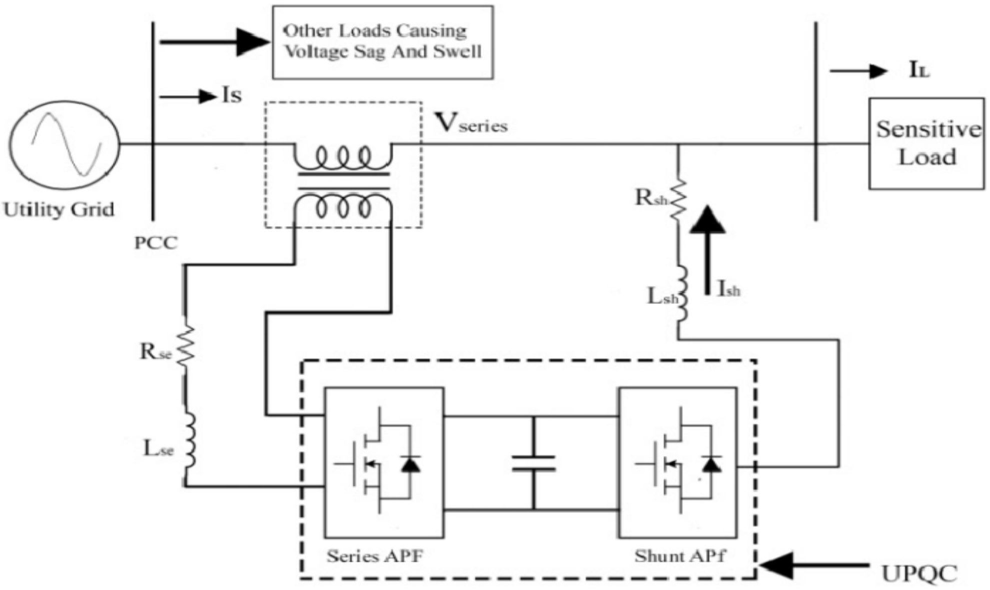

Figure 2: Block Diagram of Unified Power Quality Controller

II. Literature review

(Karthik, 2021) [15] UPQC control quality is used to adjust for voltage and current sound concerns. The Controller is used by UPQC, and it calculates error values differentially among measurable and desired set points. The DC link voltage law of the PI controller is the only limitation of the traditional UPQC instrument. It also includes a three-phase transformation that utilizes a unique multi-winding transformers connecting approach. In this study, a MATLAB simulation is used to show how the UPQC can reduce the percent THD in source voltage, source current, and stacking voltage waveforms driven by non - linear loads. A nonlinear load is used to examine UPQC execution, and simulation experiments using MATLAB/Simulink show that UPQC is properly executed.

(Amini & Jalilian, 2021) [16]In order to apply the OUPQC in DN, a planned approach has been proposed that takes into account time-varying and rising loads over the planning horizon. The program's technical constraints, such as current and voltage limits, are taken into account throughout the planning process. The goal of the optimizing work is to identify the best value of the objective function, which represents the cost-benefit ratio. IEEE 69-bus, realistic 95-bus Iranian DN, IEEE large scale 119-bus DN, and geo-referenced DN were all used to test the proposed planning technique. The results reveal that the proposed method is successful in overcoming the voltage or current inadequacies of DNs while delivering the most cost-effective solution.

(Dheeban & Selvan, 2021) [17]An Adaptive Neuro-Fuzzy controller with a reinforcement learning algorithm was used to analyze the PV-UPQC system. The Fuzzy-Model-Based (FMB) controller boosts system performance by inferring system parameters using language principles and assisting with reference present generation. Even under varying load situations, the PV-UPQC performed admirably. The percentage of Total Harmonic Distortion is minimized when an Adaptive Neuro-Fuzzy Inference System is implemented.

(Gupta, 2022) [18]In a cascaded H-bridge Nine-Level Multi-Level Inverters, counts the operational impact of the Distribution Static Compensator (D-STATCOM) and the Unified Power Quality Compensator (UPQC) (NL:MLI). At a constant 200 V DC voltage and two 100 KW each SPV arrays, the effectiveness of the suggested architecture is tested. Under faulted conditions under linear load, a PQcomparative analysis is offered. The use of competence control mechanisms is essential for the suggested system to perform well under changing environmental conditions. As a result, the D-STATCOM and UPQC control approaches correct for loads and utility-grid reactive energy requirements.With distortion-free output currents acquired at coupled locations, total harmonic distortion (THD) and DC offset current are computed. The IEEE-519 standard is used to validate THD levels.

(Goud & Rao, 2021) [19] The unified power quality Compensator (UPQC) with atom search optimization (ASO) is designed to overcome the PQ concerns in the HRES system. The work's major goal is to reduce PQ difficulties and compensate for load demand in the HRES system. The UPQC devices in the systems is used to solve the PQ issue difficulties. To alleviate current and voltage PQ concerns, a fractional order proportional integral derivative (FOPID) with an ASO-based control is used in series and a shunt active power filter is used to improve UPQC performance. HRES was first built with a photovoltaic (PV) system, a wind turbine (WT), and a battery energy storage system (BESS) that were all linked to the system analysis and design. The non-linear load is linked to the process to generate PQ difficulties in the system in order to analyze the presenting of the suggested controller structure. With the help of the HRES system, PQ concerns are addressed and load demand is repaid. The suggested method has been implemented in the MATLAB/Simulink environment, and its results have been evaluated.

(Meng et al., 2021) [20] This research investigates the mechanics of voltage level ripple production and its effects on compensating voltage and current. For the single-phase UPQC, a controlling approach is provided to suppress the influence. A notch filter is used in the paralleled converter's adjustable voltage loop to prevent voltage ripple from entering the control loop, and specific harmonics correction is used in the interior current loop to reduce network current harmonics. The dc power feedback is used in the series converter to reduce the effect of voltage ripple on the compensating performances. When compared to the standard control technique, model and experimental result reveals that the constant voltage capacitance effectively reduces grid current total harmonic distortion (THD).

(Rajendran, 2020) [21] To improve UPQC device power quality (PQ), a number of intelligent predicted methods have been employed. Artificial neural network (ANN) controller, fuzzy logic controller (FLC), neuro-fuzzy controller (NFC), and adaptive neuro-fuzzy interfering systems are among the several intelligent methods (ANFIS). In particular, series active power filters and shunt active power filters are subjected to a variety of optimization control approaches. The intelligent control methods have been applied in the MATLAB/Simulink environment, and the efficiency of the predicted methodology was assessed by comparing it to conservative methods.

(Lakshmi & Ganguly, 2019) [22] proposes a multi-objective approach to planning for the best PV-BESS integrated open UPQC (PV-BESS-UPQC-O) allocations for radial distribution system peak load shaving. The UPQC-O (open UPQC) is a bespoke energy device made up of series and shunt inverter. Its purpose is to compensate for power flow and to reduce some power quality issues. During peak hours, the UPQC-O is integrated with BESS to inject power factor into the system for peak usage shaving. The PV panel will be used to charge the BESS.The objective functions of a multi-objective optimization process include maximizing of peak load shave, minimizing of PV-BESS-UPQC-O installation cost, and minimization of overall energy losses during peak load demand with PV-BESS-UPQC-O placing.

III. Methodology Used

Figure 3 shows the equivalent circuit schematic of a Unified Power Quality Conditioner. The voltage level is 2 Vs, the series compensation voltage is Vac, the reactive power compensation current is Iac, and the loading voltage and current are Vload and Iload, respectfully. Negative, zero, and harmonic distortion may be present in the emitter terminal. The program's per-phase voltage can be written as

$$V_a = V_{1pa} + V_{1na} + V_{10a} + \sum_{k=2}^{\infty} V_{Ka} \sin(k\omega t + \theta_{Ka})$$

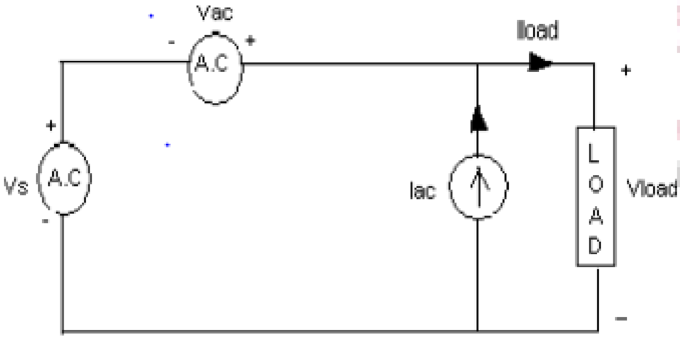

Figure 3: Basic Circuit Configuration of the Unified Power Flow Controller.

where is V1 pa the fundamental frequency positive sequence components, and V1na and V10a are negative and zero sequence components respectively. The voltage's harmonic components is represented by the last term of the equation. The series filter should generate a value of in ensure for the voltage level to be precisely sinusoidal and balance.

