INVESTIGATING THE CHANGE IN HARMONICS CHARACTERISTICS OF DIFFERENT LIGHTING LOADS DUE TO VOLTAGE DROP

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ABSTRACT

This paper studies the effects of voltage drop, due to the length of the radial distribution feeders, on different types of lamps. The study will be operated at the laboratory to define the waveforms and the resulting harmonics of the voltages and currents for each type of lamps with gradually decreasing of the applied voltages.

INTRODUCTION

In Egypt, the ring-main distribution system is applied at cites only. At the countryside or rural areas, radial distribution is used. Beside the problem of discontinuity of power supply, there is another important problem in applying the radial system which is the voltage drop due to the length of the radial distribution feeders. The end of the radial feeders may suffer from voltage regulation of about 30% or more. Really, the utility is doing its best to solve this situation, but it is still a problem.

As the lighting loads consume considerable amount of power at the countryside, it is very important to study the effect of voltage drop at harmonics with different types of lamps. Lamps include Incandescent lamps, Fluorescent lamps, Compact Fluorescent lamps, Mixed Blended lamps, Halogen Dichroic lamps, Mercury-Vapor (MV) Lamps, Metal-Halide (MH) lamps, High Pressure Sodium (HPS) lamps, etc. This study covers the following points:

- Defining the voltages and currents waveforms for each type of lamps when decreasing of the applied voltages.
- Defining the harmonics orders at voltages and currents waveforms by estimating their magnitudes using Fast Fourier Transform (FFT) for each type of lamps with gradually decreasing of the applied voltages.
- Defining the voltages at which lamps will be light-off.

The measurements were operated at the laboratory by using power/harmonic analyzer. The results contain many recommendations that may be valuable for both consulting electrical engineers and customers.

THE ANALYSIS OF THE PERFORMANCE OF EACH TYPE OF LAMPS

Incandescent Lamps

The lamp under test has rated voltage of 220 volts and rated active power of 220 watts. Fig. 1-(a) represents the voltages and currents waveforms when applying rated voltage. Also, it defines the harmonics orders at voltages and currents waveforms by estimating their magnitudes using Fast Fourier Transform (FFT) from 1up to 65. Every order of harmonics is represented by two bars, the first is for the voltage and the other is for the current as a percentage of the first harmonic (fundamental). It has unity power factor and there is nearly no distortion except the 5th harmonic which was injected from the supply and affected the current. By decreasing the applied voltage step by step and observing the variation of harmonics and power factor, it is found that the distortion in current wave slightly increases, as shown in Fig. 1-(b), with applied voltage of 100 volts. The lamp will be light-off at nearly 55 volts.

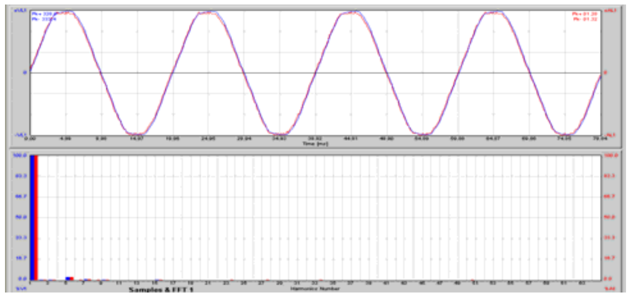

Fig. 1- (a): Performance of Incandescent lamp at 220 volts.

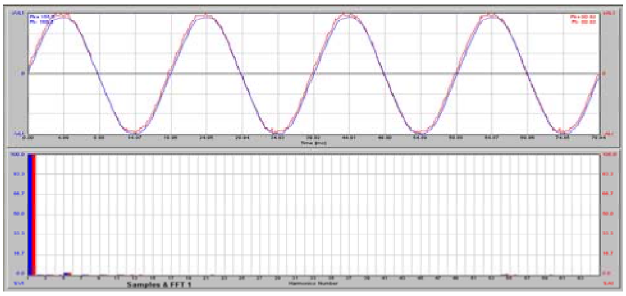

Fig. 1- (b): Performance of Incandescent lamp at 100 volts.

