

Effects of Compact Fluorescence Light (Cfl) Bulbs on Power Quality

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Abstract

In recent time, the power quality has attracted a lot of attention due to extensive emphasis by power utility on the power system efficiency and end users awareness of power quality issues. This has occurred mainly due to the sensitivity of the modern equipment and the deregulation of the power distribution. In addition, there are usually massive losses both to power utility and end users due to poor power quality supplies which fall below the set standards. Power quality primarily consists of voltage dip/ swell, power system interruptions, harmonic distortions, voltage flickers and frequency deviations. This study looks at effect of CFL bulbs on power system in relation to harmonic distortions and low power factor inherently associated by CFL. It has established that the bulbs generate substantial harmonic distortions and leading power factor. Combination of incandescent and CFL bulbs in one circuit was noted to improves the power quality.

Keywords: CFL bulb, Harmonic distortion, Power factor, Reactive power

1. Introduction

Due to increase of power demand, the power utility has introduced Compact Fluorescence Light (CFL) bulbs as one way of reducing power consumption to enhance security of energy supply. The bulbs are able to consume less power by up-to 80% of the lighting energy and can last 10 times more than the ordinary bulbs (incandescent bulbs). Nevertheless, the bulbs are known to produce harmonics which are expected to have negative impact on the power quality as they degrade the supplied power with high harmonic distortions and low leading power factor. This implies high technical losses and equipment damage [1].

This paper presents the results of investigation done to determine the effects of the phasing out of incandescent lamps and replacement with more energy efficient CFL bulbs on power quality supplied by the power utility. The CFL bulbs are technologically developed from conventional fluorescent lamps and differ mainly in size and shape, in that they can directly fit into normal light socket holders.

1.1 Principal and construction of the CFL

A fluorescence lamp generates light from collisions in a hot gas ('plasma') of free accelerated electrons with atoms – typically mercury- in which electrons are bumped up to higher energy levels and then fall back while emitting at two UV emission lines (254nm and 185nm). The created UV radiation is converted into visible light by UV excitation of a fluorescence coating on glass envelope of the lamp. The construction of a CFL bulb tube consists of a tube filled with a gas containing low pressure mercury vapour and noble gas at total pressure of about 0.3% of the atmospheric pressure. A pair of filament emitters is heated by a current and emits electrons which excite the noble gases and the mercury gas by impact ionization [2].

1.2 Harmonic definition and it characteristics

Harmonics are usually a superposition of signals which are exact multiples of fundamental frequency (50Hz or 60Hz); they can be voltage or currents. An important characteristic of harmonics is that they are transmitted upstream from the load to the transformer's secondary windings, back to the service entrance and eventually to the utility line as shown in Figure (1).

1.2.1 Causes of low power factor

The contributing factors that causes a low power factor is excess reactive current and harmonic current. Sources of reactive power are capacitive and inductive loads. Capacitive load produces an electric field thereby generating reactive power, whilst an inductive load produces a magnetic field hence absorb reactive power. CFL bulbs produce an electric field thus generating reactive power (hence leading power factor) and high odd harmonics pollution. Harmonic distortions usually complicate the computation of apparent power and power factor because voltage and current equations contain harmonic components. For sinusoidal waveform, the total power (S) is given by;

$$S = \sqrt{p^2 + q^2} \qquad (1)$$

Where; p is active power and q is reactive power
In the presence of harmonic components, equations (1) do not hold because S contains cross terms, the product of the Fourier series that correspond to voltage and currents of different frequencies, whereas p & q correspond to voltage and currents of same frequency [3]. The three phase distorted voltage is therefore given by;

$$v(t) = \sum_{h=1}^{\infty} \sqrt{2}\ v_h \sin(hw_1 t + \theta^v h) \qquad (2)$$

$$i(t) = \sum_{h=1}^{\infty} \sqrt{2}\ I_h \sin(hw_1 t + \theta^i h) \qquad (3)$$

The total power in presence of the harmonic distortions is therefore given by;

$$S = \sqrt{p^2 + q^2 + d^2} \qquad (4)$$

Where; d is distortion factor
Apparent (total) current (I_S) consist of real current (I_P), reactive current (I_Q) and harmonic distortion current (I_D). Their relationship is defined as by the following equation;

$$I_S^2 = I_R^2 + I_Q^2 + I_D^2 \qquad (5)$$

This is well illustrated in Figure (2).

Increase of apparent power causes the PF to decrease as in equation (6).

$$\text{Total power factor} = \frac{p}{\sqrt{p^2+q^2+d^2}} \qquad (6)$$

1.2.2 Effects of harmonic distortions on the power system

The adverse effects of harmonic distortions can be grouped into two basic categories namely; short term and long term effects. The short term includes; failure of capacitor banks due to electric breakdown that is caused by heating and dielectric stress, causes any equipment that uses zero crossing as a reference to malfunction as voltage and current waveform is distorted, nuisance tripping of circuit breakers and fuses due to confusion resulting from harmonics frequencies and neutral overloading and unacceptable neutral–to–ground voltage. On the other side, the long term undesirable effects of harmonic distortions noticeable on the power system and end users are; excessive losses resulting in heating of induction and synchronous machines, heating on switchgear and relays where they reduce steady state current capability and shortening the life of some insulating components. Moreover, it has been proven that harmonic distortions cause an error in energy meter and instrument readings. This is because induction disk devices normally 'see' only fundamental current. Phase imbalance caused by harmonic distortion can also cause erroneous operation of these devices [2].

2.0 Methodology and data analysis

2.1 Materials used during the study

The study was done using 10 CFL bulbs each of 8 Watt and voltage rating of 240V, as shown in Figure (3) and reference working equipment shown in figure (5). The equipment provides the instantaneous active power, reactive power, total power, power factor and harmonic distortions values. Ten incandescent bulbs of 40 Watt and voltage rating of 240V were used as benchmark of the investigation (Figure 4)

2.2 Collected data

The Figures (7- 13) show the data collected using reference equipment used for this study on above bulbs circuits.

2.3 Data analysis

From the data collected, it is observed that CFL bulbs generate high reactive power hence low leading power factor and substantial odd harmonic distortions as depicted in Figure (9). This is mainly because of the Switch Mode Power Supplies (SMPS) incorporated in its electronic circuit. They generate considerable odd harmonic current distortions due to its inherent drawing of non sinusoidal current as shown in Figure (7). The current Total Harmonic Distortion (THDi) is high for CFL bulbs (137%) as given in Figure (11) vis- a –vis incandescent bulbs (4%) due to inherent non linearity of electronic components. In additional, CFL bulbs consume less active power (78% less than counterpart bulbs) as they draw discontinuous current of each half cycle.

Incandescent bulbs consume more active power thus causing the system to carry more current (Figure 10). However, they do have almost a unity power factor and low total harmonic distortions (4%) as revealed in Figure (12) hence less harmful on power quality. It is worth noting that, combination of CFL and incandescent bulbs improve considerably the power quality (reduces the harmonic distortions by drawing a continuous current waveform) as shown Figures (13).

3. Conclusion

The following can be concluded from the investigation on the effects of CFL on power quality;

a) The CFL bulbs are more efficient vis – á – vis incandescent bulbs on lighting power (consume 78% less power).

b) The total current drawn by the CFL, more than 50% constitute reactive and harmonic currents.

c) The generated reactive power by CFL bulbs can be absorbed by most of domestic inductive loads such as fan, fridge, air conditioners hence minimizing the negative effects of low power factor such as poor voltage profile and high technical losses.

d) Combining CFL and incandescent bulbs improve the quality of the power supplied at the point of common coupling (PCC).

4. Recommendations

i. The CFL bulbs manufacturers should improve on design of CFL bulbs to mitigate the high level of harmonic distortions and low power factor inherently associated with the CFL bulbs.

ii. It is recommended to combine other loads (resistive and inductive) with the CFL bulbs to improve the power quality of the power supplied at PCC.

References

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BORN AT NYADARUA DISTRICT IN 1974. JOIN PRIMARY SCHOOL IN 1981 TO 1989. ENROLLED IN SECONDARY EDUCATION IN 1990 TO 1993. JOINED MOI UNIVERSITY AT ELDORET IN 1995 TO UNDERTAKE BSC OF ELECTRICAL AND TELCOMMUNICATIONS ENGINEERING AND GRADUATED IN 2000. COMPLETED A MSC IN CONTROL ENGINEERING AT JOMO KENYATTA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY IN MARCH 2012. Currently working with Kenya power utility as energy meter engineer. My area of study is on power quality: harmonic distortions, reactive power compensation and power factor improvement

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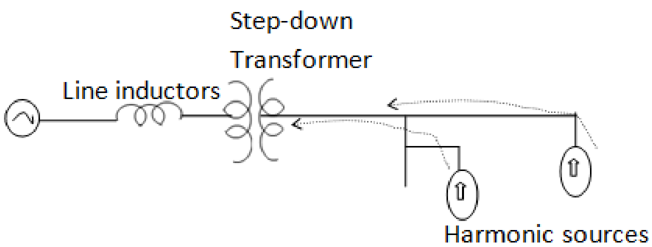