UPQC's dc link current is matched to a continuous source current with a magnitude equivalent to the harmonics current's peaks. In an HDE controllers, the difference among measured dc linking present and reference current is analyzed. Instantaneous reactive power in orthogonal coordinate can be estimated using the relevant equations by adding the outputs of the HDE controllers to the real power loss components. The afferent nerves to the shunted inverters are then calculated by comparing the reference currents to the actual source present in a hystersis controlling band.

The differentiated evolutionary approach is used to optimise this controller. The technology takes full advantage at the load terminals as an optimal equation for balancing and modifying the condition of the load line as the load varies. Figure 3 shows the process flow of the optimization process, which is implemented in MATLAB as linear equations and code for producing pulse for per phase converters and booster pulse.

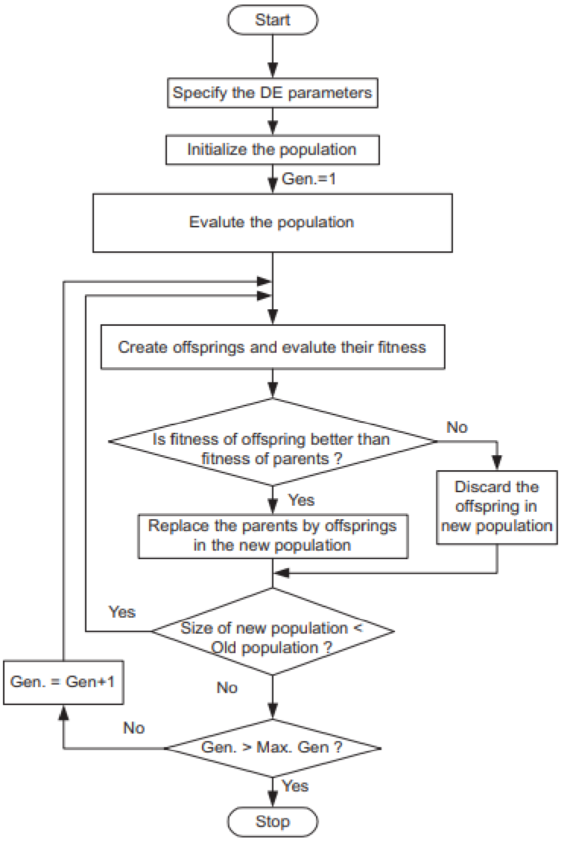

Figure 4: Flow chart of proposed Differential Evolutionary Algorithm for converters

DE is a population-based heuristic technique for solving global optimization problems with a variety of features in continuous domain. It performed admirably in solving non-differentiable, non-continuous, and multi-modal combinatorial optimization simple structure. In simple DE, DE/rand/1/bin , an initial population of NP individuals (X_j), j=1, 2,.., NP , is generated at random according to a uniform distribution within lower and upper boundaries (x_j^L , x_j^U). To create a trial vector, individuals are evolved through crossover and mutation. In order to pick the fittest for the future generation, the trial vectors competes with his parents.

Table 1: Parameters of non-linear load

Diode Résistance Ron (ohms)	0.1
Snubber resistance of diode (ohms)	1000
Capacitance (µ F)	6000
Resistance (ohms)	50
Inductance (Henry)	1×10^{-3}

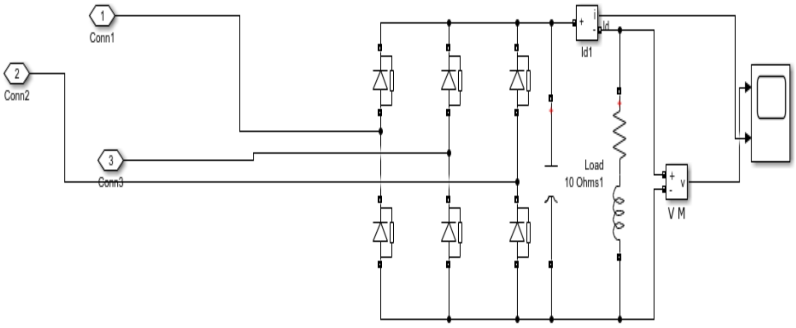

Figure 5: MATLAB/SIMULINK model of non linear load

Table 2 : Parameters of unbalanced load	
Resistance of phase one (ohms)	2
Resistance of phase two (ohms)	4
Resistance of phase three (ohms)	6

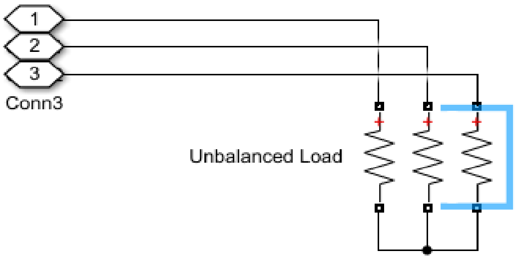

Figure 6: MATLAB/SIMULINK model of unbalanced load

IV. Result

Under regular unbalanced loads, non-linear loads, sagging, and swelling situations, UPQC performs well. The energy on the system line is set at 310V. The simulated results for UPQC as a harmonics compensation in non linearity and unbalanced circumstances under voltages sag and swell conditions are shown. The findings are analyzed using three phase input signal, sources current flow, voltage output, load conditions, shunt compensation current flow, DC bus voltage, and injecting power output of the step down transformer.

The full analysis was carried out in the SIMULINK environment by constructing two devices. For both end conversion, the first design used UPQC with series shunted circuits regulated symmetrically by PI regulatory controllers. The second system is created with a controllers modifications that uses the harmonic targeting differential evolutionary (H-DE) algorithm to improve the program's quality when it is subject to varying loads.

Case 1: System with UPQC having controllers regulated by PI method

Case 2: Modified system with controllers using HDE algorithm for quality enhancement

