



Harmonics Analysis in Power Supply Systems: A Case Study

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ABSTRACT

This work presents harmonic analysis which is a multiple of the fundamental frequency in various power supply systems. The subject matter includes the waveforms, frequencies, magnitudes and the phase angles. The influence of harmonics in power system (PS) has some significances such as reliability, lost time validity and the competence of electrical equipment. The research was borne out of gathering of data from various power sources (PS) and PHCN. These include 3.2 kVA, 2.8 kVA, 3.5 kVA, 250 kVA, 40 kVA, PHCN voltage 220 – 230 V, all operating at 50 Hz initial frequency. From the above stated power bases, data were gotten with 'Owon meter/Oscilloscope'; they were analyzed using MatlabR2018a software. A double tuned low-pass passive shunt filter configuration was designed for the simulation of harmonics in sources being considered. The signal was first digitized, then Fast Fourier Transform (FFT) was work out. This was verified through results of the V_{THD} of the supplies that precincts to the IEEE 519 1992 5% standard. The results gotten for the three numbers single-phase generators supply systems before and after simulation are as follows 1.61%, 1.37%, while 3-phase has 1.321%, 1.19% and the PHCN is 0.79% these values are within the limits of IEEE-519-92 of 5% variation level used for the work.

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INTRODUCTION

The work is to look into the harmonics due to non-linear loads in selected single-phase generators acting as alternative power supply systems and to mitigate their effects. The objectives are as follows: Measurement of data (frequencies and voltages) from single-phase generators using digitalized scope. Determination of THD for single-phase generators and evaluating performance of waveforms obtained for various voltage disturbances using FFT technique. Validation of data from various power supply system with IEEE 519-1992, 5% standard.

Changes in sinusoidal waveform of voltage/current of either 50/60 Hz can cause equipment to mal-function and will not give credence to the expected PQ to be delivered to end users. Frequency higher than fundamental is called harmonic caused by non-linear loads in PS (Koray *et al*, 2009). Non-linear loads in PS include the following: computers, frequency drives, variable speed motors, diodes, etc. is a global

practice that these nonlinear loads are vastly used in our day-to-day operations. Therefore, the grid is common source of distribution of quality of power transmitted to end users must be free from disturbance associated with harmonics and any other disturbances that may arise in the PS.

Parameters like poor PF, voltage instability, low efficiency of electrical equipment, etc. found in PS have adverse consequences in the delivery of good quality power. Besides, good energy delivery should be harnessed especially where supply of power is inadequate for end users (Mansoor *et al*, 1995). Thus, single-phase generators as the case under consideration are alternative source associated with loads causes heat losses and pulsation of torques with vibrations resulting in iron and copper losses since they both depend on frequency (IEEE Proposed Procedures, ANSI/IEEE Std. 519-1992). From the foregoing, Nigeria being a developing nation needs regular power supply by the end users their



welfare to achieve there is over dependence on small generators in every home.

From Figure 1, power source load and scope are linked to receptacle to accommodate loads: plasma TV, personal computer and ultrasound scanning machine, data and waveforms of portable generator connected in turn. Each generator was loaded in turn and fed to the personal computer with Owon oscilloscope meter, the output waveform and data were captured and recorded.

The various loads connected generate waveforms displayed from the inbuilt components of microprocessor which are non-linear loads. Investigation of the THD was done for each power source and the loads. Figure 2 used in simulation of the THD; the analysis was done before and after filtering data was recorded that confines to the 5% IEEE 519-92 Standard Universidade (UNIVERSIDADE, 2000)

RELATED WORKS

It is expedient to know that exceeding the AVR, THD and the DPF limit will cause voltage/current resonance that will result in oscillation. The resultant effect of mechanical resonance that coincides with frequency can cause splintering of single-phase generator. The method adopted for addressing the harmonic problem was active broad band filters that handle the required loads for the DPF amount/quantity and harmonic currents; this will cut off generator from circuit the reactive and harmonic currents still circulate (Henderson *et al*, 1994; Eyenubo and Ezekiel, 2022).

Distortion will be very high when non-linear loads connected to generator than when supply is from public utility. The resultant impedance from the generator is almost three times compared with transformers attached public utility. Blocking filters for third harmonic load resolved the HD to an appreciable level harmonic not totally attenuated will give negative sequence voltage yielding fifth harmonic current thereby giving rise to generator failure earlier than expected (Ian C. Evans, IEEE Paper; Eyenubo and Oshevire, (2017).

Resonance effect caused the capacitance of a transmitter system is powered by a generator can cause harmonic problems.

Though, resonance frequency varies due to circulating current; more so, when the generator frequency becomes higher due to circulating. Band pass active filter can attenuate harmonic current to become in-active; which can also regulate the impedance thereby suppressing resonance but some instability of the circulating current. (Gregory and Williams).

RESEARCH METHODOLOGY

The study presents an investigation and harmonic mitigation in PS, it involves the following:

1. Carrying out literature review of harmonic in PS through recording of frequency and voltage using Owon meter Oscilloscope instrument from the following single-phase generating system systems. Data analysis using reliable assessment tools Matlab R2018a software. Validation of data from various power supply systems with IEEE 519-1992, 5% standard.
2. Analysis and guidelines are necessary tools in determining the problems created by harmonics
3. Study of Useful Guidelines and Standards available in agreement with IEEE- 519 is the main standard in US places limit on voltage/current distortion THD) IEC- 555 for Europe and some areas of South America places limit on voltage distortion IEC- 61000-3- 12 proposed draft places limits on voltage distortion for input current > 16A and < 75A.

Data Collection

Three power sources of single-phase generators were used for data capturing. The Owon meter/Oscilloscope linked to the computer to record the frequencies at each interval. Data collected from the power sources selected for this study for the following ways using the following loads - deep freezer, fridge, water pump, ultrasound scanning machine, plasma TV and the personal computer.

Mathematical Method Using Fourier Analysis

(Huang *et al*, 2001; Churchill and Brown, 1987; Eyenubo, Ubeku and Oniyemofe, 2016; Eyenubo and Ubeku 2018; Eyenubo, 2019).

$$THD = \frac{V_i}{V_1} \quad (1)$$

$$V_1 = \sqrt{V_2^2 + V_3^2 + V_4^2 + \dots + V_n^2}$$

V_1 = rms fundamental voltage

V_n = rms harmonic RMS

It has a null value for a pure sinusoidal voltage/current. THD

Calculating the THD percentage using power equations:

$$M = \frac{\text{Harmonic Magnitude}}{\sqrt{2}} \quad (2)$$

$$\%THD = 100 * \frac{\sqrt{\sum_{i=2}^m M_i}}{M_1} \quad (3)$$

Where

M_i is the magnitude corresponding to the harmonic order i^{th} ; analyzing the Fourier coefficients for determining the amplitude of frequency components given by:

a_n = imaginary (unfiltered signal); a_{na} = imaginary (filtered signal)

b_n = real (unfiltered signal); b_{na} = real (filtered signal)

$$c_n = \text{sqrt} \left\{ (a_n)^2 + (b_n)^2 \right\} \text{ (Unfiltered data);}$$

$$c_{na} = \text{sqrt} \left\{ (a_{na})^2 + (b_{na})^2 \right\} \text{ (filtered data)}$$

Scope_data = s / n harmonic order.