Figure 1. Harmonics characteristic

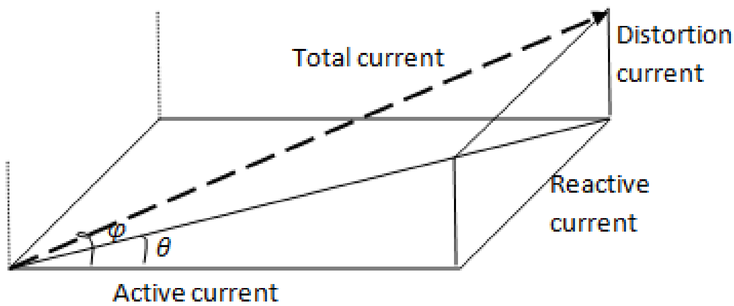

Figure 2. Total current for calculating a apparent power

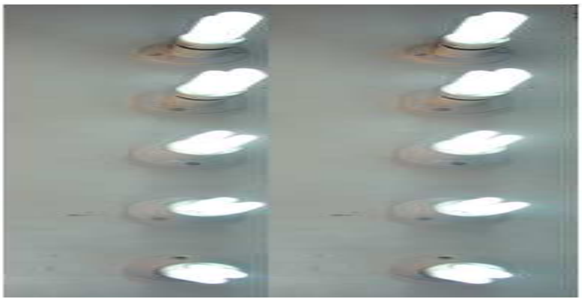

Figure 3. CFL bulbs used during the study

Figure 4. Incandescent bulbs used during the study

Figure 5. Reference working standard

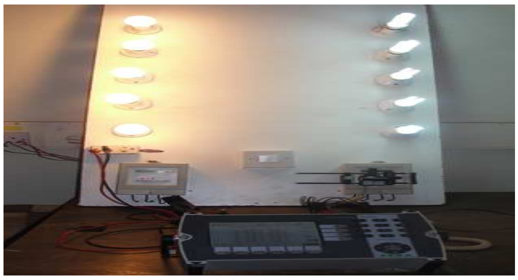

Figure 6. Combined bulbs circuit

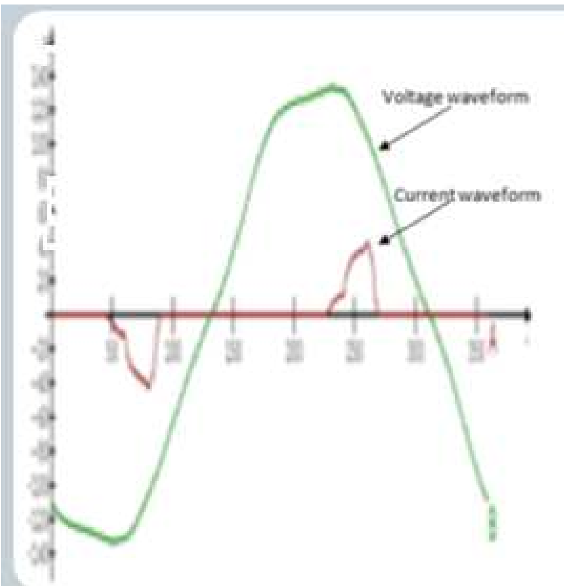

Figure7. CFL bulbs waveforms

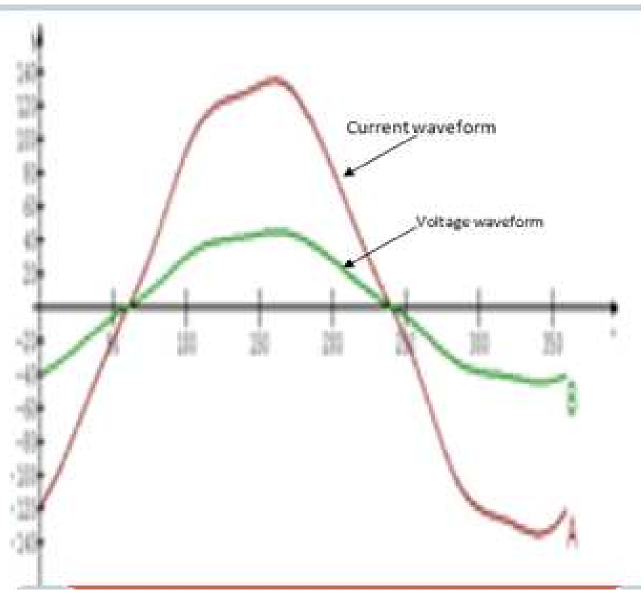

Figure 8. Incandescent bulbs waveforms

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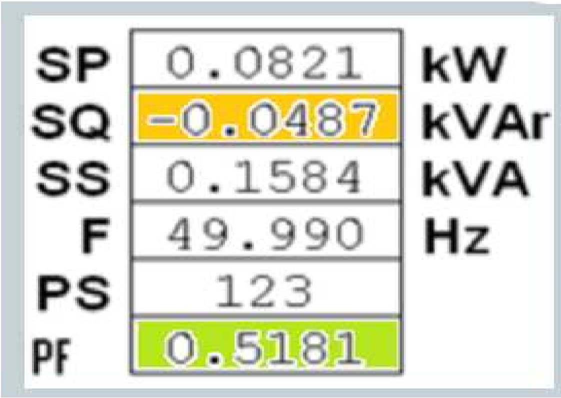


Figure 9. CFL bulbs instantaneous values

Figure 10. Incandescent bulbs instantaneous values

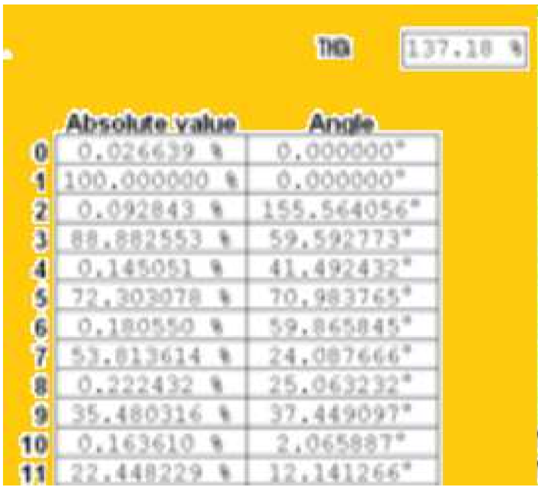


Figure 11. CFL bulbs THDi values

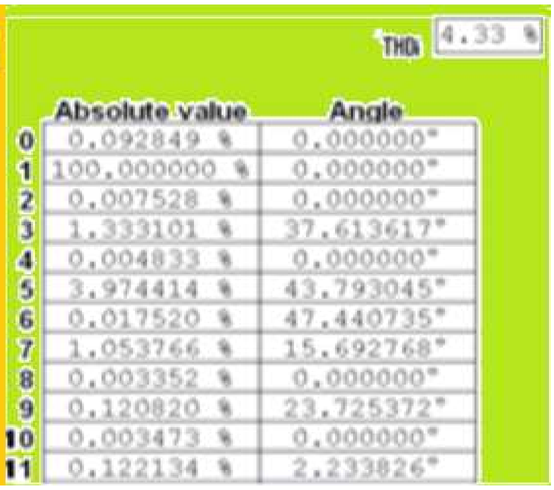
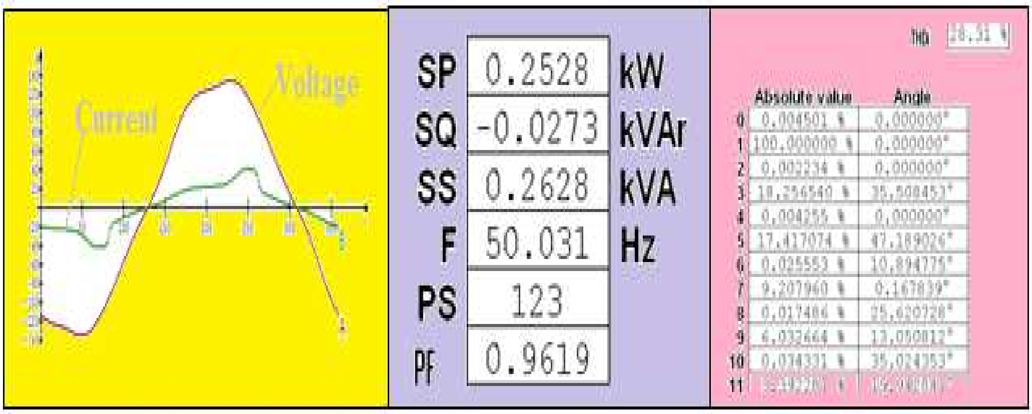


Figure 12. Incandescent bulbs THDi values

Where; THDi is Total current Harmonic Distortion



Figures 13. Combined bulbs waveforms and instantaneous values