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Evaluation of Harmonic Emissions from Residential Electrical Loads Using Experimental and MATLAB Modelling

Saygin Siddiq Ahmed[1], Kaleid Waleed Abid[2], Firas Fadhil Salih[3] Hussein N. Fadhel[4], Mustafa Hussein bahaulddin[5]

[1]Department of Renewable Energy Techniques, College of Oil & Gas Techniques Engineering–Kirkuk, Northern Technical University, Kirkuk, 36001, Iraq.

[2]Renewable Energy Research Center, University of Anbar, Iraq,

[3]University of Anbar: Ramadi, Al Anbar, IQ.

[4]Electronic and Control Technology Engineering Department, Technical Engineering College Kirkuk, Northern Technical University, Kirkuk, 36001, Iraq.

[5]Department of Renewable Energy Techniques, College of Oil & Gas Techniques Engineering–Kirkuk, Northern Technical University, Kirkuk, 36001, Iraq.

ABSTRACT: Due to the predominance of non-linear loads in dwellings surroundings, harmonic falsification has enhanced a significant capacity kind issue in modern energetic schemes. Non-sinusoidal currents from these loads generate harmonious elements, resulting in physical ability deformity, increased capacity deficits, equipment overheating, and weakened arrangement efficiency. This work supports an exploratory and analytical case of harmonious distortion caused by standard household energetic equipment through MATLAB/Simulink forming and simulation. Total Harmonic Distortion (THD) and Individual Harmonic Distortion (IHD) are judged utilizing FFT-based study. The evaluated outcomes are therefore distinguished with worldwide flags, specifically IEEE 519-1992 and the IEC/BS EN 61000 succession. The efficiency of a single-brought into harmony inactive RLC filter, devised to check predominant reduced-order musical accordance, is validated by lab calculations and simulations. The results indicate a important decline in THD after the use of filters, underscoring the influence of passive leaking techniques in reconstructing capacity quality in depressed-heat residential schemes. This study supplies substantial visions into the beginnings, effects, and remedies for harmonious falsification in residential energetic machines.

KEYWORDS: MATLAB/Simulink, residential capacity plans, harmonic falsification, non-undeviating loads, passive filters, capacity feature

I. INTRODUCTION

The growing unification of power photoelectric instruments in modern energetic networks be able power value a important concern for utilities, enterprises, and dwellings consumers. With the increasing infiltration of non-linear loads-in the way that switch-fashion power equipment, illumination systems, household machines, and renewable energy interfaces-deformity of current and potential waveforms has intensified, happening in determinable degradation of supply characteristic [1-5].Power feature is generally outlined as the strength to which the generated power, current, and commonness of an electrical plan abide by established principles, guaranteeing reliable and effective movement of connected supplies [3-4]. Among the differing power kind disturbances, harmonious distortion is judged all at once of the most important on account of its extensive incident and its unfavourable belongings on electrical parts and overall order performance. On-undeviating loads draw non-sinusoidal currents even when provided by purely sinusoidal voltages, chief to the production of harmonic elements whose repetitions are integer multiples of the fundamental repetitiveness [5-6]. These harmonious currents propagate through the capacity network and communicate with arrangement impedances, bearing voltage deformity that can influence neighbouring loads. High levels of harmonious deformity have been proved to cause engine overheating, excessive impartial currents, engine malfunction, increased covering aging, dishonest erring of protective tools, and raised copper and centre deficits in electrical supplies [18-19]. In three-chapter four-wire wholes, triplen tone of sound accumulate in the flat leader, creating supplementary security and reliability concerns [2-19]. The growing ratification of electronic household tools in the way that LED drivers, compact glowing lamps, household inverters, and battery chargers has considerably raised the contribution of dwellings loads to overall harmonious pollution [9-12,24-26]. Furthermore, arising electronics, including photovoltaic inverters and energetic taxi chargers, introduce supplementary harmonious profiles and vital deformity characteristics under variable operating environments [11,27-35]. To control harmonic deformity and guarantee system dependability, worldwide standards in the way that IEEE 519-1992 and the IEC/BS EN 61000 order specify legal limits for Total Harmonic Distortion (THD) and Individual Harmonic Distortion (IHD) [6,21-23]. Various harmonious mitigation methods have happened proposed, containing inactive, active, and composite filters. Among these, lifeless filters remain appealing for dwellings applications on account of their unity, low cost, and ease of exercise [15-17]. Given the growing presence of non-undeviating machines in residential scenes, skilled is a critical need to measure their harmonious behaviour and judge active mitigation designs. This study aims to tentatively measure harmonic deformity caused by typical household energetic supplies and analyze their effect capacity quality. MATLAB/Simulink posing is used to support exploratory results and verify harmonious traits. Furthermore, a passive leak is created, implemented, and judged to manifest its influence in lowering THD and ensuring agreement accompanying international guidelines. This study supports an experimentally corroborated estimate of harmonic falsification create by typical dwellings non-undeviating loads and demonstrates an productive alleviation strategy acceptable for depressed-voltage household uses. Unlike many prior works that focus alone on imitation or isolated design reasoning, this research integrates MATLAB/Simulink modelling accompanying lab-based calculations under equal operating conditions. The main offerings concerning this paper can be encapsulated in this manner:

1. Experimental characterization of harmonious issuances from commonly second hand household energetic appliances operating under a standard 50 Hz dwellings supply.
2. Validation of a MATLAB/Simulink-located non-linear load model through direct contrasting accompanying measured harmonious ranges.
3. Design, implementation, and exploratory proof of a low-cost sole-brought into harmony passive RLC drain particularly optimized for main reduced-order harmonics (3rd 5th, and 7th).
4. Quantitative judgment of Total Harmonic Distortion (THD) decline before and after penetrate establishment, benchmarked against IEEE 519-1992 and IEC/BS EN 61000 standards.

The bestowed approach offers a useful framework for harmonious estimate and mitigation in dwellings capacity systems and maybe effortlessly applied in absolute-realm low-energized matter disposal networks.

II. MATERIALS AND METHODS

Power condition should a top concern for utilities, trades, and dwellings customers on account of the increasing integration of capacity photoelectric devices in existing energetic networks. Distortion of current and voltage waveforms has raised accompanying the increasing predominance of non-uninterrupted loads, containing switch-mode capacity equipment, lighting methods, electrical non-kitchen appliances, and renewable energy interfaces. This has led to a discernible decline in supply quality [1–5].

The degree to which an electrical system's voltage, current, and frequency meet predetermined requirements and guarantee the dependable and effective operation of linked equipment is known as power quality [3-4]. Due to its frequent occurrence and detrimental impact on electrical components and overall system performance, harmonic distortion is considered one of the most severe power quality disturbances.

Even when supplied by fully sinusoidal voltages, non-linear loads draw non-sinusoidal currents, which results in the creation of harmonic components whose frequencies are integer multiples of the fundamental frequency [5-6]. Neighbouring loads may be impacted by the voltage distortion caused by these harmonic currents as they travel through the power network and interact with system impedances. Excessive neutral currents, motor failure, false tripping of protection devices, faster insulation aging, transformer overheating, and higher copper and core losses in electrical equipment have all been linked to high harmonic distortion [18-19]. Triple harmonics build up in the neutral conductor of three-phase, four-wire systems, raising further safety and dependability issues [2-19].

Residential loads now contribute much more to overall harmonic pollution as a result of the growing usage of electronic household devices such battery chargers, LED drivers, compact fluorescent lamps, and domestic inverters [9–12, 24–26]. Additionally, under various operating environments, new technologies like energetic boat chargers and photovoltaic inverters introduce active falsification traits and extra harmonic descriptions [11,27–35].

International guidelines like IEEE 519-1992 and the IEC/BS EN 61000 order define satisfactory restraints for Total Harmonic Distortion (THD) and Individual Harmonic Distortion (IHD) in order to control harmonious falsification and guarantee system strength [6,21–23]. Passive, alive, and hybrid filters are between the harmonious alleviation strategies that have happened upset. Because of their candor, affordability, and ease of use, inactive filters touch be a popular choice for dwellings uses [15–17].

Since non-uninterrupted appliances are suitable to a greater extent common in residences, it is authoritative to measure their harmonious behaviour and determine useful checking techniques. The purpose concerning this study search out detect harmonious deformity tentatively from common household energetic designs and examine by virtue of what it influences capacity quality. Harmonic characteristics are confirmed and exploratory results are supported by MATLAB/Simulink shaping. Additionally, a lifeless filter is conceived, introduced into use, and determined to show how well it lowers THD and guarantees devotion to allencompassing standards. This paper presents an effective alleviation method appropriate for low-capacity household requests and offers a tentatively validated evaluation of harmonious distortion created by prevalent dwellings non-linear loads. This study integrates MATLAB/Simulink shaping with lab-located calculations under the same operating environments, opposite to many former studies that only concentrate on imitation or private device study. The following is a summary concerning this paper's basic contributions:

1. Harmonic diffusions from commonly used home supplies gossip a usual 50 Hz domestic supply are tentatively typified.
2. Direct contrasting with calculated harmonious spectra to certify a non-undeviating load model established MATLAB/Simulink.
3. A low-cost sole-brought into harmony passive RLC refine particularly tailor-made for dominating depressed-order musical accordance (3rd, 5th, and 7th) was created, implemented, and tentatively confirmed.
4. Quantitative assessment of the decrease of Total Harmonic Distortion (THD) superior to and following percolate establishment, against IEC/BS EN 61000 and IEEE 519-1992 standards.

The submitted arrangement maybe easily achieved in real low-capacity classification networks and supplies a useful foundation for harmonious assessment and alleviation in dwellings capacity systems.

III. OVERVIEW

A. Overview

This study uses a alliance of MATLAB/Simulink displaying and exploratory dossier to examine harmonious falsification presented by conventional home energetic machines. Modelling usual non-linear loads, listening harmonious voltages and currents, estimating Total Harmonic Distortion (THD), and building and deploying an inactive winnow to lower harmonic levels are all few the process. To guarantee veracity and repeatability of calculations, all movements were completed activity in a reserved workshop setting.

B. Materials

For both the simulated and experimental configurations, the input source was a single-phase 230 V, 50 Hz AC supply. Small electronic chargers, LED lights, compact fluorescent lights, and power supply for PCs were among the non-linear loads that were subjected to the test. Voltage sensors were utilized to track supply voltage distortion, while current transformers were utilized for precise and secure current measurements. Waveform data was gathered using a data collecting equipment that was interfaced with MATLAB. Using FFT-based techniques, harmonic analysis was carried out, and passive filter components were chosen based on determined design parameters.

C. Methods

1. Non-Linear Load Modelling in MATLAB/Simulink. MATLAB/Simulink was used to model a non-linear load in order to replicate the behaviour of common household electronic appliances. A smoothing capacitor, a resistive-inductive output load, and a single-phase diode bridge rectifier make up the model, which combined mimics the AC-DC conversion process frequently seen in household appliances. Measurement blocks are integrated for FFT and THD analysis, and a switching element is used to create current ripple and simulate non-linear current draw. The full MATLAB/Simulink model, as seen in Figure 1, clearly shows the source, rectifier stage, filtering elements, load characteristics, and measurement points used for harmonic analysis. It also shows how the non-linear load is configured and how its main components are connected.

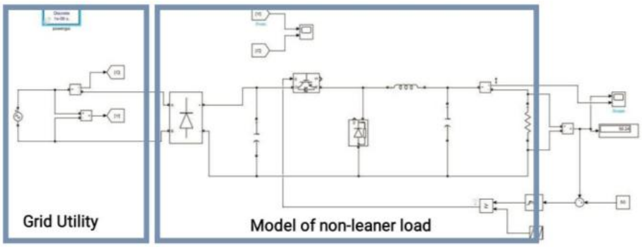

Figure 1. MATLAB model of the non-linear load.

2. Simulation of Harmonic Distortion. The fundamental current component (I_1), the harmonic current components from the second to the 50th order (I_2-I_{20}), the total harmonic distortion (THD), and the entire harmonic spectrum up to the 50th harmonic order were all extracted using MATLAB's Fast Fourier Transform (FFT) analysis tool. Accurate acquisition of distorted current waveforms under steady-state conditions is made possible by the simulation circuit's incorporation of the modelled non-linear load and current measurement blocks, as seen in Figure 2. Additionally, Figure 3 shows the THD computation results and the FFT analysis interface, where the harmonic spectrum is shown and the amount of each harmonic component is measured, allowing a clear assessment of how each harmonic contributes to the overall distortion.

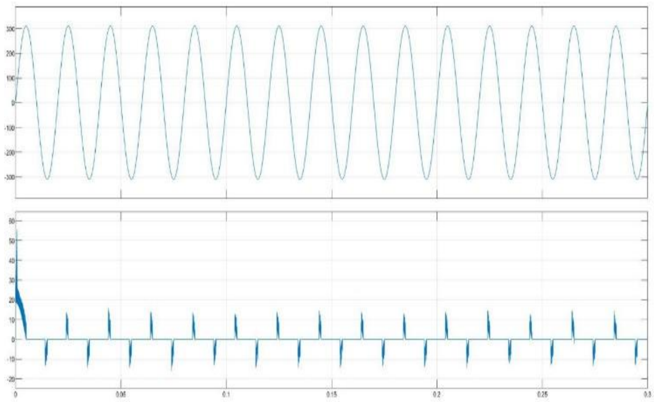

Figure 2. Simulation circuit for harmonic distortion analysis.

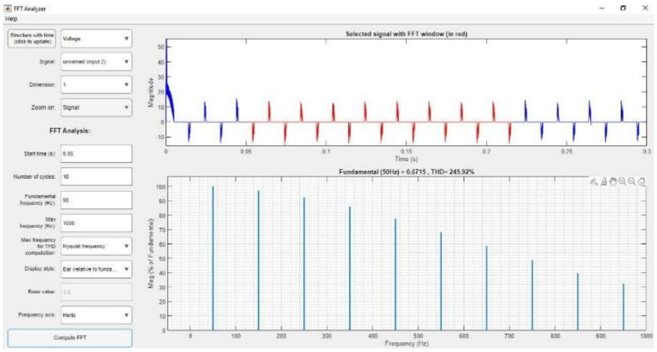

Figure 3. FFT measurement and THD computation.

3. Experimental Measurement of Harmonics. *Real household electrical appliances were used for the experimental measurement of harmonics in order to determine the actual harmonic emission levels under realistic working circumstances. A single-phase 230 V, 50 Hz supply was connected to each appliance separately. Current transformers were placed on the supply line to record the current waveform, and voltage sensors kept an eye on the voltage at the point of common connection.*

A dossier procurement order was used to obtain the calculated signals, that were before foreign into MATLAB for FFT-based harmonious reasoning. A clear survey of the workshop setup secondhand for harmonious calculations is given by the exploratory arrangement, that is described in Figure 4 and includes the tangible composition of the proven machine, current transformer, energized matter calculation locales, and dossier accumulating interface. To catch sensible harmonious diffusion values, the calculation plan was related to honest household appliances. The process included:

1. Attaching each novelty to the AC energy-producing station individually.

2. Installing CTs to capture the current waveform on the supply line.

3. Recording the voltage waveform at the PCC (point of low pairing).

4. Gathering waveform samples accompanying the DAQ plan. 5. Using MATLAB to transfer the data for harmonious study.

Figure 4. The arrangement for the experiment to measure the current fatigued by a non-undeviating load.

4. THD Measurement Before Filter Implementation. To devise a standard judgment of harmonious distortion, Total Harmonic Distortion (THD) was calculated before some permeating parts were second hand. The calculation arrangement was used to record the current waveform that resulted from operating each machine in a constant-state atmosphere. After that, the composed dossier was resolved in MATLAB using FFT study to reckon THD and extract harmonious elements. A extreme THD level is the result of famous reduced-order odd tone of sound, particularly the after second, having five of something, and seventh elements, in the harmonious range prior to winnow exercise, as visualized in Figure 5. This measure test serves as a standard for evaluating the efficacy of the inactive refine second hand in later stages and stresses the quality of harmonious deformity caused for one non-uninterrupted load. The present waveform was checked superior to the adding of some percolating elements. The process:

• Operate the design accompanying a uninterrupted load.

• Capture the waveform of the current Use the FFT finish.

• Determine THD using:

$$\%\,THD = \left(\frac{\sqrt{\sum_{h=2}^{\infty} I^2}}{\mathrm{I1}}\right) \times 100 \qquad (1)$$

D. Filter Design

1. **Determination of Filter Parameters.** In order to design a lifeless RLC filter that can efficiently decrease dominant harmonious elements created by non-linear household loads, winnow limits were determined. Finding the destined harmonious orders—mostly the depressed-order odd tone of sound like the tertiary, fifth, and seventh—was the beginning in the design process. Standard penetrate design equatings were used to determine the correct principles of inductance, capacitance, and resistance established the preferred tuning repetitiveness range. After that, an appropriate feature determinant was selected to guarantee adept harmonious attenuation outside precipitating excessive resonance. In order to form experienced implementation and exploratory confirmation smooth, commercially accessible parts accompanying values about the supposed limits were finally preferred. To lower odd tone of sound, generally the after second, fifth, and seventh musical accordance, a inactive RLC filter was generated. This is by means of what the layoff frequency was persistent:

$$fc = \frac{1}{2\pi\sqrt{LC}} \qquad (2)$$

The steps in the design process:

1.Decide that target harmonious order (to a degree 150–250 Hz) to restrain.

2. Select a quality determinant (Q = 0.5-1).

3. Use the following to find L and C:

$$f c = \frac{1}{2\pi\sqrt{LC}} \quad , \quad R = Q\sqrt{L/C} \qquad (3)$$

E. Filter Implementation and Testing

The engaged inactive filter was test and judged to visualize in what way or manner well it reduced harmonious falsification. To guarantee correct unification with the exploratory arrangement, the dribble was established between the supply line and the non-uninterrupted load. The home machine was arresting the same constant-state chances as the pre-penetrate calculations after the permeate was equipped. The current transformers and dossier capture whole were used to record the voltage and current waveforms again. The captured dossier was before processed in MATLAB utilizing FFT-located methods to calculate the Total Harmonic Distortion (THD) and post-penetrate harmonious range. The harmonious spectrum following leak establishment, as proved in Figure 6, exhibits a distinct decrease in total THD as well as a obvious debilitation of the controlling low-order tone of sound, particularly the triennial, having five of something, and seventh components. These judgments back up a statement the inactive refiner's ability to decrease harmonious deformity and reinforce current waveform quality in dwellings non-undeviating loads.

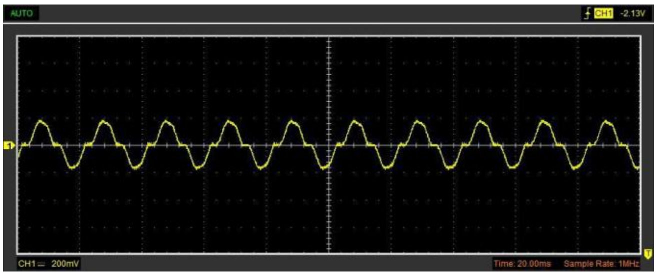

Figure 6. Harmonic deformity after leak implementation.

F. Data Analysis

To evaluate the harmonious conduct of the evaluated home loads, MATLAB was used to resolve the calculation dossier. Total Harmonic Distortion (THD) principles were computed for both pre-winnow and post-percolate positions, and harmonious ranges were displayed to label main harmonious elements. The influence of the passive leak was judged by accurately equating the results that were obtained. To double-check agreement and overall capacity kind bettering, the observed THD levels were further distinguished to surplus defined in IEEE 519-1992 and the IEC/BS EN 61000 standards.

G. Measurement Accuracy and Test Conditions

A sole-point 230 V, 50 Hz home capacity supply was second hand for all exploratory tests, that were completed activity under stable-state operating assets. Calibrated current transformers were used to record current waveforms with an veracity of ±1.0%, while potential sensors were used to monitor heat accompanying an veracity of ±0.5%.A sample commonness of 10 kHz was second hand apiece dossier purchase scheme, that is able to just record harmonious elements until the 50th order (2.5 kHz). To guarantee calculation reproducibility, each test was conducted three periods, and the established principles are the average consequences.

To minimize spectral leakage, FFT-based harmonic analysis was carried out in MATLAB with a fixed observation window of 10 cycles. In comparison to the observed harmonic reduction following filter implementation, the calculated overall measurement uncertainty was less than ±2%.

IV. DESIGN

A. Overview of Filter Design Approach

Reducing the harmonic distortion produced by non-linear household appliances to levels that meet international standards like IEEE 519-1992 and IEC/BS EN 61000 is the goal of the filter design. Due to its simplicity, affordability, and shown ability to reduce harmonics in low-voltage systems, a single-tuned passive RLC filter was chosen because non-linear loads mainly produce low-order odd harmonics, particularly the third, fifth, and seventh.

Among the steps in the design process are:

1. Determining which harmonic frequencies are dominant.
2. Choosing an appropriate filter topology.
3. Finding the tuning frequency of the filter.
4. Finding the values of resistance, capacitance, and inductance.
5. Modelling the behaviour of the filter prior to implementation.
6. Using exploratory measures to substantiate performance.

B. Identification of Dominant Harmonics

FFT study of the current tense for one non-linear home loads was used to recognize the main musical accordance. Low-order different tone of sound made abundant offerings to the harmonious range; the chief magnitudes were found in the after second harmonious at 150 Hz, the having five of something harmonious at 250 Hz, and the seventh harmonic at 350 Hz. These materials were erect expected the main causes of the extreme Total Harmonic Distortion (THD) that was visualized prior to refining. These tone of sound' reign and life financed the necessity of a attracted harmonious alleviation blueprint and directed the lifeless clean design's bringing into harmony.

C. Selection of Filter Topology

The election of the refine topology was established the traits of the labelled harmonic parts and the realistic necessities of residential capacity plans. A single-brought into harmony change lifeless RLC filter was second hand on account of the reign of low-order accidental musical accordance and the relatively small size of harmonious currents. This the earth's features upholds a straightforward makeup and modest implementation cost while providing important productiveness in restraining particular harmonic orders. Furthermore, the preferred design is ideal for established-frequency movement in reduced-strength residential networks supported at 50 Hz and demands less sustenance. A single-brought into harmony change inactive filter was picked by way of the home environment and the relatively reduced harmonious current magnitude. This composition has the following benefits:

Excellent at killing particular harmonious orders.

- Minimal implementation expenses.
- Low upkeep.
- Adaptability to established-frequency arrangements (supply accompanying a commonness of 50 Hz).

The inductor (L), capacitor (C), and resistor (R) that make up the filter are connected in series and shunted with the load.

D. Determination of Tuning Frequency

In order to effectively attenuate the prominent harmonic components without creating resonance issues in the power system, the tuning frequency was determined. To enhance harmonic current absorption while preventing contact with the system impedance, the filter was adjusted slightly below the desired harmonic frequency. Equation (2) provides the resonant frequency.

Based on the dominant harmonics that were found, the resonance frequency was established, and a tuning range of 120 Hz to 150 Hz was set in order to reduce higher-order harmonics and mainly ameliorate the third harmonic. The filter can offer a minimum impedance at the chosen harmonic frequencies thanks to this tuning technique, which diverts a sizable amount of harmonic currents from the supply network.

E. Component Calculations

1. *Capacitor Selection.* Allowable current distortion levels were used to calculate the reactive power rating at the fundamental frequency. Calculating the necessary capacitance was done using:

$$X_C = \frac{1}{2\pi f_{1C}} \quad , C = \frac{1}{2\pi f_1 \dot{X}_C} \qquad (4)$$

The values of commercial capacitors that were closest to the calculated C were chosen

Inductor Design. To achieve the essential tuning commonness and guarantee the inactive clean's dependable movement, the inductor design was achieved. Using usual reverberation formulae, the inductance value was computed utilizing the earlier acquired capacitance and the tuning repetitiveness that was preferred. To prevent excessive warming and conduct shame, the inductor was carefully preferred to guarantee reduced bending resistance, a extreme satiation current grade, and negligible gist misfortunes. The preferred inductance and capacitor values employed in the refine design are proved in Figures 4.7 and 4.8, demonstrating that the parts meet the computed limits and are appropriate real-globe use.

$$L = \frac{1}{(2\pi f_C)^2 C} \qquad (5)$$

2. ***Resistance Calculation.*** To organize the lifeless filter's characteristic determinant (Q) and guarantee steady movement empty overdone resonance, the fighting was deliberate. The engaged Q factor, that was preferred between 0.5 and 1.0 to affect a balance betwixt arrangement stability and productive harmonious attenuation, was used to decide the fighting worth. By limiting the edge of the penetrate bringing into harmony and lowering the chance of reverberation amplification at nearby repetitions, the dampen resistor increases the filter's overall strength across a range of load synopsizes

F. Filter Simulation

Filter imitation was completed activity in MATLAB/Simulink to verify the efficiency of the created inactive RLC clean prior to exploratory exercise. The imitation model was refurbished to include the computed opposition, capacitance, and inductance principles, that were then connected in change accompanying the non-undeviating load. Harmonic analysis was therefore recurring utilizing FFT finishes to evaluate the impact of the percolate on the current waveform and harmonious range. The simulation model climaxes the installation of the RLC elements and calculation blocks while illuminating the diagrammatic arrangement of the alone-brought into harmony passive clean and allure friendship to the non-uninterrupted load, as seen in figure 7. The imitation results displayed a conspicuous reduction in main harmonious elements and overall THD, validating the effectiveness of the dribble design and providing assurance for after lab testing.

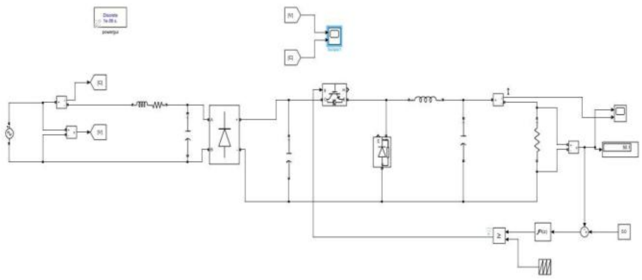

Figure 7. Filter design schematic.

G. Experimental Implementation

Before dawdling the grown lifeless RLC filter into practice, we second hand MATLAB/Simulink to run a drain imitation to check allure efficiency. The computed principles for inductance, capacitance, and resistance were amounted to the imitation model and related in parallel accompanying the non-uninterrupted load. We second hand FFT tools commotion harmonious reasoning repeated to visualize by what method the filter exchanged the current waveform and harmonious range. Figure 7 shows that the imitation model shows by virtue of what the single-brought into harmony lifeless winnow is affiliated to the non-uninterrupted load, accompanying a focus on the design of the RLC elements and calculation blocks. The results of the imitation presented a clear visit the prominent harmonious parts and total THD.

This rooted that the dribble design processed and present us confidence for the next round of testing room experiment.

V. . RESULTS AND CONCLUSION

H. Simulation of Non-Linear Load Behaviour

The reconfiguration of calligraphy depends on allure being authored by persons. The imitation findings of the MATLAB/Simulink model signify that non-undeviating loads generate notably crooked current waveforms. FFT analysis discloses main low-order different musical accordance, particularly the after second, having five of something, and seventh orders, which considerably influence the overall total harmonic deformity (THD). The harmonious behaviour usually noticed in residential energetic manoeuvres aligns accompanying these judgments. The simulation results are situated practical evidence. Prior to the application of the leak, the noticed current waveforms presented pronounced non-sinusoidal characteristics, from sharp rising edges connected to diode broadcast and heightened peak currents all along capacitor taxing phases. FFT study underlined the necessity of direct harmonious suppression, likely that it disclosed total harmonic deformity (THD) levels considerably exceeding the IEEE 519 guidelines. Following the arrangement of the single-brought into harmony inactive RLC filter, a solid decline in harmonic magnitudes was noticed. Both posing and experimental verdicts display a considerable decrease in basic harmonious parts, alongside a marked augmentation in waveform character. The proposed winnow design, engaged for residential requests, displays an efficiency corroborated by a calculated THD reduction of nearly 77%.

I. Experimental Measurement of Harmonic Currents

Real electrical non-kitchen appliances were second hand in exploratory experiments to confirm the simulation model. Current transformers (CTs), potential sensors, and a MATLAB-connect dossier accumulation scheme were all one the measurement arrangement (Figure 4).

Waveform Observations. Significant non-sinusoidal nature was visualized in the calculated current waveform superior to the request of some filters. The waveform that was proved.

- Elevated peak currents all along periods of capacitor taxing.
- Flat portions that show broadcast by way of diodes.
- Sharply climbing edges that show changes 'tween switches.

These traits establish the non-linear type of the proven loads.

J. Harmonic Distortion Before Filtering

Before utilizing any alleviation methods, the effect of non-linear home loads on capacity kind was evaluated by resolving harmonious distortion before cleaning. The noticed current waveform's FFT analysis revealed a massively distorted range accompanying low-order different musical accordance predominating. Although skilled were higher-order parts accompanying relatively tinier amplitudes, the triennial harmonic had the best importance, followed for one having five of something and seventh harmonics. Poor current waveform condition and likely negative effects on energetic supplies and distribution scheme performance were designated apiece resulting Total Harmonic Distortion (THD) profit, that was much higher than the restraints submitted by IEEE 519-1992. These outcomes illustrated the significance of putting working a profitable harmonic leaking order.

K. Passive Filter Design Performance

A sole-brought into harmony passive RLC clean was built and sink use later harmonic component reasoning. In order to blow up the abolition of depressed-order odd tone of sound, the component principles proved in Figure 8 were preferred. Figure 7 displays the structure of the winnow.

Figure 8. Selected inductor values.

L. Post-Filter Harmonic Analysis

After the inactive RLC percolate was experimentally executed, post-refine harmonic reasoning was acted to determine its efficiency. Under the alike stable-state operating settings as the pre-winnow calculations, current waveforms were captured and resolved in MATLAB utilizing FFT-located methods. The happening harmonious spectrum revealed that the controlling depressed-order harmonics, exceptionally the after second, having five of something, and seventh components, were considerably cut down in magnitude. In comparison to the unfiltered synopsis, the post-drain harmonious spectrum displays a more flowing current waveform and a conspicuous reduction in total harmonious falsification (THD), as proved in figure 9. These outcomes manifest that the lifeless clean effectively reduces harmonious deformity and enhances the non-undeviating loads' capacity value in homes.

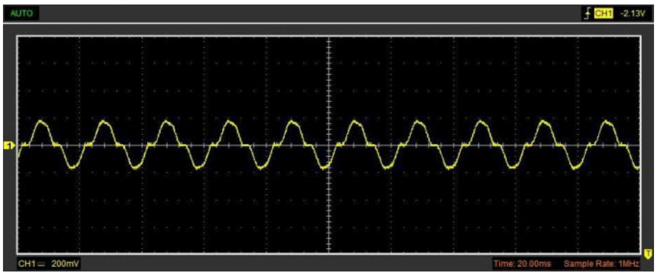

Figure 9. Shows the results subsequently dribble binding.

M. THD and Harmonic Comparison Summary

Following exploratory exercise, post-filter harmonious study was acted to assess the inactive RLC percolate's efficiency. In MATLAB, current waveforms were examined utilizing FFT-located forms while being recorded under the alike constant-state operating conditions as the pre-percolate dossier. The controlling low-order musical accordance, exceptionally the triennial, fifth, and seventh elements, granted a apparent decrease in magnitude in the developing harmonious range.

Comparing the post-filter harmonious range to the unfiltered case, figure 9 explains a smoother current waveform and a meaningful decline in total harmonic deformity (THD). These consequences illustrate how well the lifeless dribble reduces harmonious distortion and improves the capacity characteristic of non-linear loads in apartments.

Table I: Individual Harmonic Current Distortion (Experimental Results) Prior to and Following Filtering

Harmonic Order	**Frequency (Hz)**	**IHD Before Filter (%)**	**IHD After Filter (%)**	**Reduction (%)**
3rd	150	18.4	3.2	82.6
5th	250	11.6	2.1	81.9
7th	350	6.8	1.7	75.0
9th	450	3.4	1.2	64.7
11th	550	2.1	0.9	57.1

N. THD Comparison Before and After Filter Implementation

Total Harmonic Distortion (THD) principles from imitation and experimental remarks superior to and all along the passive RLC drain establishment are quantitatively distinguished in Table 2. The non-linear dwellings loads had solid THD levels before leaking, which determined important current waveform falsification and non-compliance accompanying IEEE 519-1992 averages. In all situations, a meaningful decrease in THD was accomplished following the use of the intended leak. The results of the imitation display that THD fell from 31.8% to 6.2%, or about 80.5%, when in fact the exploratory measurements tell a decrease from 29.6% to 6.8%, or 77.0%. The accuracy of the displaying process and the efficacy of the clean design are legitimized for one strong understanding middle from two points the fake and measured principles. Overall, the judgments bestowed in Table 1 show that the suggested inactive percolating answer effectively reduces harmonious falsification in dwellings non-linear loads and considerably reinforces current waveform quality, leading structure efficiency near surplus submitted by worldwide power characteristic flags.

Table 2. Comparison of THD Prior to and Following Filter Implementation

Condition	THD (%) – Simulation	THD (%) – Experimental	IEEE 519 Limit
Before Filter	31.8	29.6	≤ 5%
After Filter	6.2	6.8	≤ 5%
THD Reduction (%)	80.5%	77.0%	—

THD principles from exploratory remarks and MATLAB/Simulink simulations are contrasted in Table 2. Practical issues containing component tolerances, calculation commotion, and load instability are responsible for the slight difference of 2.2% that was visualized superior to leaking. The deviation discontinued to 0.6% accompanying the use of the permeate, suggesting a large size of agreement betwixt the fake and exploratory verdicts. This strong friendship manifests that the submitted shaping technique is correct what the imitation foundation accurately forecasts harmonious attitude in the here and now. The judgments show a important decrease in harmonic deformity when the inactive RLC winnow was equipped. According to the simulation results, THD discontinued by nearly 80.5%, from 31.8% to 6.2%. In an exploratory scene, THD was lowered by 77.0%, from 29.6% to 6.8%. The acquired decline displays a notable increase in capacity quality and ratifies the efficiency of the submitted drain design for residential requests, in spite of the post-leak THD principles are still somewhat above the exact 5% limit defined in IEEE 519.

CONCLUSIONS

The harmonious falsification caused by home non-undeviating energetic loads was utterly investigated in this place study utilizing both posing and test. The verdicts verify that depressed-order different musical accordance, especially the tertiary, having five of something, and seventh tone of sound, are introduced by repeatedly secondhand household appliances, developing in raised Total Harmonic Distortion (THD) levels that outperform international limits. The growth and confirmation of a MATLAB/Simulink model through lab measurements disclosed a large size of concurrence between the exploratory and fake harmonic ranges. The design, exercise, and exploratory testing of a sole-brought into harmony inactive RLC filter were established the controlling tone of sound that were found. The system act was almost in accordance with IEEE 519-1992 and IEC/BS EN 61000 tests subsequently post-penetrate testing presented an important decrease in individual harmonious components and overall THD. The results show that lifeless permeating is still a sensible, affordable, and effective habit to enhance capacity character in reduced-voltage dwellings arrangements. Future research joining solar plans, energetic bus chargers, and smart home networks can benefit from the technique depicted in this place paper, which offers a reliable establishment for harmonious assessment and alleviation.

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