Thus,

$$c_n = \sqrt{(a_n)^2 + (b_n)^2}; \varphi = \tan^{-1} \left(\frac{b_n}{a_n} \right) \quad (4)$$

$$c_{na} = \sqrt{(a_{na})^2 + (b_{na})^2}; \varphi = \tan^{-1} \left(\frac{b_{na}}{a_{na}} \right) \quad (5)$$

The coefficient a_n Fourier cosine coefficients

The coefficient b_n the Fourier sine coefficients

The coefficient c_n the resultant of the squares of a_n and b_n coefficients

Capacitor Bank Calculation: with respect to figure 3, bank of capacitors are quite expensive, it accounts for about 50% - 70%; the vars required for filter circuit at fundamental frequency is the total capacitance needed by the circuit (Kanter and Boonseng, 2002; Eyenubo and Ubeku, 2014):

$$MAVR = 2f\pi CV^2 \times 10^{-6}$$

$$C = \frac{MAVR \times 10^6}{2f\pi V^2} \quad (6)$$

where

C = capacitance (F)

f = frequency (Hz)

V = voltage (volts)

Calculating the filter inductance size: (Soomro and Almelian, 2015): Having fixed value of the inductor/capacitor arm calculating reactor required to produce series resonance at that particular harmonic frequency for the n^{th} harmonic

$$X_L = \frac{1}{n^2} X_C \quad (7)$$

where,

X_L = fundamental reactance of inductor

X_C = fundamental reactance of capacitor

n = harmonic number

$$2 * \pi * f * L = \frac{1}{2 * \pi * f * C}$$

$$L = \frac{1}{\omega_n^2 C} \quad (8)$$

ω_n = normal resonance frequency

The quality factor of coil for the fundamental kVA of reactor is given by:

$$Q = \frac{\omega_n - L}{R} \quad (9)$$

Filter Detuning: (IEC 61000-4-34, Ed 1 2013; Eyenubo, Ubeku E. U and Ofor, 2014): Filter arms are sharply tuned to dominant harmonic frequencies, i.e. 11th, 13th, 15th and higher order harmonics and a damped arm filter for higher harmonics. At resonance filter impedance is purely resistive given by

$$R_n = \frac{1}{\omega x C_n x Q} \quad (10)$$

However, the filter arm may become detuned due to component changes caused by frequency due to ambient temperature, number of capacitances rise with temperature due to power loss. When a filter frequency becomes detuned its impedance become capacitive but if above resonance frequency it becomes inductive:

$$Z = R(1 + j2x\delta xQ) \quad (11)$$

Where

$$\delta = \frac{\omega - \omega_n}{\omega_n}$$

But

$\omega_n = 2\pi \times \text{normal resonant frequency}$

$\omega = 2\pi \times \text{actual frequency}$

The optimum value of Q is:

$$Q = \frac{1 + \cos \phi_a}{2 * \delta * \sin \phi_a}$$

Where

ϕ_a = system impedance angle.

When harmonic current divide between the PS and filter parameters there is an inverse ratio of their impedances, so for increased impedance the filter efficiency will be lowered; thus, the frequency response of resonant filter arm with a typical detuning range δ . Besides lowering the filtering efficiency will the a-c network impedance may produce undesirable resonance phenomena

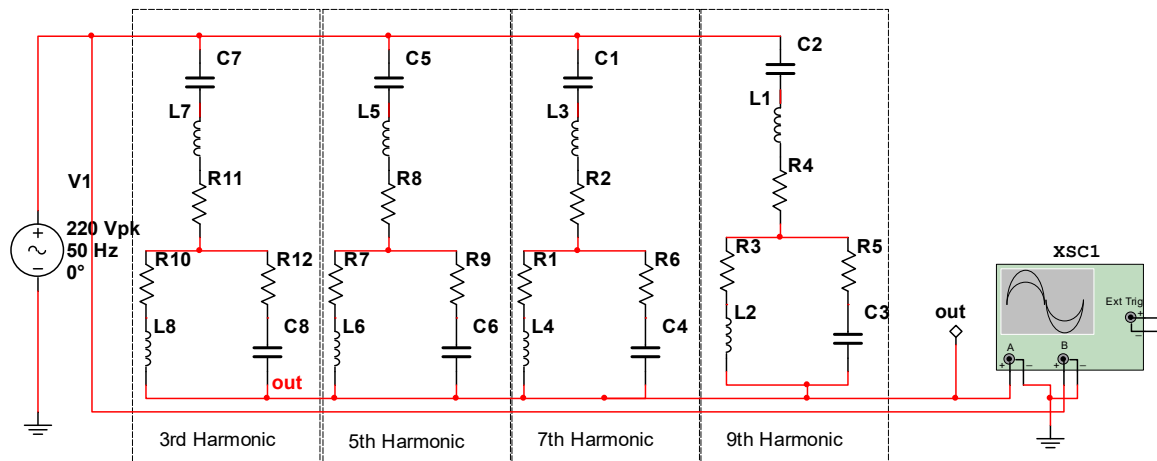


Fig. 3: A developed section of double filter circuit for simulation (Eyenubo and Ubeku, 2018)



The combination of passive element forms the double this reduces the power loss at fundamental frequency. The filter components made of four parallel circuits.

RESULTS AND DISCUSSION

1. Table 1: shows power resource 1, 3.2 kVA at a frequency (F 46.517 Hz), loaded with non-linear loads this results in the output waveform illustrated in Figure 4; while Table 2 is presenting the voltage waveform and harmonic spectrum showed in Figure 5 after simulation. Figure 6 displays the voltage harmonic spectrum 1st - 5th harmonics after simulation. During loading condition, the was $0.0709 = 7.09\%$ then after simulation it was noted to be $0.0161 = 1.61\% V_{THD}$

2. Table 4: illustrate power supply 2, 2.8 kVA at a frequency (F 48.997 Hz), loaded with non-linear loads this results in the output waveform established in Figure 7; while Table 5 is illustrating the voltage waveform and harmonic form displayed in Figure 8 after simulation. Figure 9 exhibits the voltage waveform and harmonic spectrum 1st - 5th after simulation. During loading condition, the V_{THD} was $0.0524 = 5.24\%$ then after simulation it was noted to be $0.0151 = 1.51\%$.

3. Table 7 depicts power basis 3, 4 kVA at a frequency (F 43.804 Hz), loaded with non-linear loads this results in the output presented in Figure 10; while Table 8 is showing the voltage waveform and harmonic range confirmed in Figure 11 after simulation. Figure 12 shows the voltage graph and harmonic spectrum 1st – 9th after simulation. During loading condition, the V_{THD} was $0.0137\% = 1.37\%$ then after simulation it was noted become $0.0137\% = 1.37\%$.

4. Table 10 depicts power basis 4, 40 kVA at a frequency (F 50.024 Hz), is a 3- ϕ have its

operating frequency loaded with non-linear loads this results in the output waveform presented in Figure 10; while Table 11 is showing the voltage shape and harmonic band confirmed in Figure 13 after simulation. Figure 14 shows the voltage function and harmonic range 1st and 3rd after simulation. During loading condition, the V_{THD} was $0.01321 = 1.321\%$, less than the expected IEEE standard of 5% after simulation.

5. Table 13 power source 5, 250 kVA at a frequency (F 51.174 Hz), is a 3- ϕ have its operating frequency loaded with non-linear loads this results in the output waveform presented in Figure 10; while Table 14 is showing the voltage shape and harmonic band confirmed in Figure 16 after simulation. Figure 18 shows the voltage function and harmonic range 1st and 3rd after simulation. During loading condition, the V_{THD} was $0.0119\% = 1.19\%$, less than the expected IEEE standard of 5% after simulation.

6. Table 16 is utility, PHCN at a frequency (F 50.568 Hz), is a 3- ϕ have its operating frequency loaded with non-linear loads this results in the output waveform presented in Figure 19; while Table 17 is showing the voltage shape and harmonic band confirmed in Figure 20 after simulation. Figure 21 shows the voltage function and harmonic range 1st and 3rd after simulation. During loading condition, the V_{THD} was $0.0079 = 0.79\%$, less than the expected IEEE standard of 5% after simulation.

It can be observed that the frequencies 46.517 Hz, 48.997 Hz and 43.804 Hz single-phase-generators their frequencies measured during the procedure are less than the working frequency of 50 Hz as contained on their nameplates, while the 3- ϕ power sources and PHCN are 50.024 Hz, 51.174 Hz and 50.568 Hz generator with its normal rated frequency.



Table 1: Power source 1, (3.2 kVA), F (46.517), before loading

		Voltage	Voltage	Magnitude	Phase angle	
Harm nos	time	a _{na} %	b _{na} %	C _{an} , %	(rad)	scope_data
1	0	1980000	1100000	2265038.63	0.50226998	7400000
2	0.01	0	0	0	0	7200000
3	0.02	440000	440000	622253.967	0.852485484	7200000
4	0.03	0	0	0	0	7000000
5	0.04	220000	220000	311126.984	1.053185595	7400000

Table 2: Before filtering

		(Voltage)	(Voltage)	Magnitude	Phase angle	
harm no	time (sec)	a _{na}	b _{na}	(Voltage)	after filtering (rad)	scope_data
1	0	2006455.84	1102053.10	2289188.95	0.585700693	7400000
2	0.01	0.00	0.00	0.00	0	7200000
3	0.02	480310.35	549501.50	729828.71	0.907858132	7200000
4	0.03	0.00	0.00	0.00	0	7000000
5	0.04	237063.57	416343.92	479104.79	1.089096048	7400000

Table 3: After filtering

		(Voltage)	(Voltage)	Magnitude	Phase angle	
harm no	time (sec)	a _{na}	b _{na}	(Voltage)	after filtering (rad)	scope_data
1	0	158024.82	337320.00	372500.51	1.143643124	7400000
2	0.01	0.00	0.00	0.00	0	7200000
3	0.02	125157.15	43217.65	132408.76	0.481868072	7200000
4	0.03	0.00	0.00	0.00	0	7400000
5	0.04	97857.88	38602.01	105196.38	0.427845385	7200000

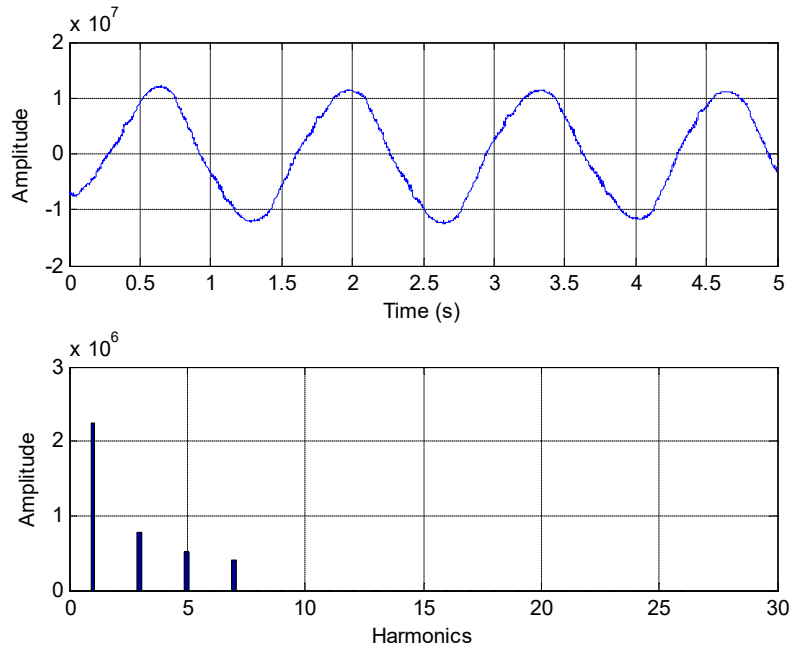


Fig. 4: Generator 1, waveform without load with harmonic spectrum showing the fundamental, 3rd, 5th and 7th harmonics.

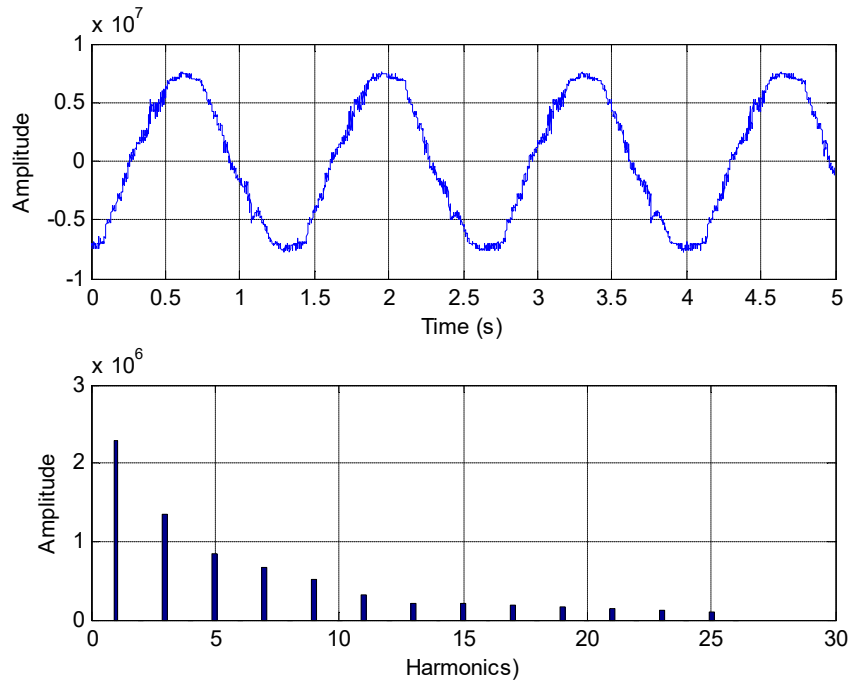


Fig. 5: Generator 1 when loaded, showing the waveform and harmonic spectrum up to 25th harmonics

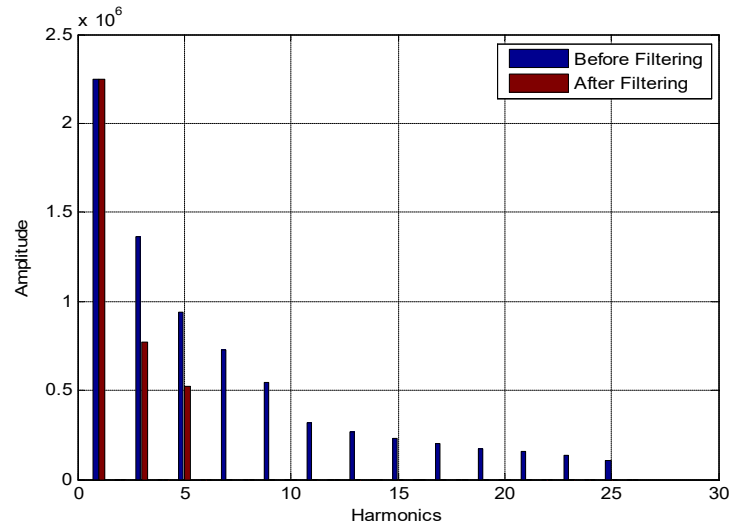


Fig.6: Generator 1 combined effect of the harmonic spectrum before and after filtering showing 1st – 5th harmonics

Table 4: Generator 2, (2.8kVA), F (48.997), before loading

		Voltage	Voltage	Magnitude	Phaseangle	
		a _{na} %	b _{na} %	Voltage	before loading	
Harm nos	time	a _{na} %	b _{na} %	C _{an} , %	(rad)	scope_data
1	0	220000	2.80E-10	220000	0.2246245	1200000
2	0.01	0	0	0	0	1200000
3	0.02	2.04E-10	2.24E-10	3.03E-10	0.276732	1200000
4	0.03	0	0	0	0	1200000
5	0.04	1.91E-10	1.06E-10	2.18E-10	0.2951422	1400000