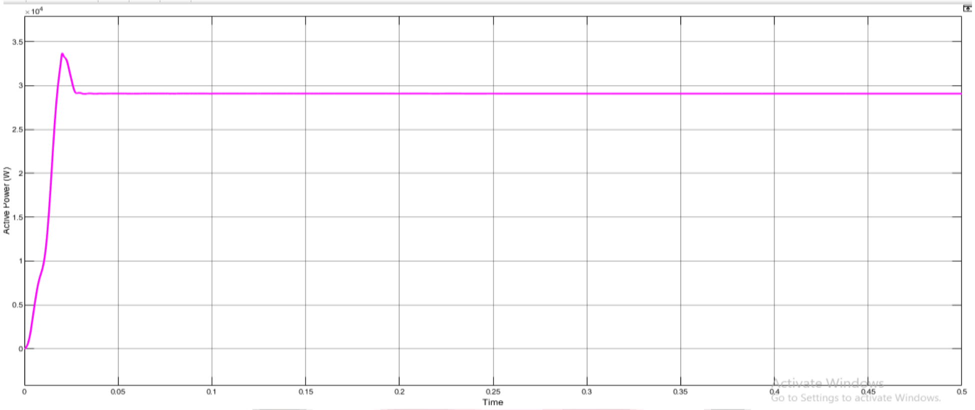

Figure 7: Active power output from the system in case 1

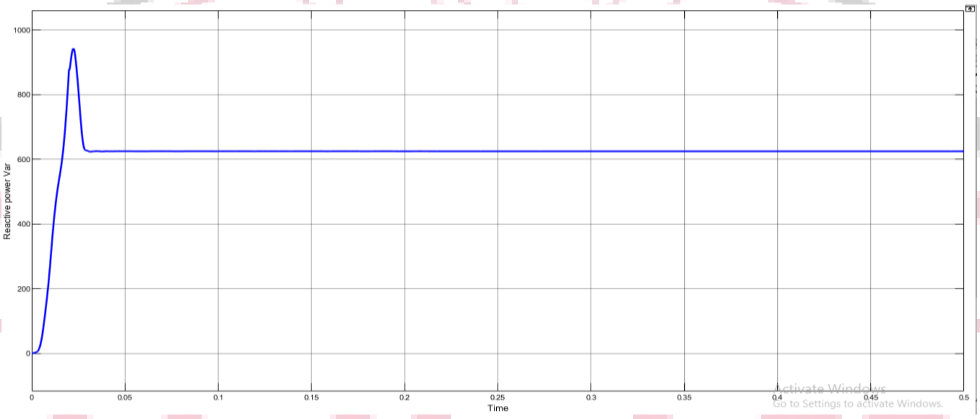

Figure 8: Reactive power output from the system in case 1

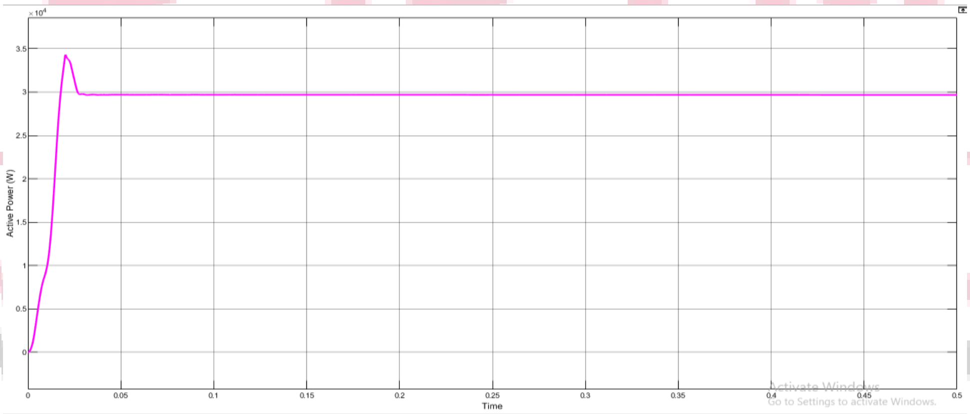

Figure 9: Active power output from the system in case 2

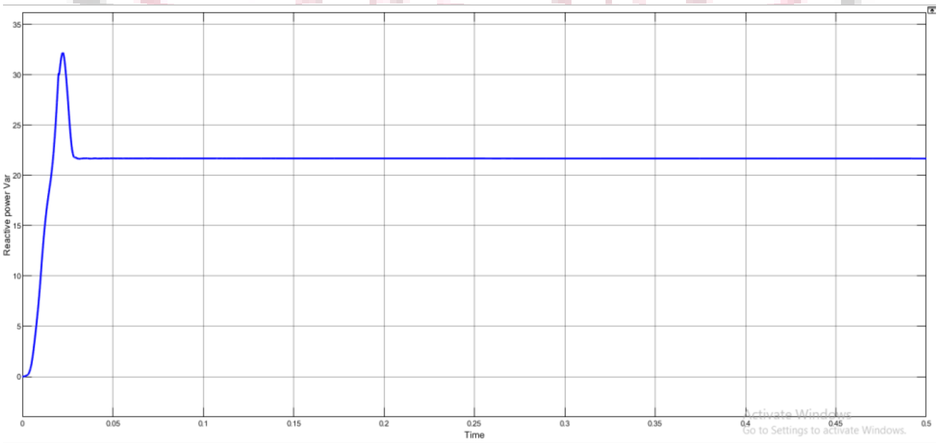

Figure 10: Reactive power output from the system in case 2

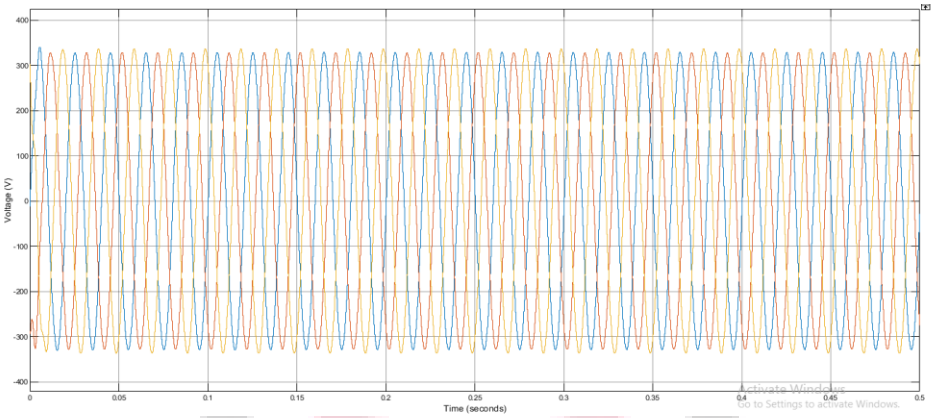

Figure 11: Voltage at the non linear load terminal of case 1

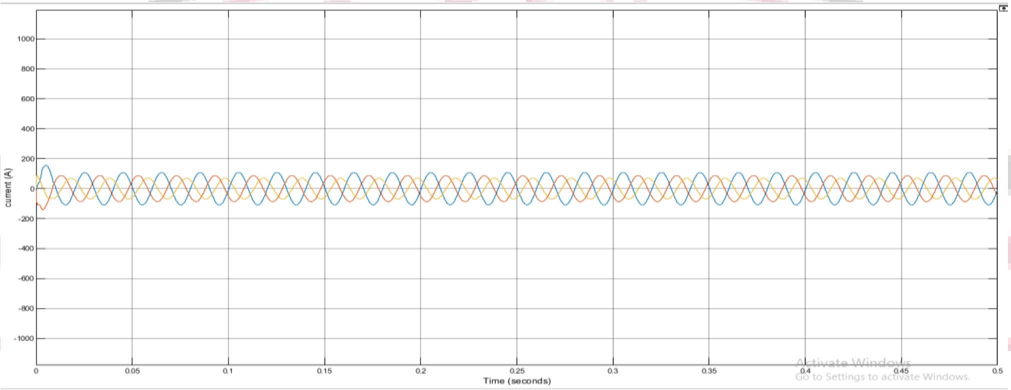

Figure 12: Current at the non linear load terminal of case 1

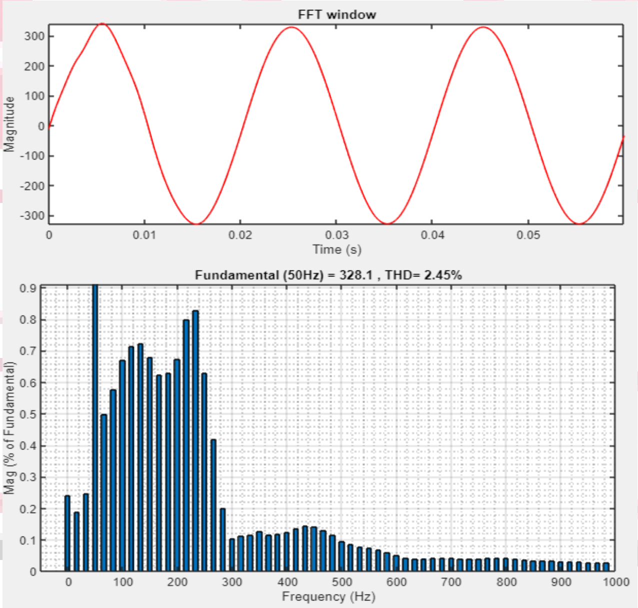

Figure 13: THD% evaluation of voltage output available at non linear load terminal in case 1

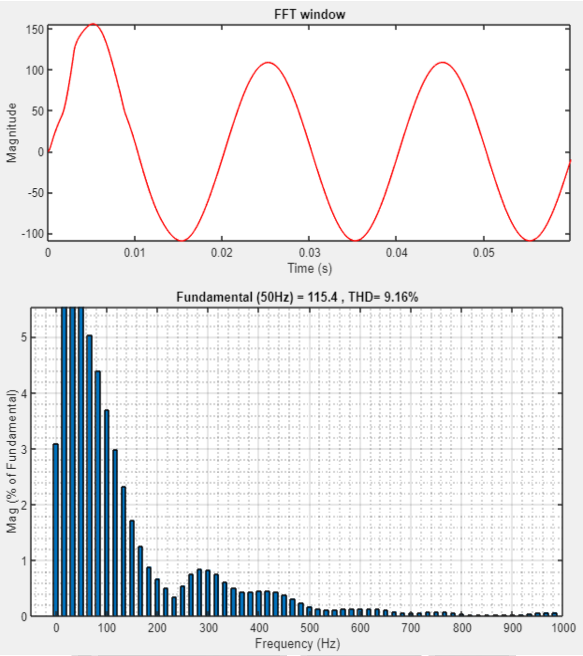

Figure 14: THD% evaluation of current output available at non linear load terminal in case 1

