Preliminary Study of Harmonic Generated by Household Appliances

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Abstract. This paper is preliminary study with focused on the harmonics generated by household appliances. There are only several household appliances that considered in this paper are television set, laptop computer and compact fluorescent lamp (CFL). To measure the input current, the measurement equipment was installed at the input side of equipment under the test. The important parameters that have been recorded are individual harmonic currents, total harmonics distortion, power factor, input current and input voltage wave form. From the results, television sets, laptop computers and CFLs have been found generate the THD, of 177%, 273.66% and 154.2% respectively. If it is widely used in residential areas, it is likely that there will be increased harmonic distortion in the electric power distribution system. Due to this research is still in its early stages, at the end of this research it will be known how much harmonics is generated by the load in the residential area. If amount of harmonics generated by the housing load that exceeds the limit, so the next step of this research a harmonics filter design will be conducted.

1. Introduction
Alternating current (AC) in distribution systems are designed to operate at constant frequency of 50 Hz or 60 Hz and specified voltage levels with constant magnitudes. With the development of sophisticated technology in power electronics over the last decade, the use of power electronics devices in household appliances has increased. Due to the switching operation of the power electronic equipment, they become harmonic generating devices. So, the application of power electronics equipment in household appliances has led to higher harmonic distortion for both load voltage and current waveforms. Harmonic currents generated by household appliances are individually too small to cause of any appreciable distortion in distribution feeders. However, as the numbers of household appliances use increases, the cumulative effect of these loads has the capability to elevate the harmonic distortion in distribution system [1], [2], [3], [4]. In fact, the source of small-scale harmonics is not important to study, but due to widespread use, it becomes important to study. The major problems associated with the harmonics generated by single-phase loads are excessive neutral currents and communication interference [5]. Single phase nonlinear residential loads have always existed and traditionally included such items that use diode bridge rectifier (DBR) like: desktop computers, laptop computers, television sets, home theater etc. Harmonic effects and analysis becomes an important and necessary task in electrical power distribution system because of the fact

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that most of switching devices is widely and heavily used in single-phase power electronic loads [6], [7], [8].

2. Residential Power Electronic Loads
Generally, the small harmonic producing in household appliances can be broadly divided into two groups:
- The first group contains those household appliances that contain of single-phase capacitive-filtered diode bridge rectifier (DBR) like personal computers, laptop, color television, electronic ballasts for gas discharge lamps, battery chargers and small adjustable speed drives (ASD) for heat pumps [2], [3].
- The second load group contains the fluorescent lamps (FL) and compact fluorescent lamps (CFL) that employ magnetic ballast or electronic ballast [9], [10].

In this paper the nonlinear load appliances under consideration are television, laptop computer and compact fluorescent lamp. Currently almost all houses have television, both in cities and in rural areas. Likewise, the use of laptops has also been widely used. They raise our working efficiency, but give large amount of harmonics to the low voltage networks [6], [11], [12]. They inject enormous harmonics into the low voltage networks in every time. Single-phase capacitor DBR is most widely used for power supply in low power applications. This type of rectifier is used on computers and color televisions as a power supply. This rectifier will produce harmonics and inject them into the electric power distribution system. This harmonic distortion has several detrimental effects including overheating of distribution system components, mechanical oscillations in generators, motors, capacitors and insulation failure due to electrical resonance [13].

3. Single-Phase Bridge Rectifier Model in Time Domain

![Figure 1](image)

Figure 1: (a) Equivalent circuit of capacitor filtered DBR load model, (b) Supply voltage, input current, and output voltage waveforms.

Figure 1(a) shows the equivalent circuit of capacitor filtered DBR load model and waveforms. The circuit operating conditions are to be assumed with highly discontinuous input current \(i_s\). Figure 1 (b) shows the fundamental input current, input voltage, pulsed input current and output voltage waveform generated by single phase capacitive filtered DBR [14].

As shown in Figure 1 (b), the input current \(i_s\) was already zero prior to zero crossing of input voltage \(v_s\) junction, for each half cycle of input waveform. There are two modes operation for this circuit. Mode 1, the diode is forward biased and the capacitor charges through the supply, the output voltage like charging voltage of capacitor. Mode 2, the diode is reversing biased and the capacitor discharges through the load, the output voltage like discharge voltage of capacitor.
The input current in steady state is the sum of its Fourier component as [15]:

\[ i_s(t) = i_{1s}(t) + \sum_{n=1}^{\infty} i_{ns}(t) \] (1)

\( i_{1s} \) is fundamental component of input current, \( i_{ns} \) is harmonic component of input current

The Total Harmonic Distortion current (THDi) according to IEEE definition is [16]:

\[ THD_i = \frac{\sqrt{\sum_{n=2}^{N} I_n^2}}{I_1} \] (2)

where \( I_1 \) is rms of the fundamental current waveform, \( I_n \) is rms n order harmonic of current waveform.