Table 5: Before filtering

		(Voltage)	(Voltage)	Magnitude	Phaseangle	
harm	time	(Voltage)	(Voltage)	(Voltage)	Before filtering	
no	(sec)	a _{na} , (%)	b _{na} , (%)	C _{an} , %	(rad)	scope_data
1	0	3651638.73	321872.47	3665796.96	0.110149879	1200000
2	0.01	0.00	0.00	0.00	0	1200000
3	0.02	270281.23	61753.92	277246.26	0.312852443	1200000
4	0.03	0.00	0.00	0.00	0	1200000
5	0.04	138900.06	39450.32	144393.75	0.583467323	1200000

Table 6: After filtering

		(Voltage)	(Voltage)	Magnitude	Phaseangle	
harm	time	(Voltage)	(Voltage)	(Voltage)	after filtering	
no	(sec)	a _{na}	b _{na}	C _{an} , %	(rad)	scope_data
1	0	1.23E-10	9.69E-11	1.57E-10	0.283358	1200000
2	0.01	0	0	0	0	1400000
3	0.02	1.01E-10	9.24E-11	1.37E-10	0.2936607	1400000
4	0.03	0	0	0	0	1400000
5	0.04	9.28E-11	8.65E-11	1.27E-10	0.3095107	1400000

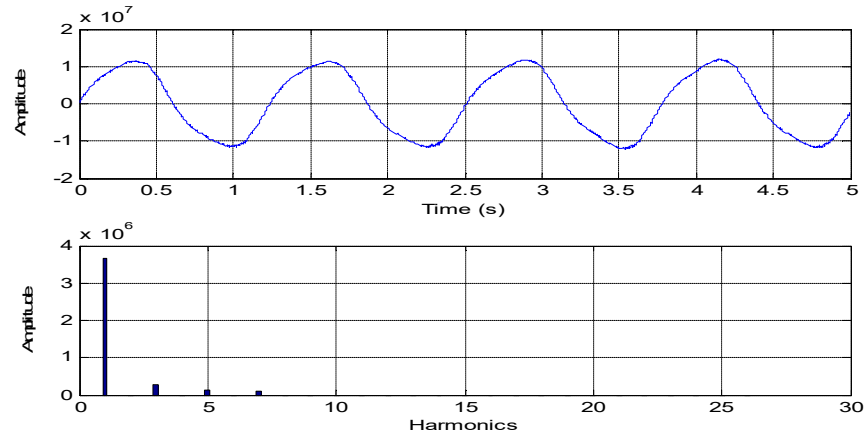


Fig. 7: Generator 2, waveform without load with harmonic spectrum showing the fundamental, 3rd, 5th and 7th harmonics.

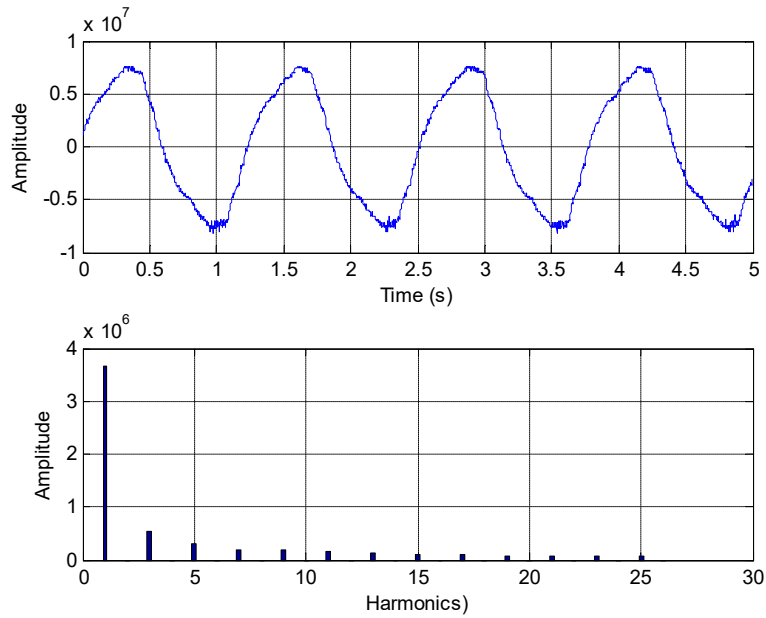


Fig. 8: Generator 2 when loaded, showing the waveform and harmonic spectrum showing up to 25th harmonics

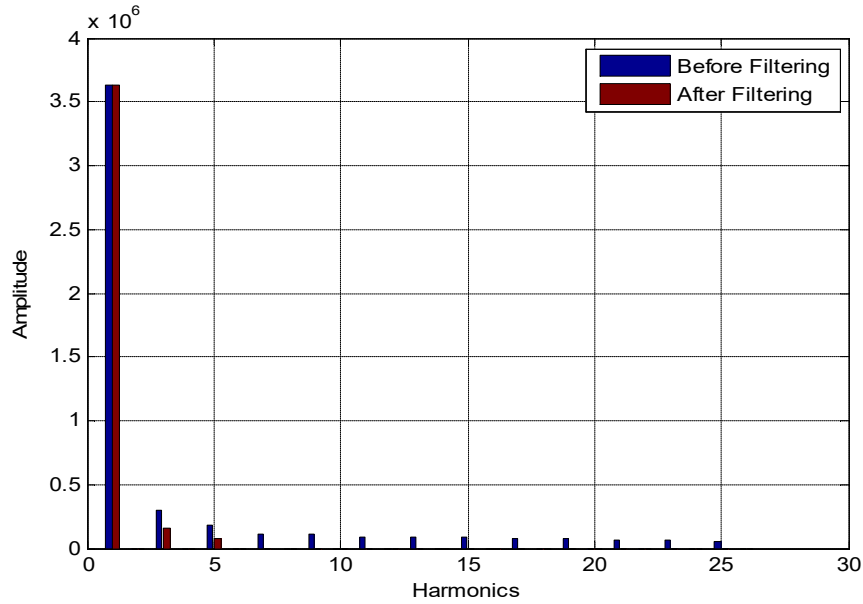


Fig.9: Generator the combined effect of the harmonic spectrum before and after filtering showing 1st – 5th harmonics

Table 7: Generator 3, (3.5 kVA), F (43.804), before loading

				Magnitude	Phaseangle	
		Voltage	Voltage	Voltage	before loading	
Harm nos	time	a _{na} %	b _{na} %	C _{an} , %	(rad)	scope_data
1	0	1760000	1100000	2075475.85	0.5419856	6800000
2	0.01	0	0	0	0	6600000
3	0.02	660000	220000	695701.085	0.4051469	6600000
4	0.03	0	0	0	0	6600000
5	0.04	440000	8.68E-11	440000	0.4193511	6600000

Table 8: Before filtering

				Magnitude	Phaseangle	
harm	time	(Voltage)	(Voltage)	(Voltage)	before filtering	
no	(sec)	a _{na} , (%)	b _{na} , (%)	C _{an} , %	(rad)	scope_data
1	0	2598777.76	1150992.83	2842257.97	0.41693202	6800000
2	0.01	0.00	0.00	0.00	0	6600000
3	0.02	828384.15	328301.65	891068.05	0.37732623	6600000
4	0.03	0.00	0.00	0.00	0	6600000
5	0.04	470467.69	264435.49	539690.63	0.51206229	6600000

Table 9: After filtering

harm no	time (sec)	(Voltage) $a_{na}, (\%)$	(Voltage) $b_{na}, (\%)$	Magnitude (Voltage) $C_{an}, \%$	Phaseangle before filtering (rad)	scope_data
1	0	220000	6.94E-11	220000	0.4576111	6600000
2	0.01	0	0	0	0	6600000
3	0.02	1.27E-10	6.29E-11	1.41E-10	0.5255412	6600000
4	0.03	0	0	0	0	6600000
5	0.04	8.63E-11	6.21E-11	1.06E-10	0.5771808	6600000

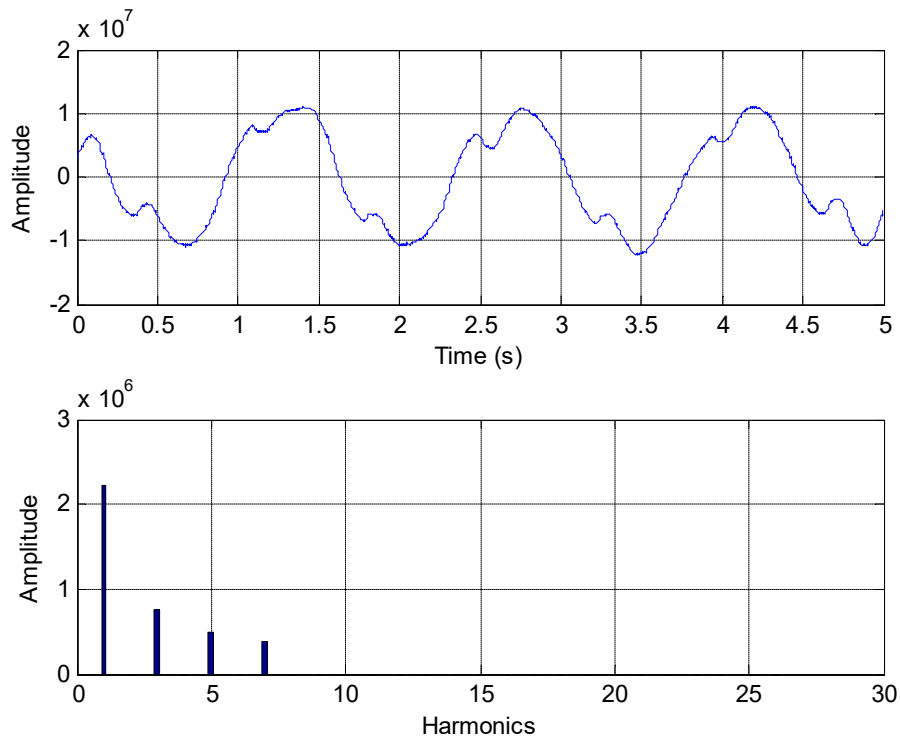


Fig. 10: Generator 3, waveform without load with harmonic spectrum showing the fundamental, 3rd, 5th and 7th harmonics.

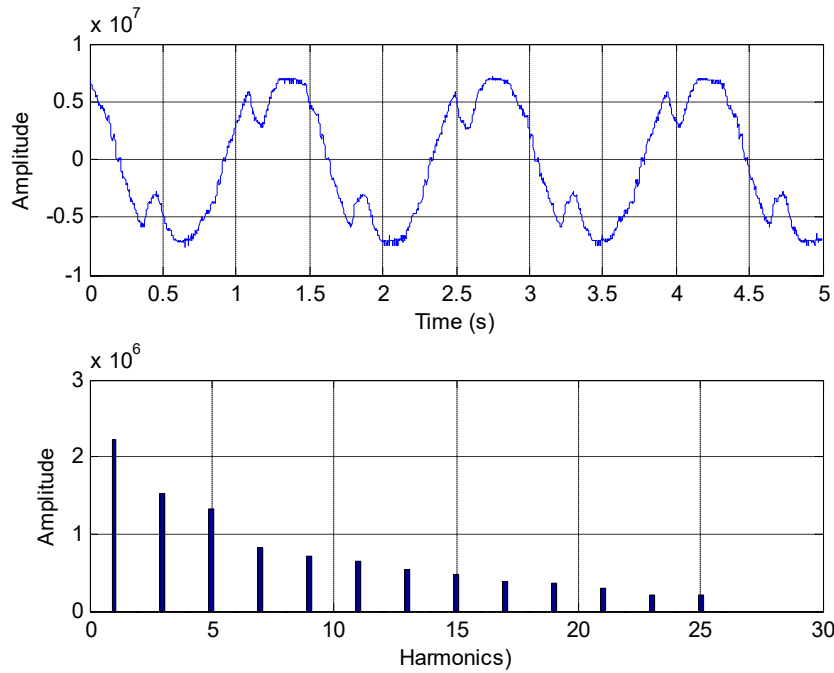


Fig. 11: Generator 3 when loaded, showing the waveform and harmonic spectrum showing up to 25th harmonics

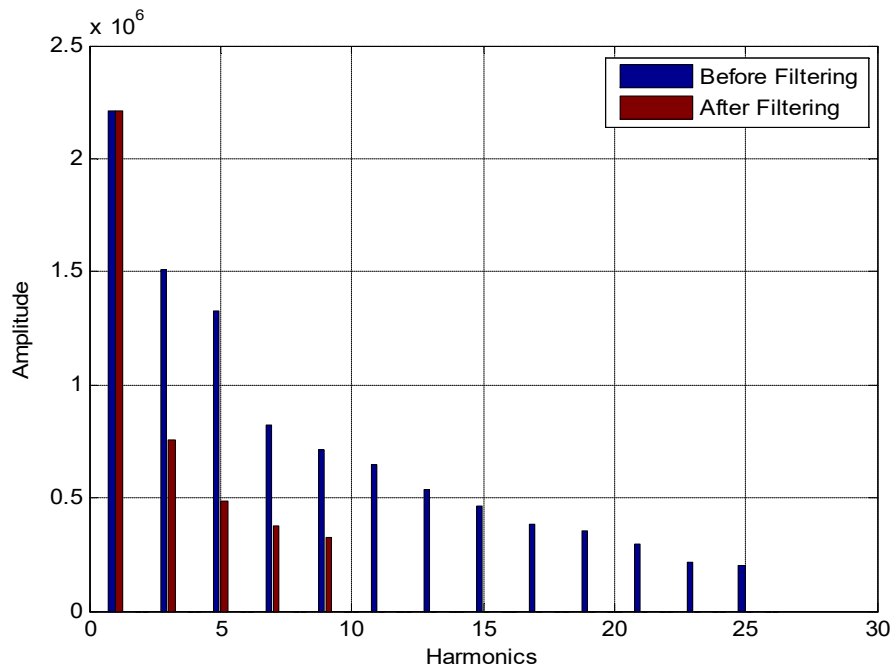


Fig.12: Generator 3 the combined effect of the harmonic spectrum before and after filtering showing 1st – 9th harmonics



Table 10: Generator 4, (40 kVA), F (50.024), before loading

harm no	time (sec)	(Voltage) a_{na}	(Voltage) b_{na}	Magnitude (Voltage) $C_{an}, \%$	Phase angle after filtering (rad)	scope_data
1	0	155254.82	48308.39	162596.93	0.275908256	-5000000
2	0.01	0.00	0.00	0.00	0	-4600000
3	0.02	111956.02	34411.50	117125.16	0.294518359	-4600000
4	0.03	0.00	0.00	0.00	0	-4600000
5	0.04	85318.43	24603.64	88795.12	0.258672296	-4600000

Table 11: Before filtering

harm no	time (sec)	(Voltage) $a_{na}, (\%)$	(Voltage) $b_{na}, (\%)$	Magnitude (Voltage) $C_{an}, \%$	Phaseangle before filtering (rad)	scope_data
1	0	3874139.74	104344.36	3875544.67	0.026927046	-4200000
2	0.01	0.00	0.00	0.00	0	-4200000
3	0.02	259685.47	50715.60	264591.41	0.19286865	-4200000
4	0.03	0.00	0.00	0.00	0	-4000000
5	0.04	148484.03	45335.49	155250.81	0.296332464	-4200000

Table 12: After filtering

Harm nos	time	Voltage $a_{na}\%$	Voltage $b_{na}\%$	Magnitude Voltage $C_{an} \%$	Phase angle before loading (rad)	scope_data
1	0	40597.12	13701.98	42847.06	0.328333381	-4200000
2	0.01	0.00	0.00	0.00	0	-4200000
3	0.02	38723.71	12040.97	40552.57	0.333956673	-4400000
4	0.03	0.00	0.00	0.00	0	-4200000
5	0.04	36756.83	11141.34	38408.25	0.308394776	-4200000

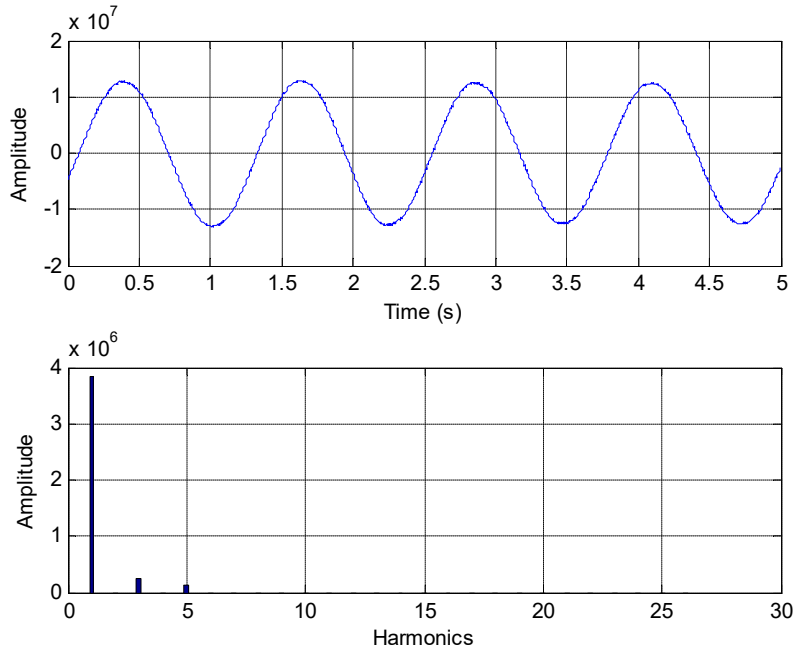


Fig. 13: Generator 4 A, waveform without load with harmonic spectrum showing the fundamental, 3rd and 5th harmonics.

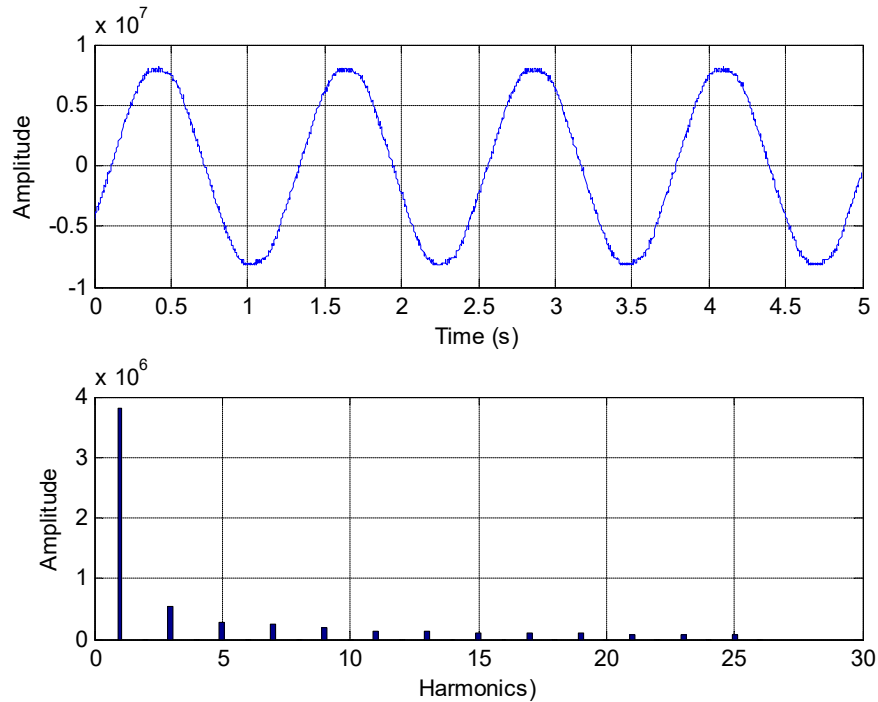


Fig. 14: Generator 4 A when loaded, showing the waveform and harmonic spectrum showing up to 25th harmonics

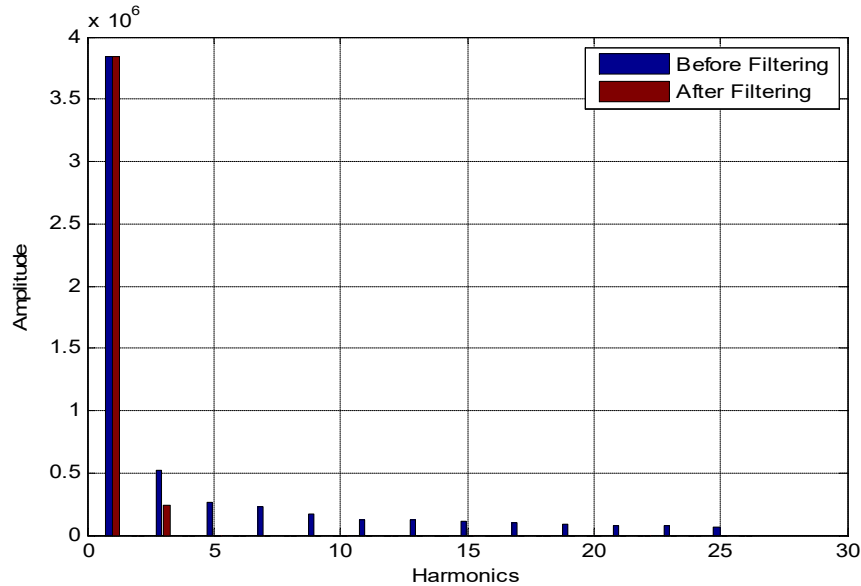


Fig. 15: Generator 4 the combined effect of the harmonic spectrum before and after filtering showing 1st & 3rd harmonics

Table 13: Generator 5, (250 kVA), F (51.174 Hz), before loading

				Magnitude	Phase angle	
		Voltage	Voltage	Voltage	before loading	
Harm nos	time	a _{na} , %	b _{na} , %	C _{an} , %	(rad)	scope_data
1	0	41815.1241	7.62E-11	1.23E-10	0.320735166	-4000000
2	0.24	0	0	0	0	-3800000
3	0.24	39811.8698	7.58E-11	1.19E-10	0.284664505	-3800000
4	0.24	0	0	0	0	-3800000
5	0.24	36024.7928	7.17E-11	1.13E-10	0.305964982	-3800000

Table 14: Before filtering

				Magnitude	Phase angle	
		Voltage	Voltage	Voltage	When loading	
Harm nos	time	a _{na} , %	b _{na} , %	C _{an} , %	(rad)	scope_data
1	0	533887.208	1.65E-11	440000	0.013485404	-340000
2	0.24	0	0	0	0	-320000
3	0.24	27498.8005	1.37E-11	2.59E-11	0.233597685	-340000
4	0.24	0	0	0	0	-300000
5	0.24	18178.1815	1.35E-11	2.02E-11	0.229406783	-320000

Table 15: After filtering

		Voltage	Voltage	Magnitude	Phaseangle	
Harm nos	time	$a_{na}, \%$	$b_{na}, \%$	$C_{an}, \%$	after filtering (rad)	scope_data
1	0	4421.83	9.90E-12	1.35E-11	0.297057451	-260000
2	0.24	0	0	0	0	-260000
3	0.24	4027.8791	8.84E-12	1.28E-11	0.25980734	-260000
4	0.24	0	0	0	0	-260000
5	0.24	3480.69564	7.20E-12	1.10E-11	0.268589874	-260000

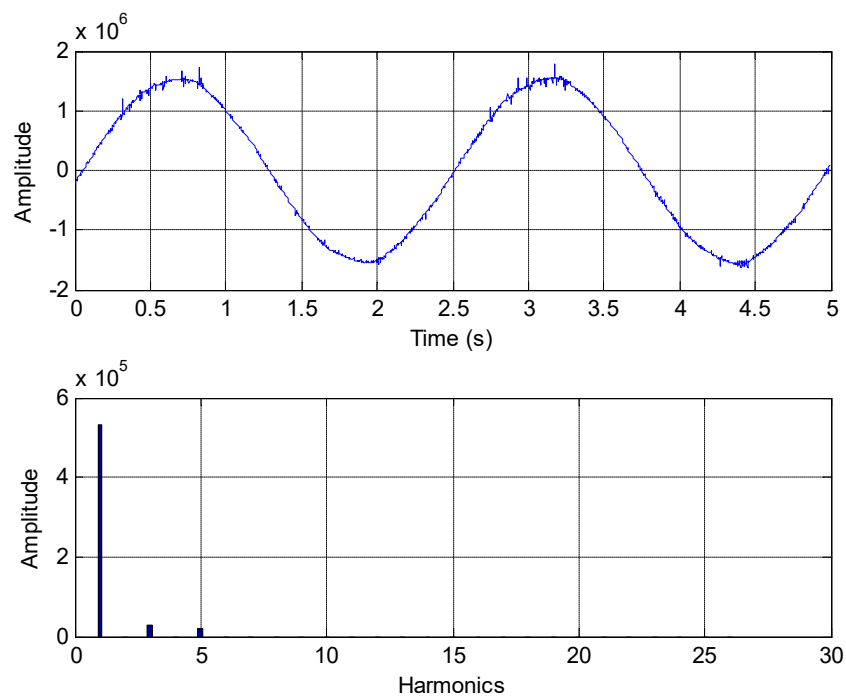


Fig. 16: Generator 5, waveform without load with harmonic spectrum showing the fundamental, 3rd and 5th harmonics.

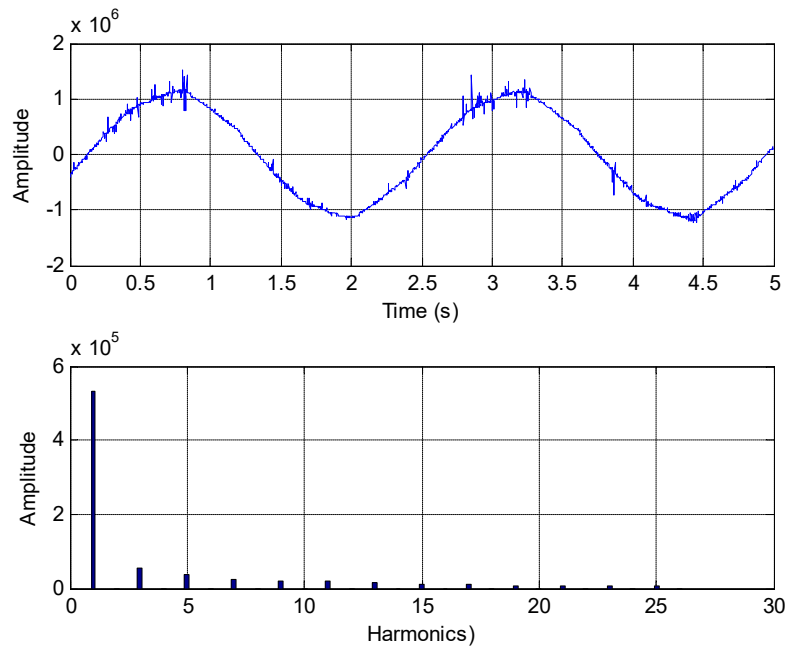


Fig. 17: Generator when loaded, showing the waveform and harmonic spectrum showing up to 25th harmonics

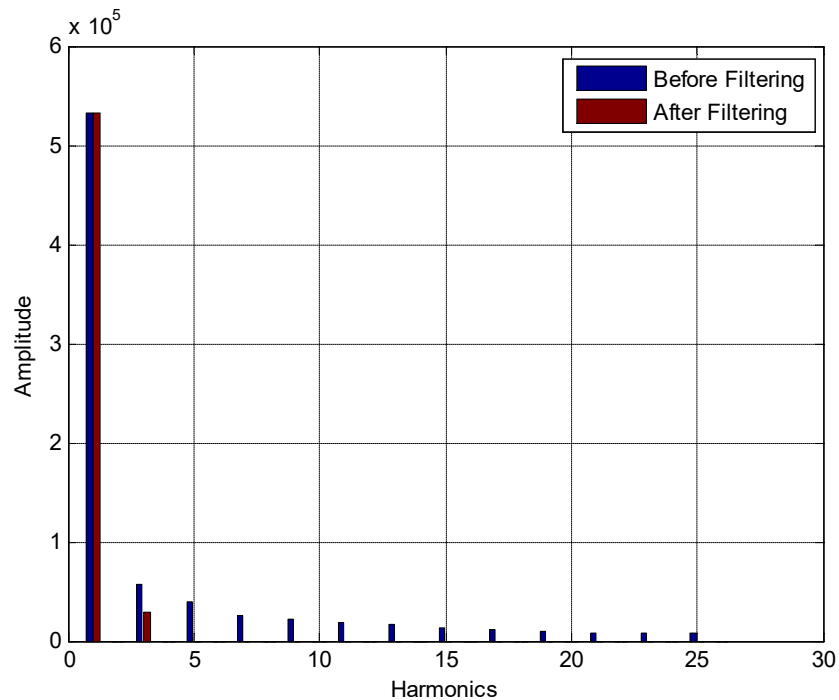


Fig.18: Combined effect of the harmonic spectrum before and after filtering showing 1st & 3rd harmonics



Table 16: Power source 6, Public utility, (F 50.568 Hz), Before loading

				Magnitude	Phase angle	
harm	time	(Voltage)	(Voltage)	(Voltage)	after filtering	
no	(sec)	a _{na}	b _{na}	C _{an} , %	(rad)	scope_data
1	0	45447.53	12465.34	47126.03	0.267696633	-2600000
2	0.01	0.00	0.00	0.00	0	-2600000
3	0.02	31350.02	8876.77	32582.53	0.275927747	-2400000
4	0.03	0.00	0.00	0.00	0	-2400000
5	0.04	25146.31	8389.00	26508.72	0.321997231	-2400000

Table 17: Before filtering

				Magnitude	Phaseangle	
harm	time	(Voltage)	(Voltage)	(Voltage)	after filtering	
no	(sec)	a _{na}	b _{na}	C _{an} , %	(rad)	scope_data
1	0	4651081.01	60333.22	4651472.31	0.012674155	-3400000
2	0.01	0.00	0.00	0.00	0	-3400000
3	0.02	148488.56	50794.12	156935.96	0.312607789	-3400000
4	0.03	0.00	0.00	0.00	0	-3200000
5	0.04	76272.28	43109.33	87612.07	0.506285205	-3400000