Fluorescent Lamps

The lamp under test has rated voltage of 220 volts and rated active power of 20 watts. It has a poor lag power factor, nearly 0.376 due to the effect of chock coil. There is some distortion in the voltage wave that appears as 5th harmonic and 7th harmonic. In the current wave, the 3rd harmonic is the most effective one as shown in Fig. 2-(a). With applied voltage of 150 volts for example, it is found that the distortion in current wave slightly increases for nearly all the harmonics orders although the value of the current is decreased as shown in Fig. 2-(b). The lamp will be light-off at nearly 85 volts.

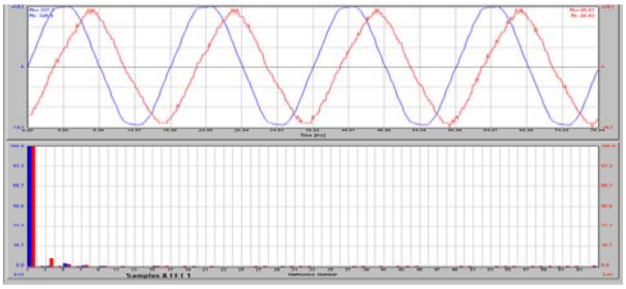

Fig. 2- (a): Performance of fluorescent lamp at 220 volts.

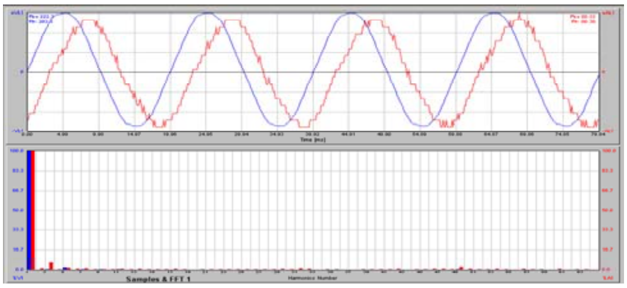

Fig. 2- (b): Performance of fluorescent lamp at150 volts.

Compact Fluorescent Lamps

The lamp under test has rated voltage of 220 volts and rated active power of 28 watts. It has a poor lead power factor, nearly 0.599. In general, there is no distortion in the voltage wave. In the current wave, the odd harmonics with relatively large values have a bad effect, as shown in Fig. 3-(a). With applied voltage of 140 volts for example, it is found that the distortion in current wave is decreased for nearly all the harmonics orders as the value of the current decreases as shown in Fig. 3-(b). The lamp will be light-off at nearly 78 volts.

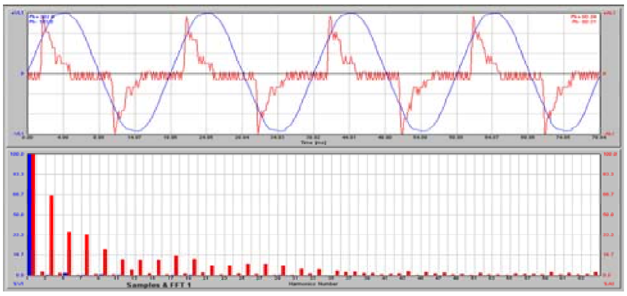

Fig. 3- (a): Performance of compact fluorescent lamp at 220 volts.

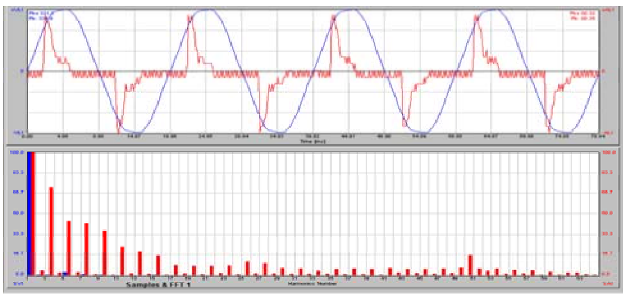

Fig. 3- (b): Performance of compact fluorescent lamp at 140 volts.

Mixed Blended Lamps

The lamp under test has rated voltage of 220 volts and rated active power of 160 watts. It has a good power factor, nearly 0.999 leading. It is clear that there is no distortion in the voltage wave. In the current wave, some small even and odd harmonics are presented as shown in Fig. 4-(a). With applied voltage of 180 volts for example, it is found that the distortion in current wave increases for nearly the small orders of odd harmonics as shown in Fig. 4-(b). At this figure, the current wave is measured and recorded out of phase to observe the changes clearly. The lamp will be light-off at nearly 150 volts.