4. Methodology

The equipment that are using for harmonic data assemble is a power analyzer PM 100 and Visual Power Analysis software (VPAS Lite). The experiment was done individually by implemented harmonic measurement on the household appliances such as color television, laptop computer and CFL and the device gives data of harmonic order from 2 until 40 for 21". The measurement is to examine the harmonics and to determine the contribution to the system harmonic levels from the household appliances. Figure 2 shows the harmonics measurement scheme. Harmonic analysis is designed to perform the harmonic study for the household appliances. For this harmonic analysis, the results will include individual current distortion, THDi, and graphs level of harmonic current.

5. Measurement Results and Analysis

5.1 Television set

Measured waveform of input voltage, current and harmonic spectrum for a 21” television with 230 V input voltage, 67 watt is shown in Figure 3(a) and (b). The voltage supply was being close to sinusoidal with \( THD_v = 0.317\% \). While the current waveform was found significantly distorted with \( THD_i = 177\% \). The 3rd harmonics until 11th harmonic order are considered high in magnitude. The odd input currents harmonic for 21’ television has been considered high, but the even harmonics can be ignored due to small value. The magnitude of third harmonics current is 93.1% of the fundamental current, and the magnitude of twenty-first harmonic current is 4.4% of fundamental current. The harmonic trend is obtained rather high for low order harmonics and low harmonics magnitude for the higher order.

\[
\begin{align*}
V_{RMS} & : 230.33 \\
I_{Peak} & : 2.229 \\
Power & : 67.0 \\
Crest Factor & : 3.919 \\
Frequency & : 50.00 \\
I_{Fund} & : 0.275 \\
I_{Peak} & : 2.229 \\
Power Factor & : 0.500 \\
THD_i & : 177\% \\
\end{align*}
\]
5.2 Laptop Computer

Laptop computer has produced significant current distortion at input side. Figure 4 (a) shows the input current significantly distorted and Figure 4(b) shows harmonic spectrum input currents which content of harmonics with THD, of 273.66% dominantly by odd harmonic. The even harmonics can be ignored due to too small value. The magnitude of second harmonic input current only 1.3% of fundamental current, but magnitude of third harmonic is 94.67% and thirty-ninth harmonic is 13.3%.

Parameter values during test:

| Parameter          | Value          |
|--------------------|----------------|
| V_RMS (Volts)      | 230.30         |
| I_RMS (Amps)       | 0.254          |
| Power (Watts)      | 19.3           |
| Frequency (Hz)     | 50.00          |
| I_Fund (Amps)      | 0.075          |
| Power Factor       | 0.330          |
| Crest Factor       | 7.089          |
| I_Peak (Amps)      | 1.739          |
| THD(%)             | 273.66         |

5.3 Compact Fluorescent Lamp with Electronic Ballast

Parameter values during test:

| Parameter          | Value          |
|--------------------|----------------|
| V_RMS (Volts)      | 230.33         |
| I_RMS (Amps):0.059 |                |
| Power (Watts): 7.0  |                |
| Frequency (Hz): 50.00 |              |
| I_Fund (Amps): 0.029 |              |
| Power Factor:0.530 |                |
| Crest Factor:4.290 |                |
| I_Peak (Amps):0.245 |                |
| THD, (%): 154.2    |                |
The measurement voltage and current waveform of a 7-watt fluorescent lamp is shown in Figure 5 (a).

![Figure 5: (a) Input voltage and current waveforms (b) Harmonic spectrum Laptop Computer](image)

The current waveform is much distorted with THD = 154.2% and input voltage waveform very close to being sinusoidal with THD is 0.3 % due to low input impedance. The harmonics spectrum injected by individual fluorescent lamp with electronic ballast is shown in Figure 5 (b). It is shown that the energy saving lamp with electronic ballast injects significant harmonic distortion into the distribution system. The measurement results show that fluorescent lamps with electronic ballasts produce quite high harmonics and the large number of uses of these lamps in residential complexes will contribute to the harmonics in the electric power distribution system. This research will still be continued by measuring other household appliances such as home theatre, kitchen appliances and all kind of lighting and heating equipment. So this research will show the overall harmonics generated by household appliances.

6. Conclusion
After measuring and analyzing the harmonics produced by television sets, laptop computers and CFLs, the following conclusions can be drawn: The harmonic currents produced by the three household appliances are quite high. The television sets, laptop computers and CFLs have been found to generate THD, of 177%, 273.66% and 154.2% respectively. The household appliances in the first group show a high source of harmonics current compared to the second group. Due to numbers of nonlinear residential loads are increasing from time to time, so that the cumulative current harmonics produced by household appliances will contribute significantly to the harmonic in electrical distribution system.

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