Table 18: After filtering

				Magnitude	Phase angle	
harm	time	(Voltage)	(Voltage)	(Voltage)	after filtering	
no	(sec)	a _{na}	b _{na}	C _{an} , %	(rad)	scope_data
1	0	19043.99	8265.22	20760.24	0.337886837	-2600000
2	0.01	0.00	0.00	0.00	0	-2400000
3	0.02	18224.13	5553.34	19051.47	0.286108052	-2400000
4	0.03	0.00	0.00	0.00	0	-2200000
5	0.04	17151.94	4647.93	17770.55	0.269737441	-2200000

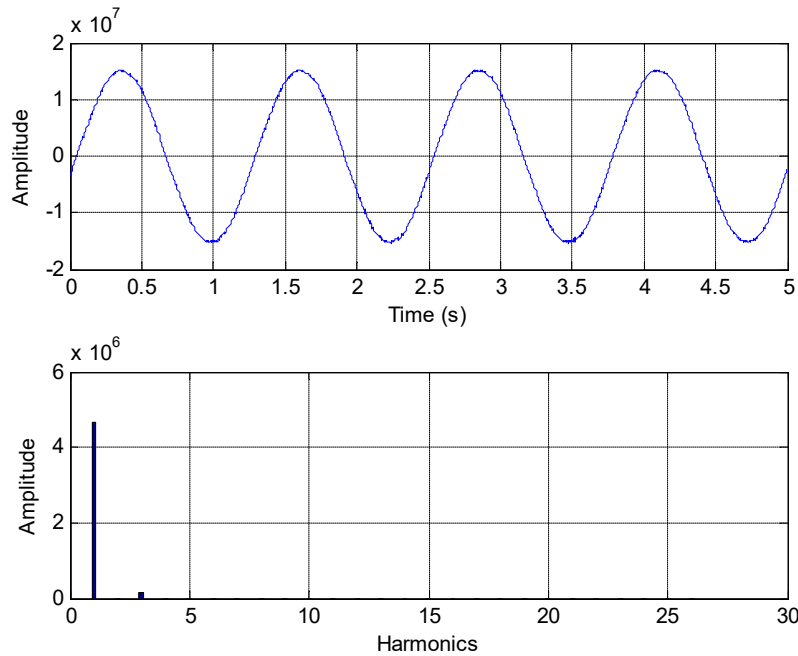


Fig. 19: Public utility, waveform without load with harmonic spectrum showing the fundamental and 3rd harmonics.

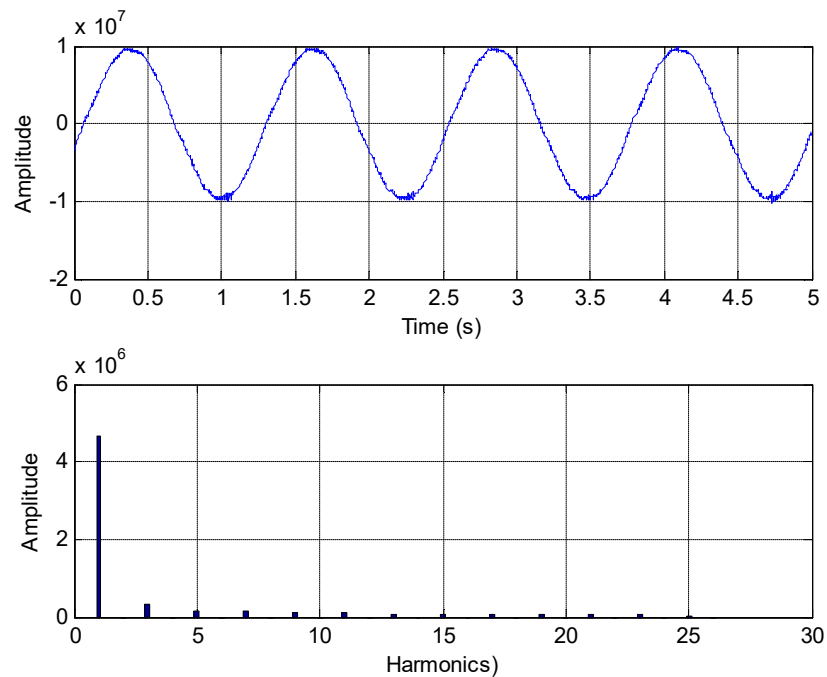


Fig. 20: Public utility, when loaded, showing the waveform and harmonic spectrum showing up to 25th harmonics

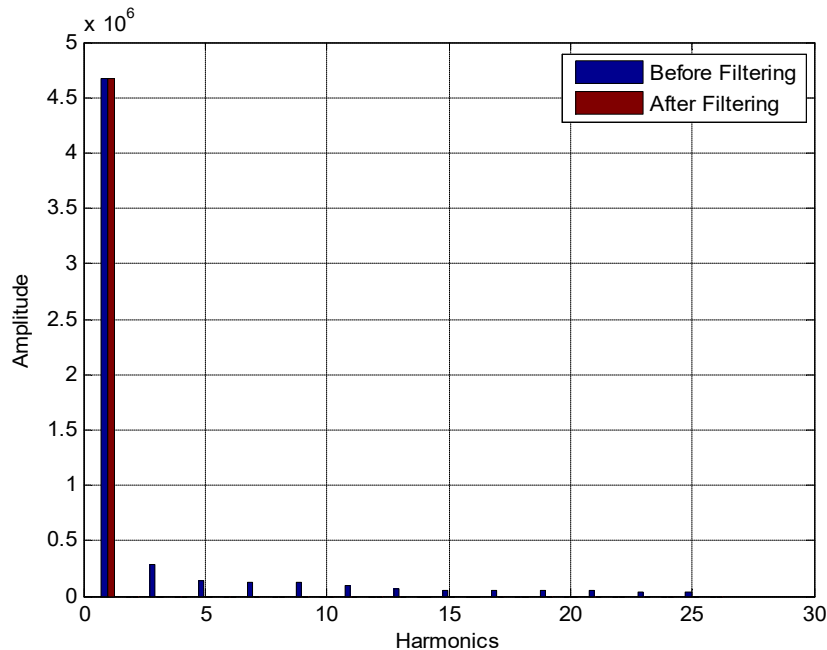


Fig.21: Combined effect of the harmonic spectrum before and after filtering showing 1st harmonic only resulting from filtration

CONCLUSION

The work reviews power quality drawbacks that trigger power structure interruption in electrical set-up. The viable means of power supply handled in review of harmonics workings data, waveforms and the phase angles are examined. The controlling benchmarks of IEEE 519-92 for establishing the voltage total harmonic distortion (V_{THD}) for the different power sources used, their function performances are also depicted in the work. The patterning simulations methods of harmonics utilizing a low-pass passive shunt filter for the various power bases were investigated using Matlab. The results gotten are verified and found suitable when evaluated with the IEEE 519-92.

Drawbacks with non-linear loads causes increase with modern office buildings having facilities that comprised of microprocessor-based apparatus. New challenge for design engineers since there is usage of electronic paraphernalia that make up major appliances used in buildings. The non-linear loads comprise the following lighting, personal computers or speed control units for motors etc. Identification of

the causes and extenuation of harmonics can assist in preventing harmonic interrelated challenges at the design period decrease the likelihood of undesired outcomes occurring.

Electronic filtering was used for the diminution harmonics; in some instances, capacitors can be installed in the filter bank for harmonic filtering know-hows. Special significance must be offered to the presentation of filters used in harmonic improvement.

CONTRIBUTION TO KNOWLEDGE

An algorithm for calculating the magnitude and the Phase angle of the waveform was achieved using the MatlabR2018a software. The contributions from this work are as follows: (1). Data base for harmonic content of commonly portable generator used in Nigeria for analysis was established, (2). The performance characteristic index V_{THD} for the investigated portable generator that will inform customers' decisions on the purchase and use of these systems in Nigerian have been obtained. (3). An electronic filter to reduce harmonic content in commonly used portable generator in Nigeria



have been designed was achieved using the Matlab software.

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