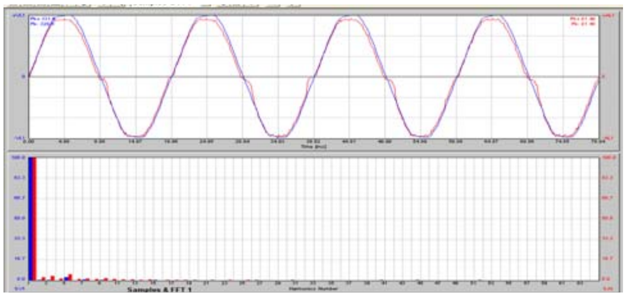

Fig. 4- (a): Performance of Mixed Blended lamp at 220 volts.

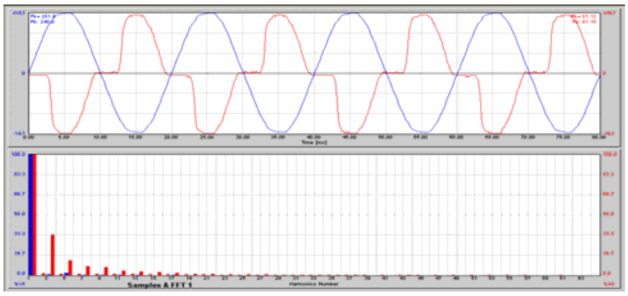

Fig. 4- (b): Performance of Mixed Blended lamp at 180 volts.

Halogen Dichroic Lamps

The lamp under test has rated voltage of 220 volts and rated active power of 39 watts. It has a good lead power factor, nearly 0.996. In general, there is no distortion in the voltage wave. The current wave looks like pulsating wave due to the structure of the lamp.

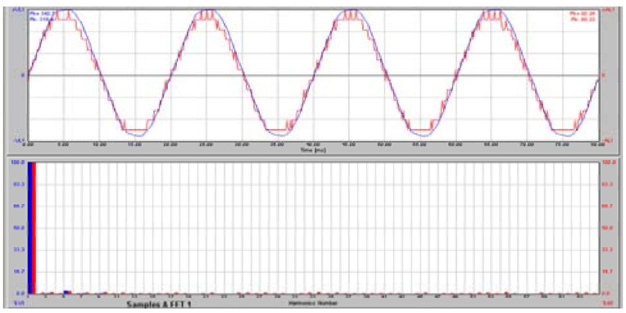

Fig. 5- (a): Performance of Halogen Dichroic lamp at 220 volts.

The odd harmonics with relatively small values affect the current wave as shown in Fig. 5-(a). With applied voltage of 170 volts for example, it is found that the distortion in current wave slightly decreases for some harmonics orders and increases in the others as the value of the current is decreased as shown in Fig. 5-(b). The lamp will be light-off at nearly 159 volts.

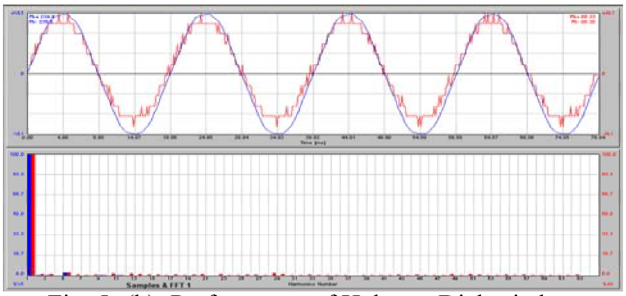

Fig. 5- (b): Performance of Halogen Dichroic lamp at 170 volts.

Mercury-Vapor (MV) Lamps

The lamp under test has rated voltage of 220 volts and rated active power of 400 watts. It has a poor lag power factor, nearly 0.398. In general, there is no distortion in the voltage wave except the 5th harmonic. The harmonic distortion in the current wave is more observed than that of the voltage wave especially the 3rd harmonic as shown in Fig. 6-(a). With voltage of 150 volts, the distortion in current wave decreases for nearly all the harmonics orders as the value of the current is decreased as shown in Fig.6-(b). So, the shape of the current wave form is improved. The lamp will be light-off at nearly 95 volts.

