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ANALYSIS AND SIMULATION OF HARMONICS FOR VARIOUS RESIDENTIAL LOADS USING SIMULINK

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ABSTRACT

Harmonics are the by-products of modern electronic devices i.e. nonlinear loads, this harmonics by drawing current in abrupt short pulses, rather than in a smooth sinusoidal manner. Any distribution circuit feeding nonlinear loads will contain some degree of harmonic frequencies in multiples. Due to the rapidly increasing number of non-linear loads in distribution systems, the harmonic distortion of the current and voltage increases. Examples of non-linear loads are personal computer, television set (TV), fluorescent tube with electronic ballast, compact fluorescent lamp, battery charger, uninterrupted power supply (UPS) and any other equipment powered by switched-mode power supply (SMPS) unit. As the number of harmonics-producing loads in residences has increased over the years, it has become increasingly necessary to address their effects on the distribution system. Power Quality of distribution networks is severely affected due to the flow of these generated harmonics. Harmonic currents generated by nonlinear loads can cause problems on the power system. These harmonics can cause excessive heat in many appliances, and hence reduce the life span of the distribution transformer supplying such loads, protecting equipments in power system. It can also increase power consumption and reduce system efficiency. It also lowers the system power factor. In this paper presents the results of a SIMULINK of harmonic distortion caused by different non linear home appliances and analysis of percentage total harmonic distortion which is found between ranges of 50 to greater than 200.

KEYWORDS: %THD, Non linear load, Matlab-Simulink, FFT tool, Power quality.

INTRODUCTION

Electric utilities are concerned about decreasing power quality and its potential impacts on the grid. As residential customers add more electronics to the home and replace existing mechanical switching equipments by electronic switching equipments, there is a concern that local grid stability could be compromised. In an effort to determine how residential power quality (as measured by power factor and total harmonic distortion) is changing over time, Advanced Energy proposed to survey the current research on residential power quality and measure actual power quality for two residential homes of different ages under different load conditions[6][1]. Harmonic distortion is the distortion of either the voltage or current waveform with the addition of frequencies other than the fundamental 50 Hertz frequency. Harmonics are generated by non-linear loads such as computers, battery charging systems, variable frequency drives and other electronic equipment. Total harmonic distortion indicates the combined impact of all harmonics upon the fundamental waveform. Since utilities provide a 50 Hertz voltage source of electricity, the voltage waveform supplied is fairly constant. Various loads on the grid can, however, impact the current waveform. The primary concern in residential locations are the third harmonic and other triplens (3rd, 9th, 15th, etc.) harmonics. Each harmonic exists at a multiple of the fundamental frequency. Many of these harmonics can cancel each other out. Triplen harmonics, however, are additive and will combine with each other, as well as the fundamental frequency, to have more deteriorating impacts.

INTEGRATED SIMULINK MODEL OF RESIDENIAL LOAD

The residential distribution network and the loads were modelled in MATLAB-Simulink. The model consist three phase residential load at 0.4 kV line voltages then it split into single phase using neutral. The composed residential network and loads connected to distribution network. For the purpose of assessing the effect of adding loads to corresponding harmonic emissions the current distortions at residential load 0.4 kV feeder and voltage distortions at distribution network substation low-voltage busbars are observed. The number and configuration of residential loads are changed for different scenarios.

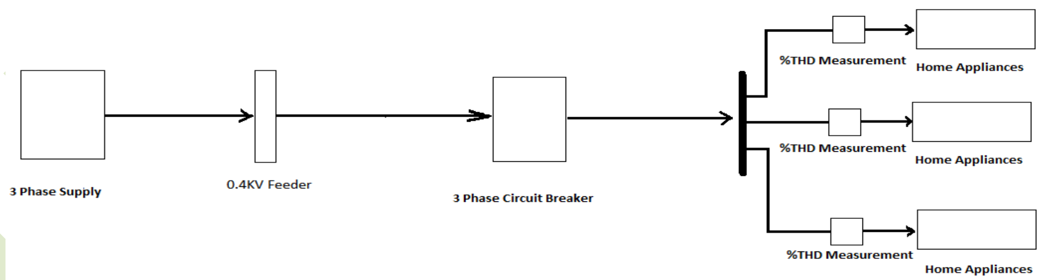

Figure 1: Block Diagram Residential load Harmonic Analysis

Each phase connected to Home1, Home2 and Home3 of Phase A, Phase B and Phase C respectively with the neutral and get voltage 230V. Below tabular data collected from FFT Tool of Simulink for Home 1, Home 2, and Home 3.

Table5: THD% of Voltage and current at Residential Load.

THD	Home 1	Home2	Home3
Current (%THD)	37.27%	22.84%	23%
Voltage(%THD)	5.06%	2.42%	2.29%

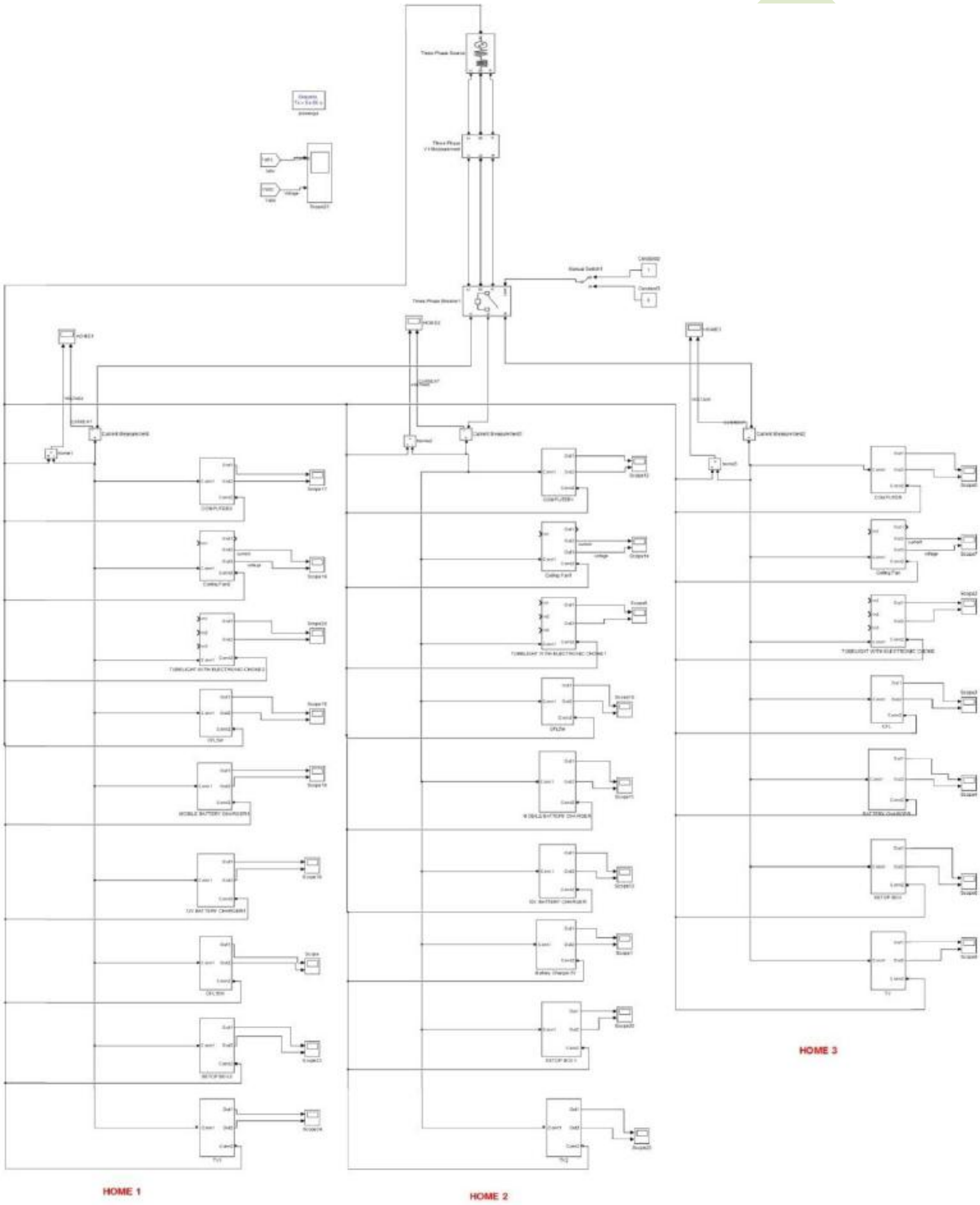

Figure 2: Schematic composed model residential loads in Simulink

Table 6: %THD of Voltage and current at 0.4KV Feeder

THD	$\%THD_A$	$\%THD_B$	$\%THD_C$
Current	22.84	22.73	33.9
Voltage	2.29	2.42	5.06

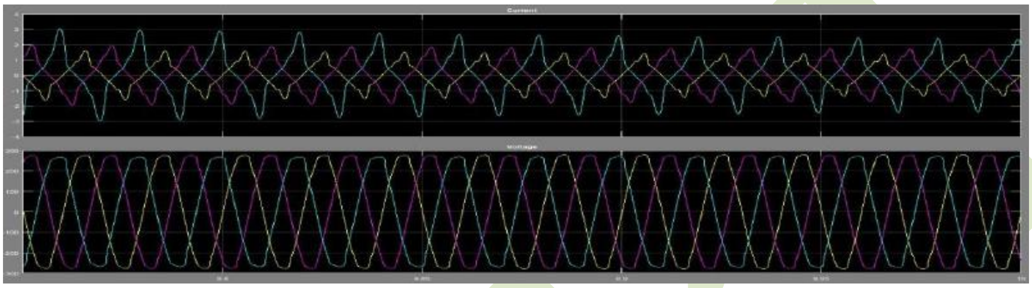

Figure 2:.Simulated waveform of 0.4KV Feeder

IEEE Standards

International Electro-technical Commission (IEC) is the widely recognized organization as the curator of electric power quality standards. IEC has introduced a series of standards, to deal with power quality issues. Integer and inter harmonics are included in IEC61000 series as one of conducted low-frequency electro-magnetic phenomena. The series also provides internationally accepted information for the control of power system harmonic (and inter-harmonic) distortion. The IEEE 519-1992 standard is a widespread alternative to the IEC series (I_{sc}- short circuit current).

Table 7: IEEE 519-1992 standards

I_{sc} /I_l	<11	11 ≤h< 17	≤h< 23	≤h< 35	≤h	TDD
<20	4.0	2.0	1.5	0.6	0.3	5.0
20<50	7.0	3.5	2.5	1.0	0.5	8.0
50<100	10.0	4.5	4.0	1.5	0.7	12.0
100<1000	12.0	5.5	5.0	2.0	1.0	15.0
>1000	15.0	7.0	6.0	2.5	1.4	20.0

Total harmonic distortion (THD) Calculation

$$\mathrm{THD_I} = \frac{1}{\mathrm{i_1}}\sqrt{\mathrm{i_{rms}^2} - \mathrm{i_1^2}} \times 100\% \quad (1)$$

$$\mathrm{THD_V} = \frac{1}{\mathrm{v_1}}\sqrt{\mathrm{v_{rms}^2} - \mathrm{v_1^2}} \times 100\% \quad (2)$$

$$\mathrm{THD_{Total}} = \sqrt{\mathrm{THD^2}_1 + \mathrm{THD^2}_2 + \mathrm{THD^2}_0} \times 100\% \quad (3)$$

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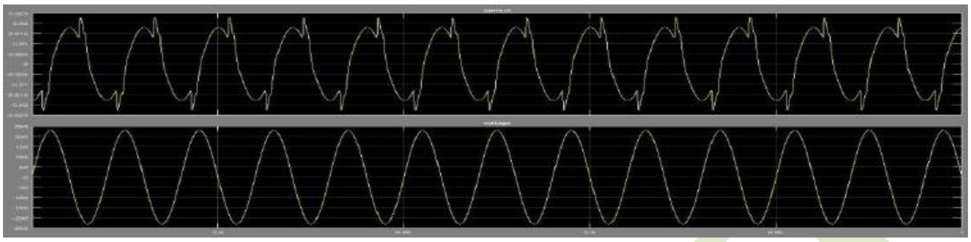
HARMONICS ANALYSIS OF INDIVIDUAL HOME APPLIANCES

Ceiling fan with electronic Regulator



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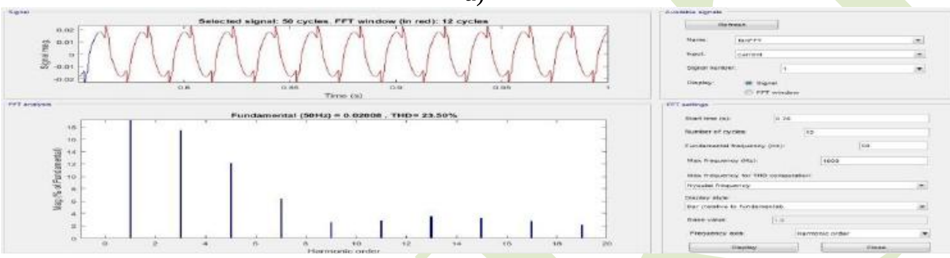

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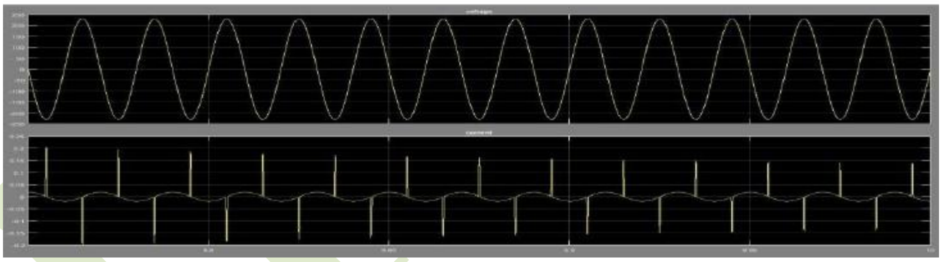
Figure 3: Simulated a) waveform b) FFT of Ceiling fan with electronic regulator

Compact Fluorescent Lamp (11W)



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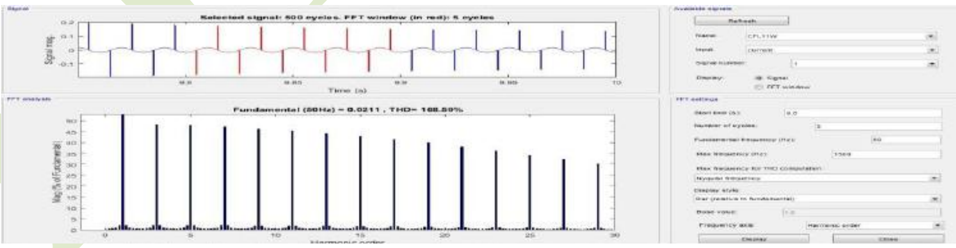

(b)

Figure 4: Simulated a) waveform b) FFT of CFL

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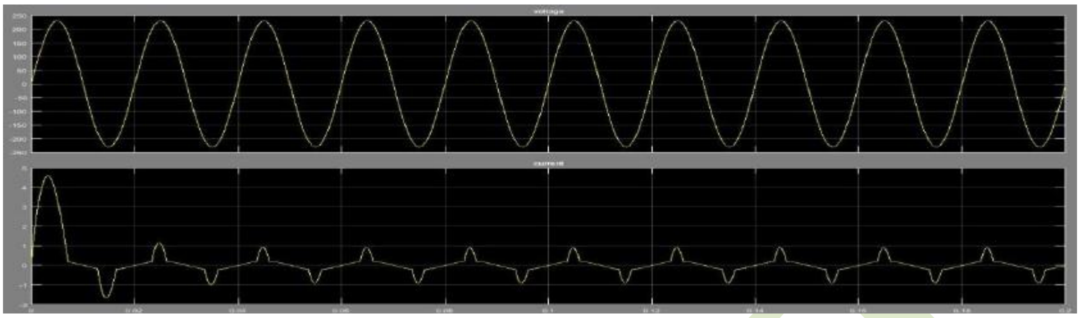
Computer (SMPS)



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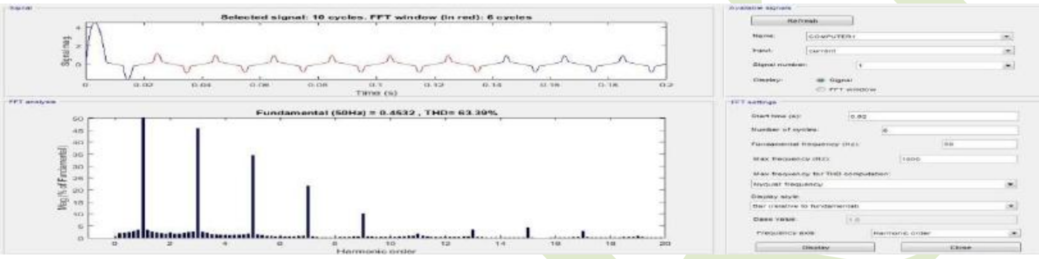
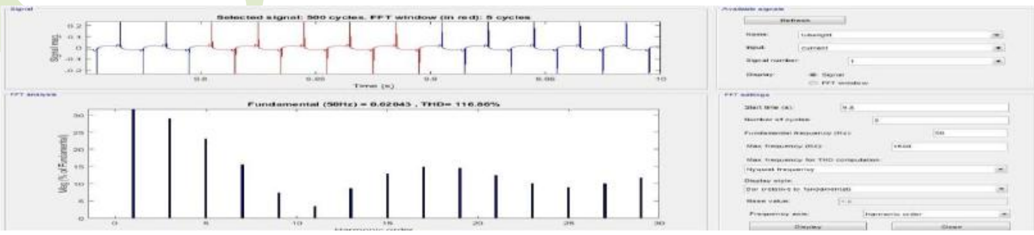


b)

Figure 5: Simulated a) waveform b) FFT waveform of Computer

Tube Light With Electronic Choke

a)



b)

Figure 6: simulated a) waveform b) FFT waveform of Tube light with electronic choke

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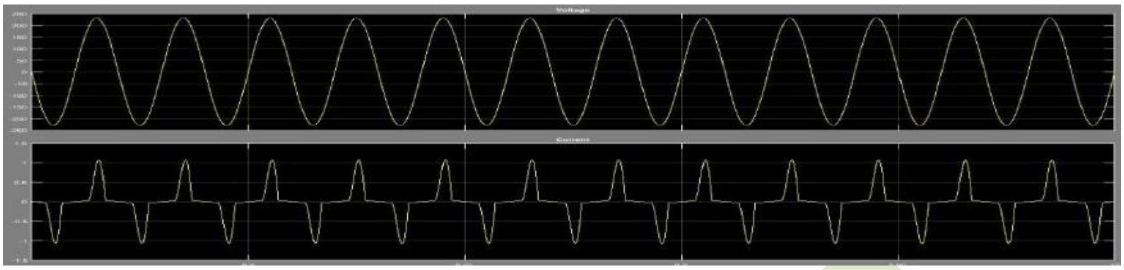
Battery Charger 24V (Laptop Charger)



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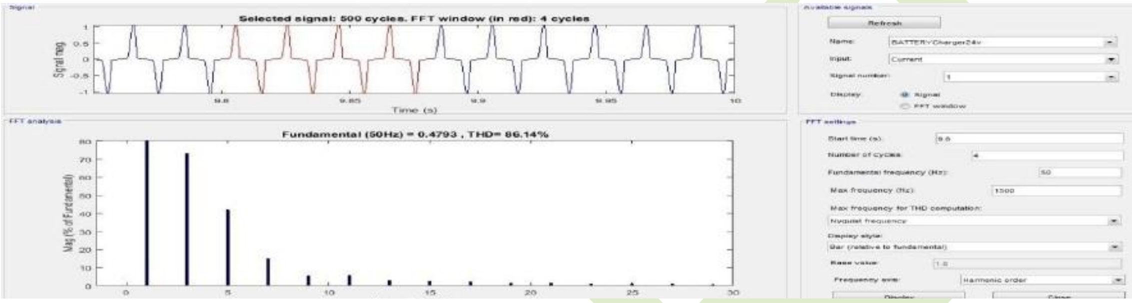
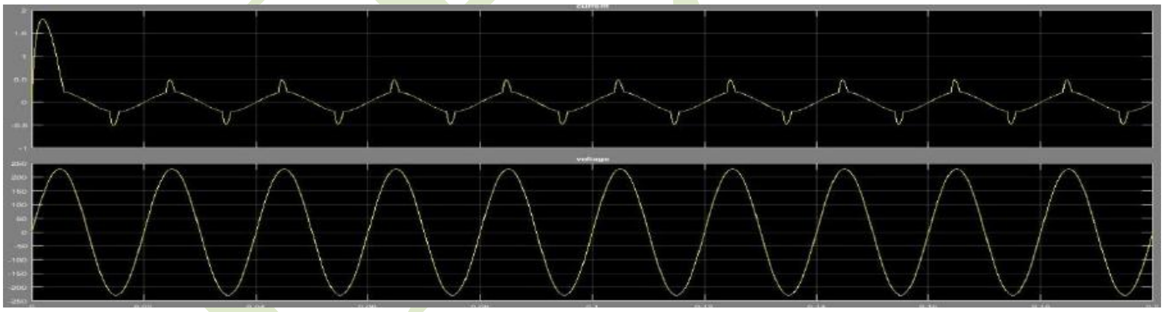


b)

Figure 7: Simulated a) waveform b) FFT waveform of Battery charger 24V

Setop Box (SMPS)



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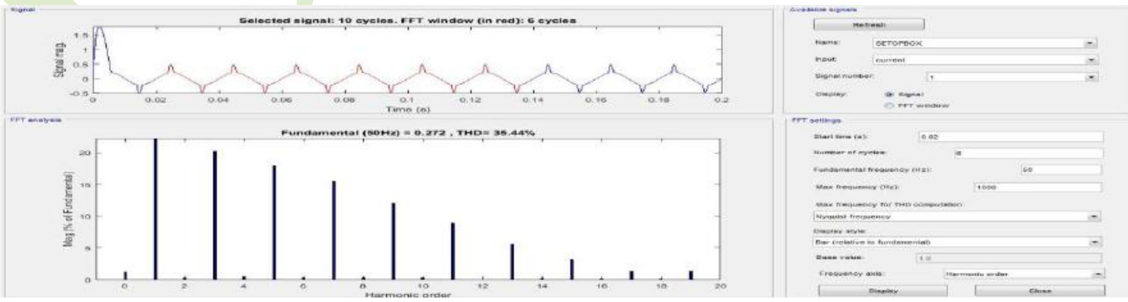
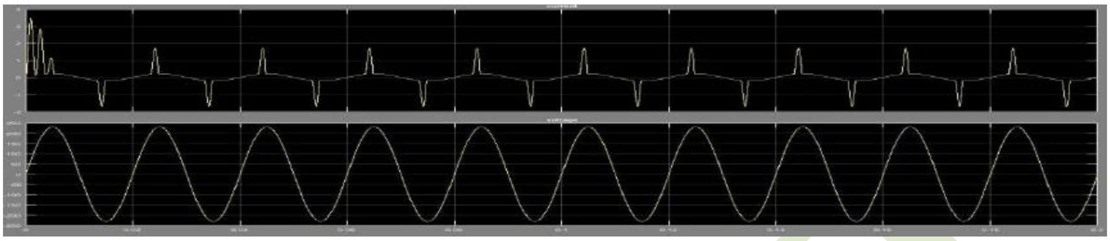


b)

Figure8: Simulated a) waveform b) FFT waveform of SETOP BOX

Television Set (SMPS)



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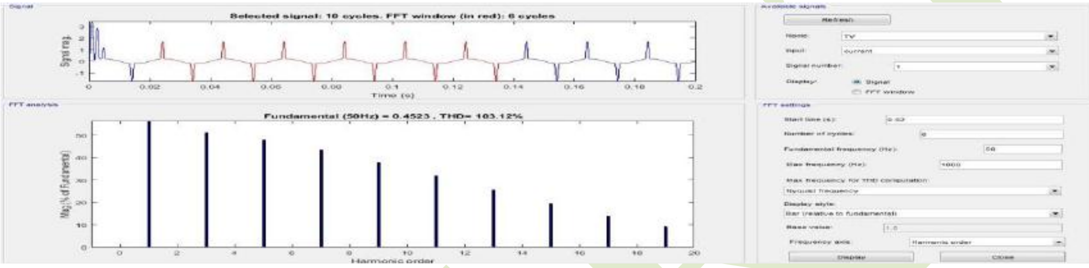
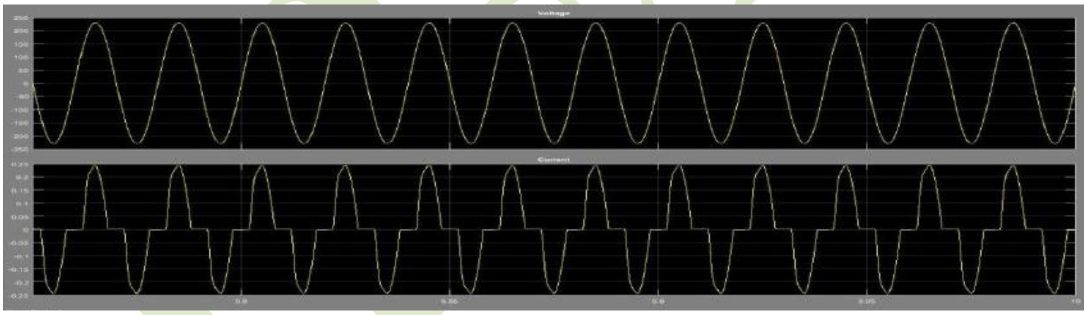


b)

Figure 9: Simulated a) waveform c) FFT waveform of TV

Battery Charger 12V



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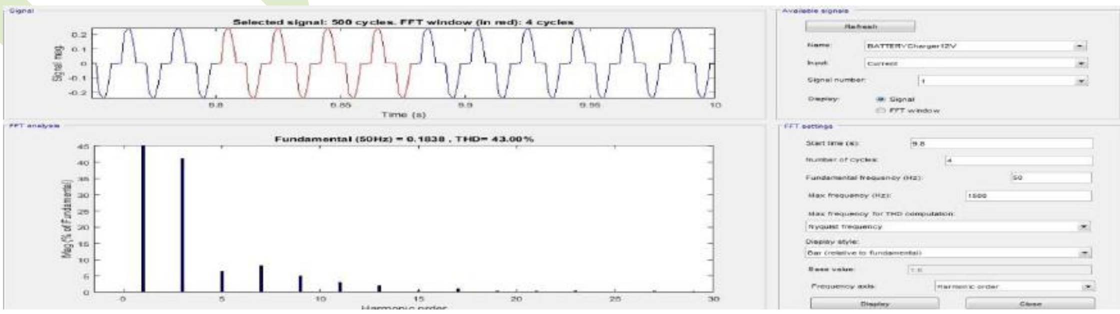
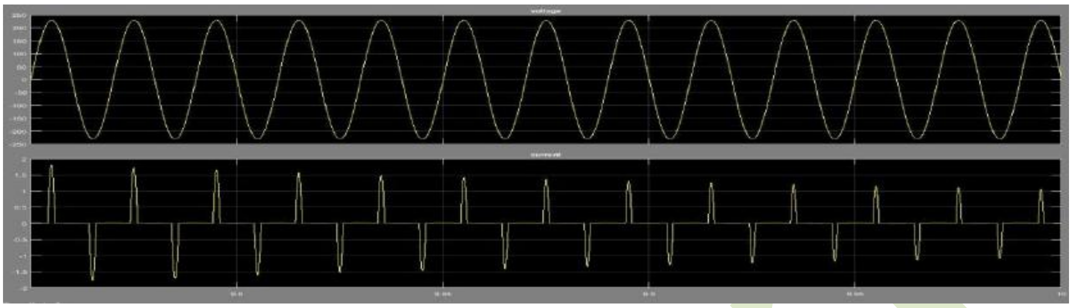


b)

Figure10: Simulated a) waveform b) FFT waveform of Battery charger 12V

Compact Fluorescent Lamp



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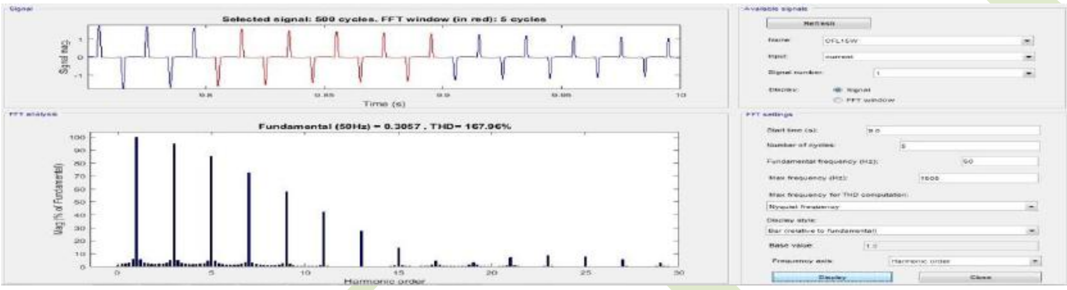
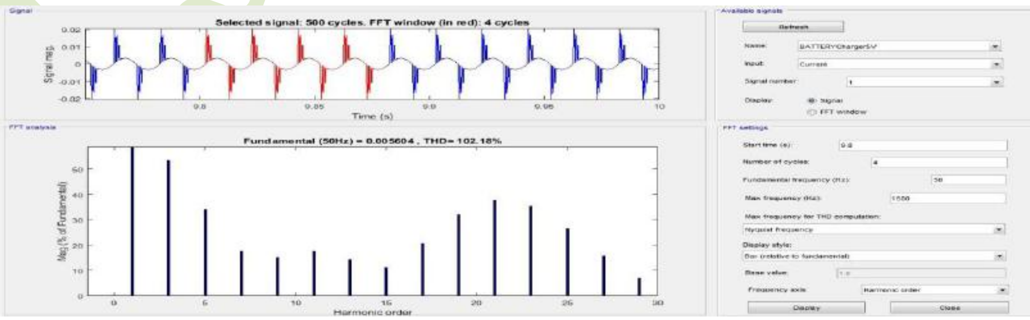


b)

Figure11: Simulated a) waveform c) FFT waveform of CFL 15W

Battery Charger 5 V

a)



b)

Figure12: Simulated a) waveform b) FFT waveform of Battery Charger 5V

TABLE OF HARMONIC CURRENT VALUES OF SIMULATED APPLIANCES

Appliances	Current (THD %)	Harmonic Order(n)	1	3	5	7	9	11	13	15	17	19	21	23	25
CFL 11w	168.4	Current (%)	100	48	47	46	45	44	43	41	39	38	36	34	27
Computer	63.39	Current (%)	100	45	34	21	10	1	3	5	2	0	1	1	1
Tube Light With Electronic Choke	116.86	Current (%)	100	29	23	15	7	3	8	12	14	14	12	10	8
Ceiling Fan	23.50	Current (%)	100	17	12	6	2	2	3	3	2	2	1	0	0
Battery Charger 24V	84	Current (%)	100	66	44	58	61	17	8	9	9	5	3	3	1
Setop Box	35.44	Current (%)	100	20	17	15	12	9	5	3	1	1	1	1	0
Television Set	103	Current (%)	100	51	47	43	37	31	25	19	13	9	5	2	1
Battery Charger 12v	43	Current (%)	100	41	6	8	4	2	2	0	1	0	0	0	0
CFL 15w	167	Current (%)	100	94	85	72	57	42	27	14	3	7	8	7	5
Battery Charger 5v	102	Current (%)	100	53	34	17	15	17	11	20	32	37	37	35	26

CONCLUSION

It is concluded that the harmonic distortion depends upon electronic elements used in appliance’s circuitry. Here, two personal computers and two mobile phone chargers of different ‘make’ are considered. It is found that %THDF of computer 1 is 63.39% whereas as Tube light with electronic choke is 116% i.e. equal to twice. Similarly for Battery charger 5V, %THDF is found as 102% whereas as CFL 15W, it is 168 %. It can be inferred that distortion in current waveform not only depends upon the ‘type’ of nonlinear load but also on the ‘make’ of that load used by the consumer. Percentage THDF are different because of different circuitry used by the manufacturers. It can also be concluded from tables that mobile phone chargers are the major sources of %THD. In present times, every member of a family has a mobile phone of latest technology and that too of different ‘make’. Numbers of nonlinear residential loads are increasing day by day; therefore harmonics caused by these loads cannot be neglected. An effect of harmonics is the overloading of distribution transformer and is main reasons of premature failure of distribution transformer. When distribution transformers are installed in India, the State Electricity Boards do not take into account the overloading due to harmonics caused by residential nonlinear loads.

FUTURE WORK

Produced harmonics due to residential loads should be minimizing. There are many techniques to reduce harmonics but economic and maintenance points of view there have necessity to select best compensation method.

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