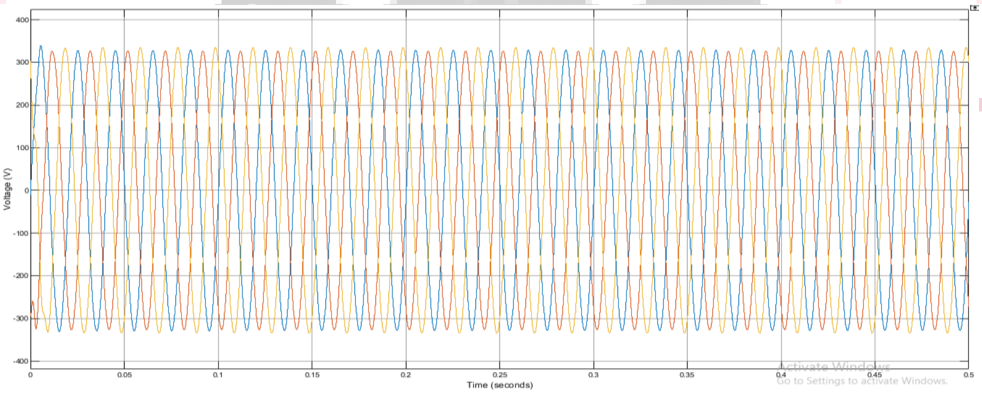

Figure 15: Voltage at the non linear load terminal of case 2

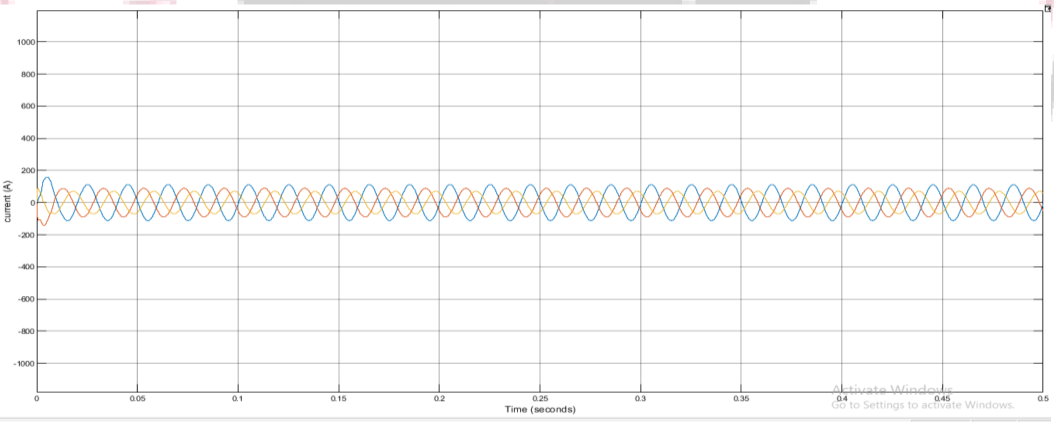

Figure 16: Current at the non linear load terminal of case 2

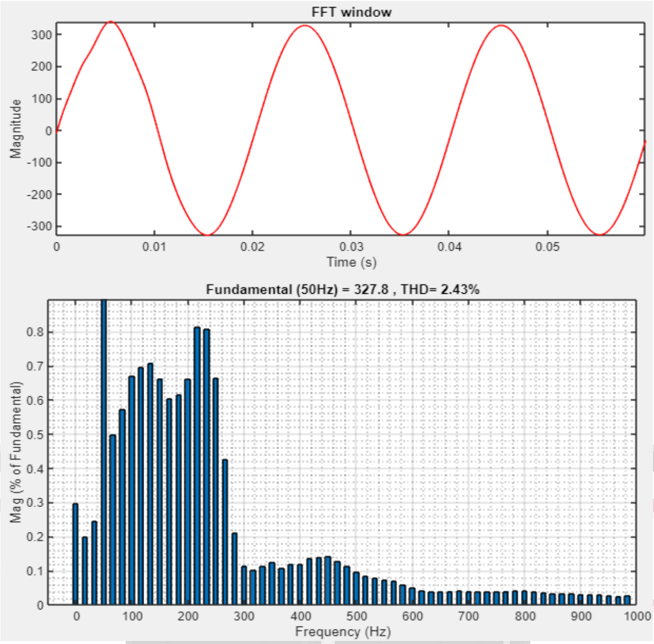

Figure 17: THD% evaluation of voltage output available at non linear load terminal in case 2

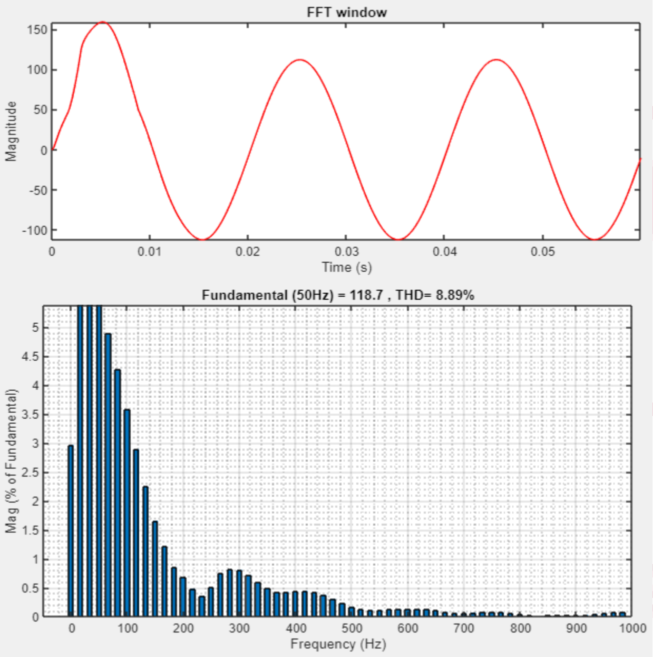

Figure 18: THD% evaluation of current output available at non linear load terminal in case 2

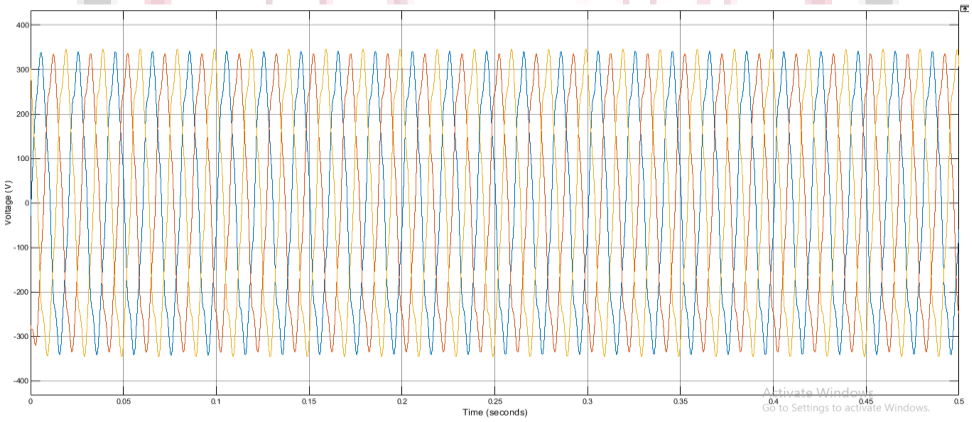

Figure 19: Voltage available at the unbalanced load terminal of case 1

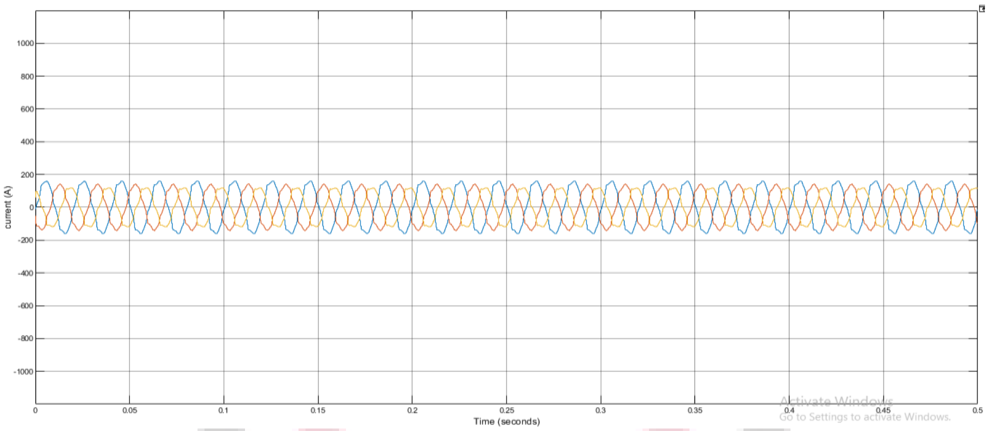

Figure 20: Current drawn at the unbalanced load terminal of case 1

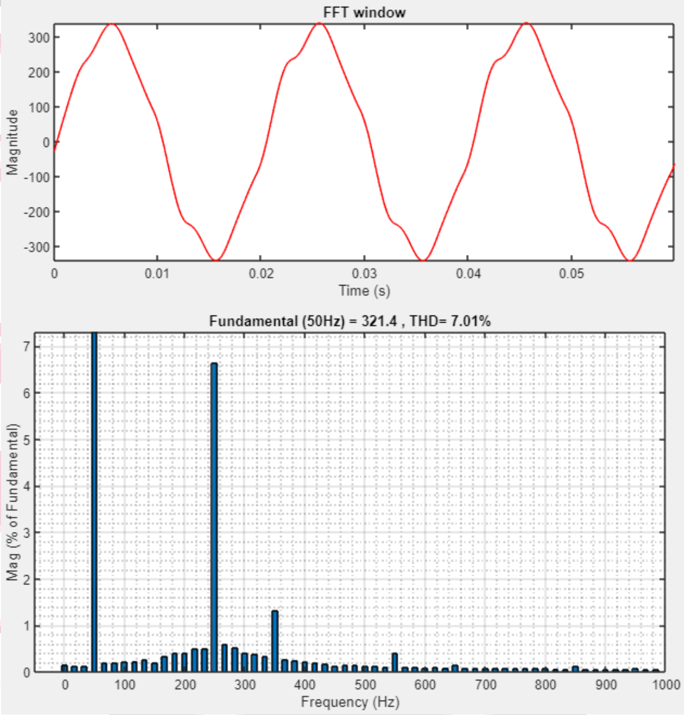

Figure 21: THD% evaluation of voltage output available at unbalanced load terminal in case 1

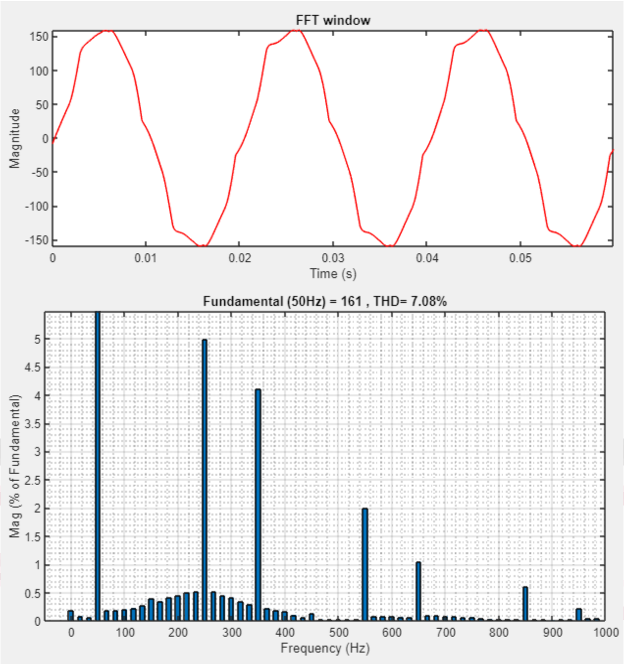

Figure 22: THD% evaluation of current output available at unbalanced load terminal in case 1

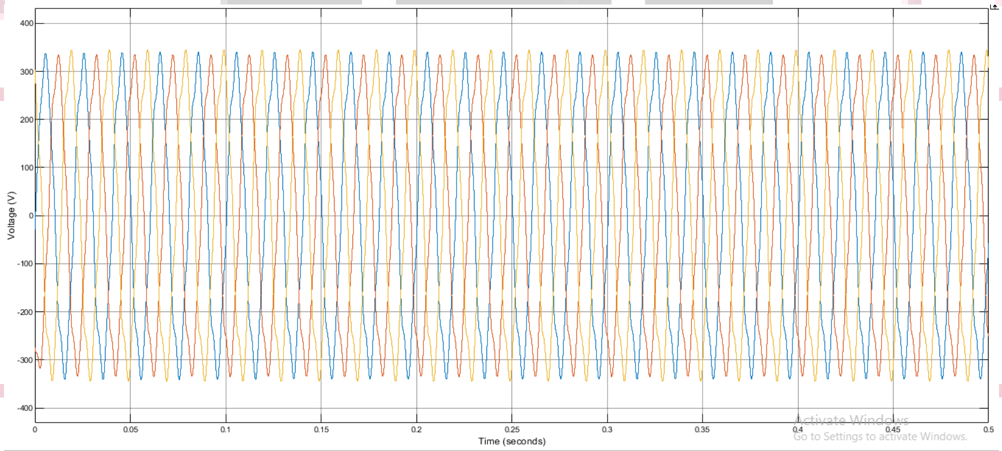

Figure 23: Voltage available at the unbalanced load terminal of case 2

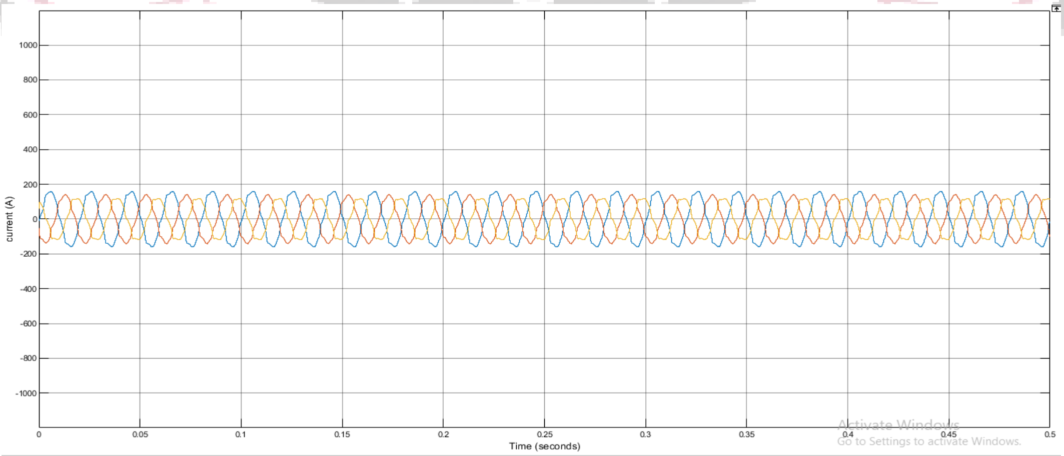

Figure 24: Current drawn at the unbalanced load terminal of case 2

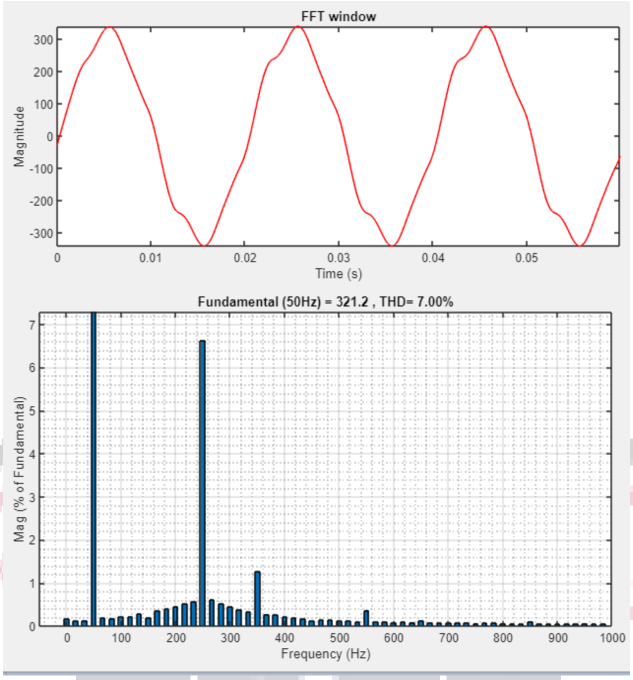

Figure 25: THD% evaluation of voltage output available at unbalanced load terminal in case 2

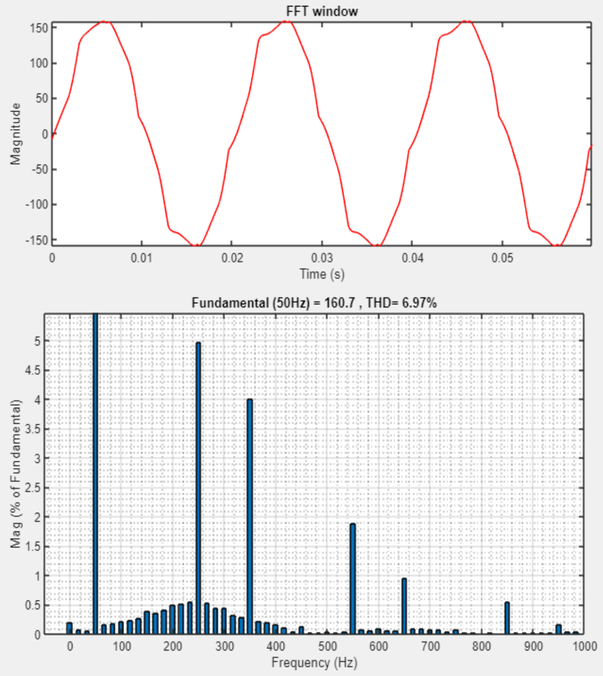

Figure 26: THD% evaluation of current output available at unbalanced load terminal in case 2

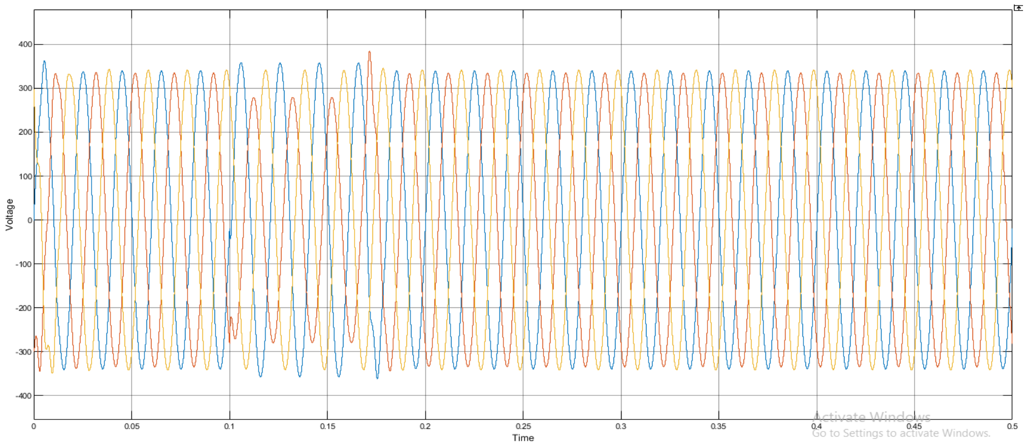

Figure 27: Voltage of system in case 1 for analyzing sag and swell in the system

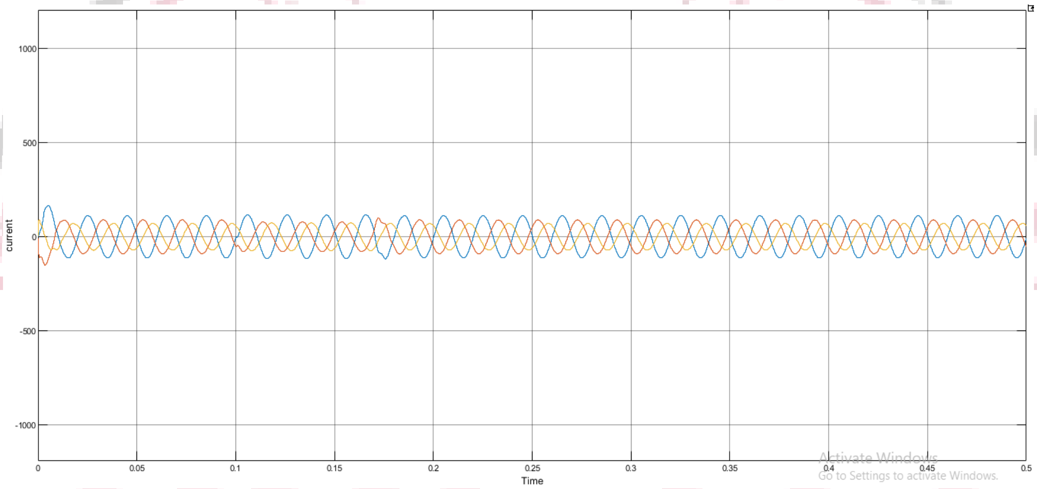

Figure 28: Current of system in case 1 for analyzing sag and swell in the system

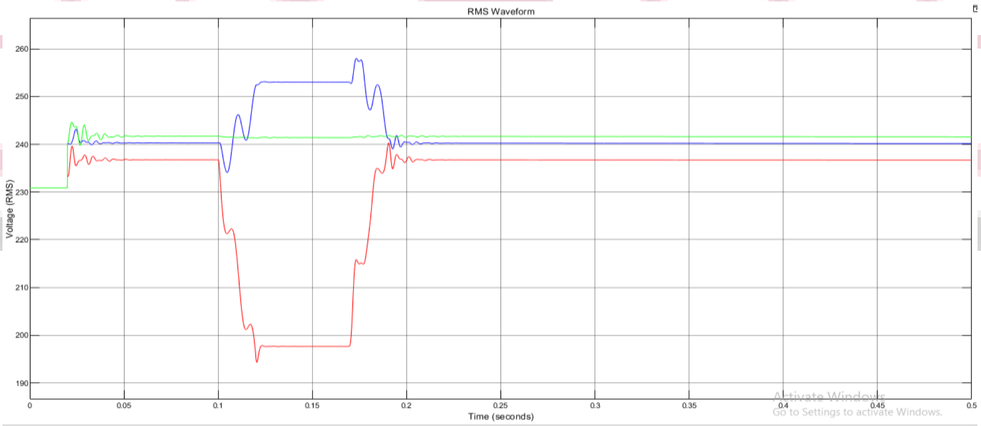

Figure 29: RMS representation of Voltage of system in case 1 for analyzing sag and swell in the system

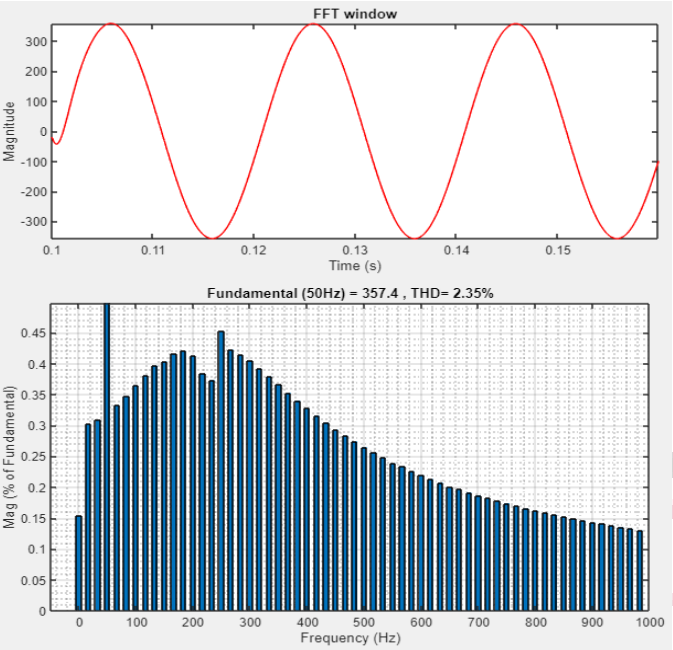

Figure 30: The THD% evaluation of voltage at the swell point in system of case 1

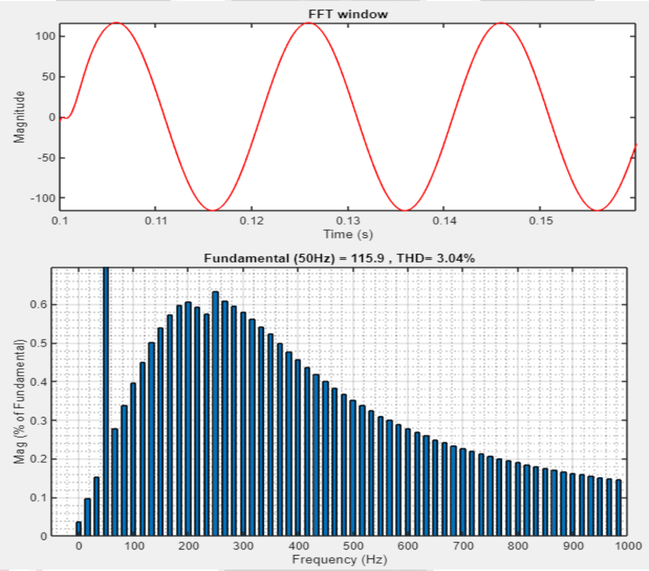

Figure 31: The THD% evaluation of current at the swell point in system of case 1

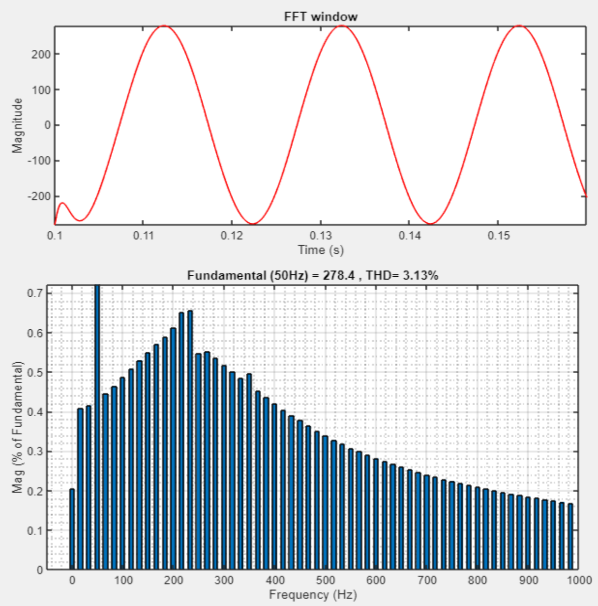

Figure 32: The THD% evaluation of voltage at the sag point in system of case 1

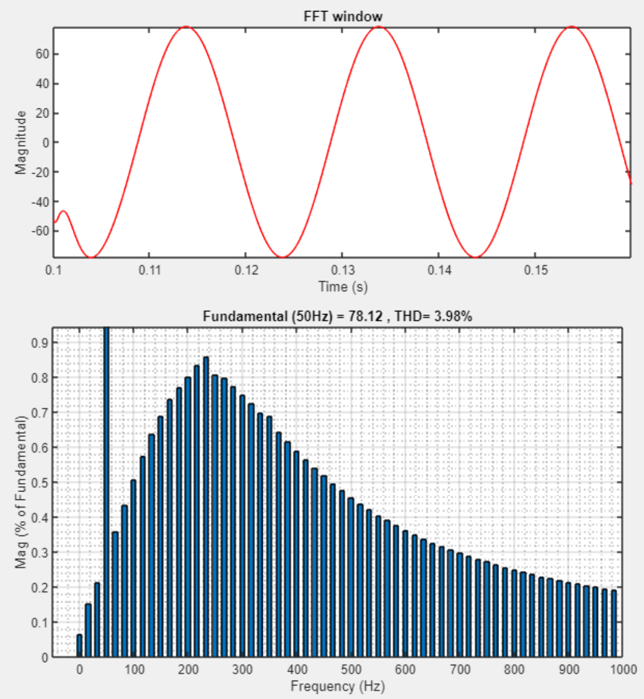

Figure 33: The THD% evaluation of current at the sag point in system of case 1

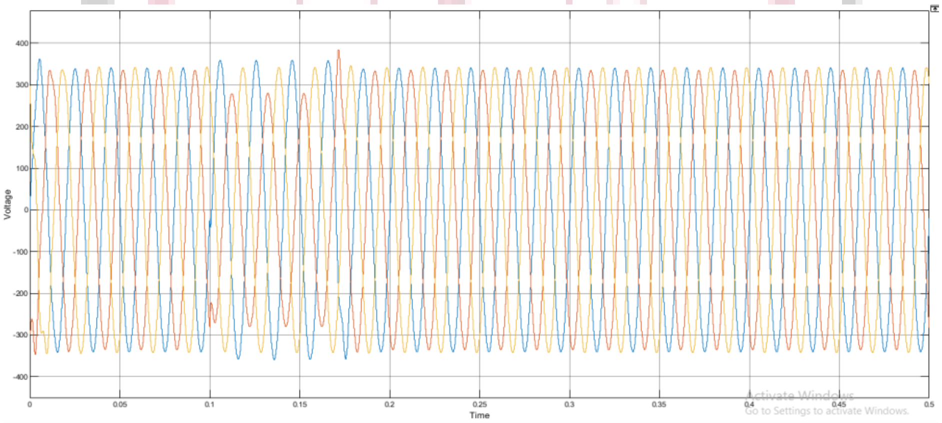

Figure 34: Voltage of system in case 2 for analyzing sag and swell in the system

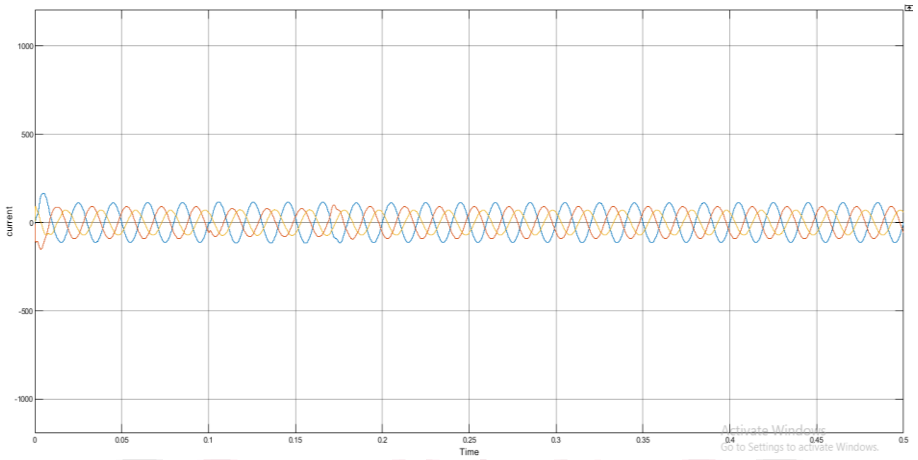

Figure 35: Current of system in case 2 for analyzing sag and swell in the system

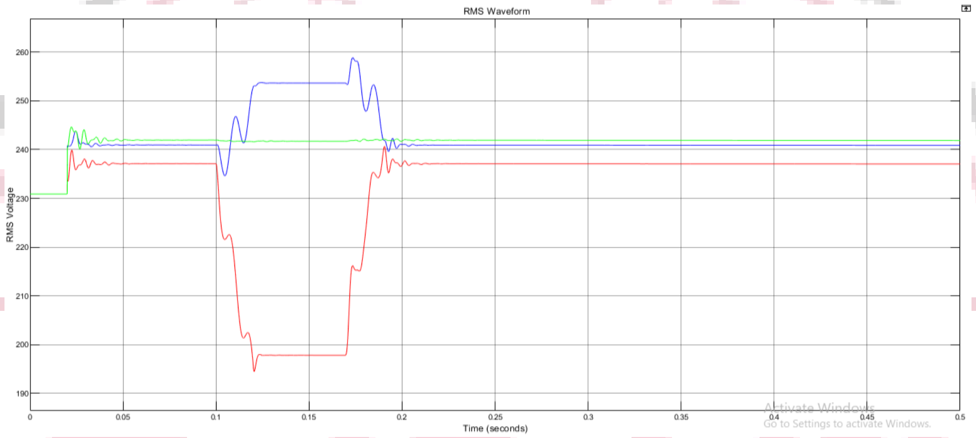

Figure 36: RMS representation of Voltage of system in case 2 for analyzing sags and swell in the system

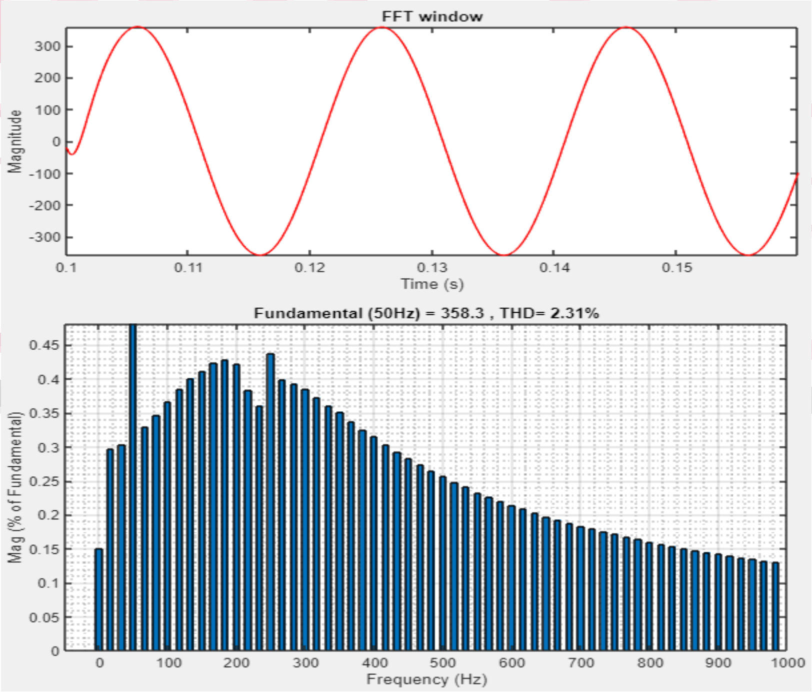

Figure 37: The THD% evaluation of voltage at the swell point in system of case 2

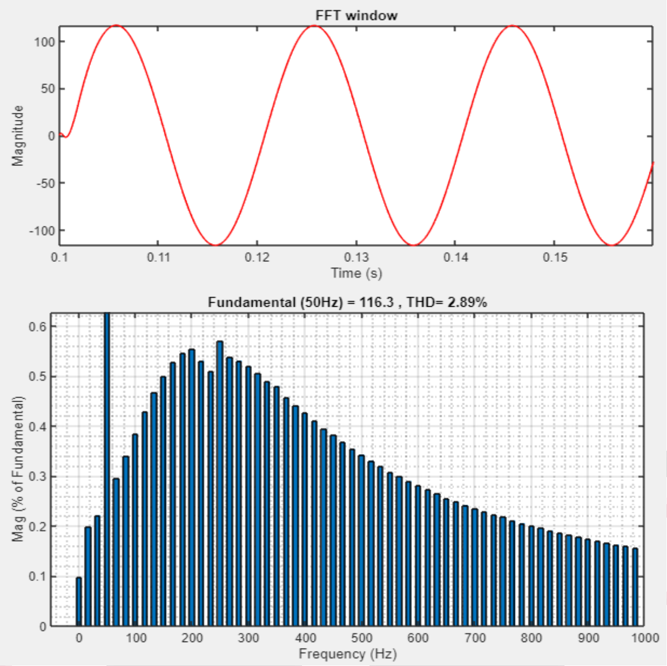

Figure 38: The THD% evaluation of current at the swell point in system of case 2

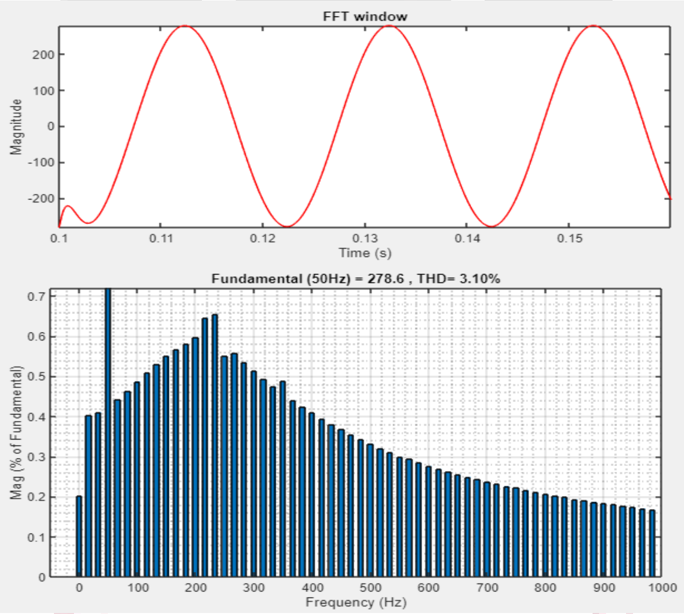

Figure 39: The THD% evaluation of voltage at the sag point in system of case 2

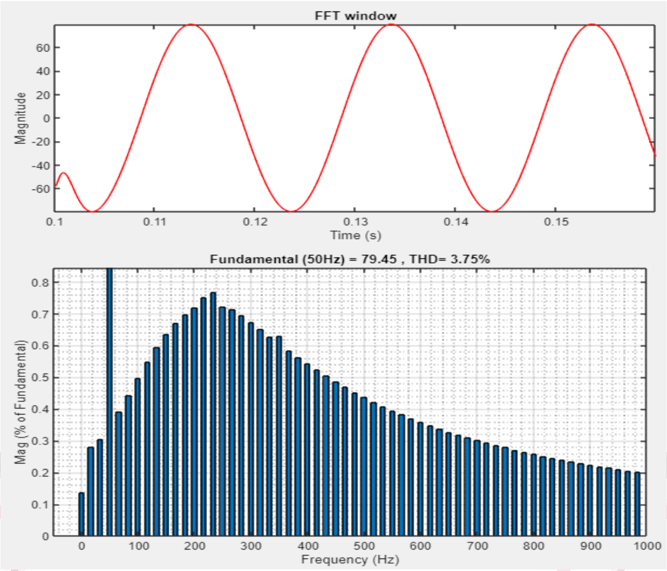

Figure 40: The THD% evaluation of current at the sag point in system of case 2

Table 3: Analysis of the systems designed with two UPQC controllers

Parameters	**System in case 1**	**System in case 2**
	Analysis while driving non linear loads	
THD% in voltage	2.45%	2.43%
THD% in current	9.16%	8.89%
	Analysis while driving unbalanced loads	
THD% in voltage	7.01%	7.00%
THD% in current	7.08%	6.97%
	Analysis when voltage swell is created at 0.1 at phase A	
THD% in voltage	2.35%	2.31%
THD% in current	3.04%	2.89%
	Analysis when voltage sag is created at 0.1 at phase C	
THD% in voltage	3.13%	3.10%
THD% in current	3.98%	3.75%
	Power Quality Assessment	
Active power (W)	29080	29680
Reactive Power (Var)	624.4	29.8

V. Conclusion

The unified power quality conditioner (UPQC), which is a multi - functional electricity purifier which can be used to compensate for various voltage disturbances in the power source, correct voltage fluctuations, and prevent harmonic current flowing from trying to enter the electric grid, is the most comprehensive structure of hybrid filters. It's a specialized power gadget made to reduce the effects of disruptions on sensitive and/or critical loads' performances.

Modifying the UPQC controls and studying the reaction under various loading scenarios were the main goals of the project. The system was created in the MATLAB/SIMULINK environment, and the suggested harmonic elimination differentiated iterative method was implemented using script. The experiment was performed by comparing the results of a typical controllers that used Programmable integral (PI) regulation to those of the suggested HDE algorithms. The following are the main results reached as a result of the research.

- An increase in power output from 29080 watts to 29680 watts, accounting for a 2% increase in power output and a reduction in reactive power to 29.8 Var in the proposed model.
- In the system with suggested HDE driven UPQC, the THD percent evaluated in the network while driving non - linearity loading was calculated to be 2.43 percent and 8.89 percent in current and voltage respectively, down from 2.45 percent and 9.16 percent in current and voltage.
- In the system with suggested HDE driven UPQC, the THD percent evaluated in the network when driving unbalance was calculated to be 7.00 percent and 6.97 percent in current and voltage respectively, which was lowered from 7.01 percent and 7.08 percent in current and voltage.
- The network was also tested for voltages sag and swell situations, and the results showed that the suggested controllers reduced the THD percent of both currents and voltages in the network under both scenarios.

The modulation scheme is straightforward to construct; the use of appropriate facts controllers can making the inverters more durable and simpler to handle. With much more sophisticated artificial intelligence, the criteria for low computational and memory usage of programs will be reduced, and it may even be able to implement more complex and effective algorithms. During the design of the compensation, the control scheme has proven to be successful. By developing a hybrid technique for this algorithms, it will be able to work even better. As a result, it is undeniably true that the field of compensators is and will remain a large open sector for scientific inquiry and commercial products for a long time.

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