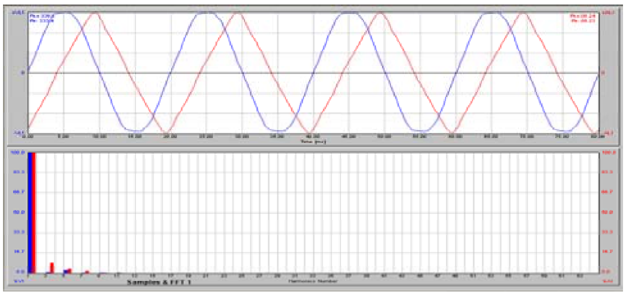

Fig. 6- (a): Performance of Mercury-Vapor Lamp at 220 volts.

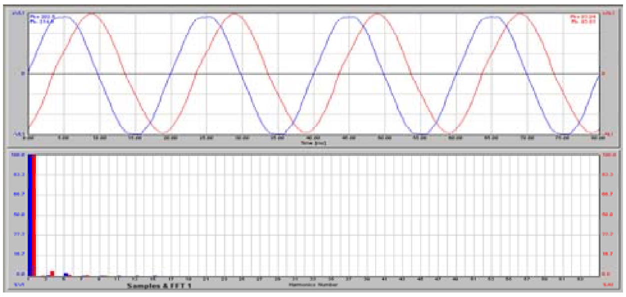

Fig. 6- (b): Performance of Mercury-Vapor Lamp at 150 volts.

Metal-Halide (MH) Lamps

The lamp under test has rated voltage of 220 volts and rated active power of 400 watts. It has a poor lag power factor, nearly 0.463. In general, the harmonic distortion in the current wave is more observed than that of the voltage wave as shown in Fig. 7-(a). With applied voltage of 165 volts for example, it is found that the distortion in current wave increases for nearly all the harmonics orders as the value of the current is decreased as shown in Fig .7-(b). The lamp will be light-off at nearly 159 volts.

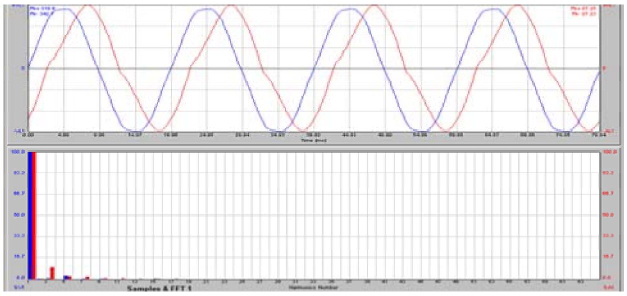

Fig. 7- (a): Performance of Metal-Halide lamp at 220 volts.

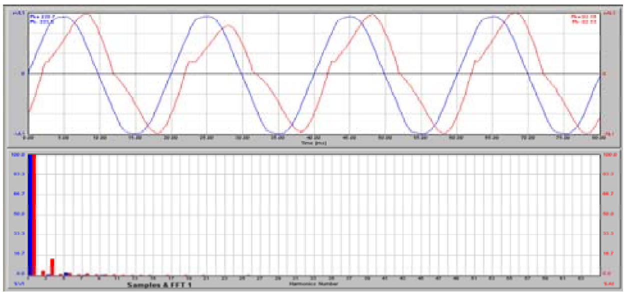

Fig. 7- (b): Performance of Metal-Halide lamp at 165 volts.

High Pressure Sodium (HPS) Lamps

The lamp under test has rated voltage of 220 volts and rated active power of 400 watts. It has a poor lag power factor, nearly 0.491. In general, there is no distortion in the voltage wave except the 5th harmonic. The harmonic distortion in the current wave is more observed than that of the voltage wave especially the 3rd harmonic, as shown in Fig. 8 - (a).

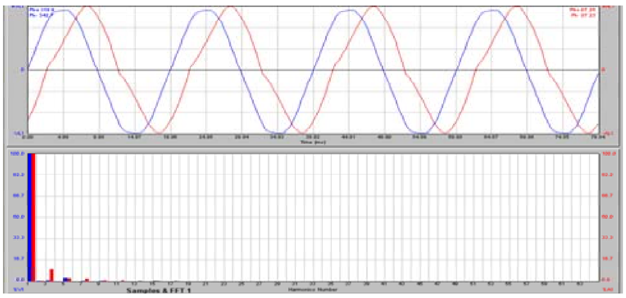

Fig. 8- (a): Performance of High Pressure Sodium lamp at 220 volts.

With applied voltage of 170 volts for example, it is found that the distortion in current wave increases especially for the 3rd harmonic as the value of the current is decreased as shown in Fig. 8 - (b). The lamp will be light-off at nearly 108 volts.

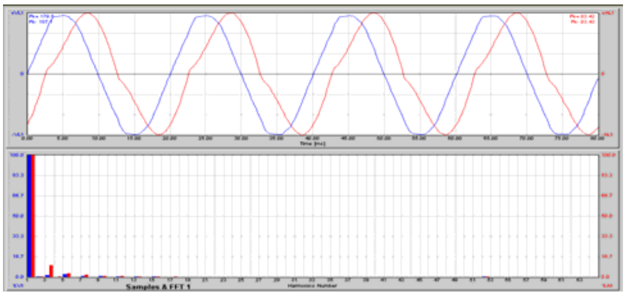

Fig. 8- (b): Performance of High Pressure Sodium lamp at 170 volts.

DISCUSSIONS AND RECOMMENDATIONS

Harmonic currents are generated by the user and are reflected into the power system. To reduce the resulting harmonics, filters are effective, however when they are connected to the network, a harmonic that is generated elsewhere on the system will find the filter. The result will be that the correcting filters of one user may filter harmonics generated by another user. Mostly, all types of lamps consume relatively small amount of energy and the filters would naturally be small. When these filters are connected to a dirty system, they will try to filter the harmonic from other users. This situation causes severe overheating of the filters and leads them to failure.

The utility controls the magnitude of these harmonics and there are standards that the manufacturers of equipment and users must comply with. Table 1 lists the IEEE 519/1992 standard for maximum harmonic current in percent of individual harmonic order (odd harmonic) for voltage < 69 kV:

Table 1: Part of IEEE 519/1992 Standard

Isc/Il	<11	11<H<17	17<H<23	23<H<35	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
100<1000	12	5.5	5.0	2.0	1.0	15
>1000	15	7.0	6.0	2.5	1.4	20
Even harmonics are limited to25%of the odd harmonics limits above						

The study showed that the harmonics of some different types of lamps may exceed the permissible standard limits of table 1 such as the cases illustrated by Figs. 3-(a), 3-(b), 4 -(b), 7-(b) and 8 - (b), respectively. It is worth to consider that the obtained results may be different when using lamps with other rated powers and made by other manufacturers. So, for the utility, it is recommended to solve the problem of voltage drop, especially at houses in countryside that use non-electrical energy sources to cook as well as heat water and space. Thus, the lighting load is a high portion of the consumed energy. On the other hand, the manufacturers must pay attention to the generated harmonics of their products of lamps at the cases of applying low voltages. It is observed that the brightness of the lamps is reduced when decreasing the applied voltages.

Also, it is important to notice that all arcing lamps such as Mercury-Vapor (MV) Lamps, Metal-Halide (MH) lamps, High Pressure Sodium (HPS) lamps, etc., will never turn-on below its rated voltages. It is recommended that the engineers must pay attention to the usage of combination of different types of lamps. Some combinations may improve the power quality and others may have a bad effect on it.

CONCLUSIONS

From the above results, the following conclusions can be deduced:

- The Incandescent lamp has the lowest value of harmonic distortion at nearly unity power factor.
- The other types of lamps generate harmonics with different magnitudes at certain orders.
- The decreasing of the applied voltage decreases or increases the harmonic distortion level depending on the type of each lamp.
- All arcing lamps never turn-on below its rated voltages.
- When the applied voltage is decreased gradually, the lamps will still turn-on until certain value of voltage.
- The manufactureres and users must pay attantion that in some types of lamps, the current waves contain odd harmonics distortion more than the values recommended by (IEEE 519/1992).

REFERENCES

[1] J. Arrillaga, B. Smith, N. Watson, A. Wood, 1997, Power System Harmonic Analysis, John Wiley & Sons Inc.

[2] R.H. Electrotek, 1999, "Harmonics of Compact Fluorescent Lamps in the Home", Domestic Use of Electrical Energy Conference, Cape Teknikon, Cape Town, 110-114.

[3] 519-1992 IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems.