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Effect of Power Quality Disturbances on Compact Fluorescent Light (CFL) Bulbs in Ibadan, Oyo State, Nigeria

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***Abstract*— It was quite established that Compact Fluorescent Light (CFL) Bulbs consumes 0ne-quarter ($\frac{1}{4}th$) to one-fifth ($\frac{1}{5}$th) of the energy used by Incandescent Light Bulb to provide the same level of light. About 25% of energy consumed by CFL is converted into visible light compared with just 5% for a conventional Incandescent Lamp. However, the unpredictable threat of Power Quality Disturbances on life span of CFL is presently mitigating against patronage of the product Their major concern are the results of voltage surge and flicker from cyclic load variation in Single Phase Energy System which have adverse effect on Compact Fluorescent Light bulbs and drastically shorten the life span of the CFL. These are ever increasing in today's voltage power supplies for every residential houses and to apply surge suppression for**

overvoltage required technical knowledge. Conversely, research has shown that voltage sag occurs more frequently than voltage surge and the influx current from under voltage can also actually cause appliances damage. Hence this study provides an insight into a failure mechanism resulted from Power Quality Disturbances that have a notable effect on the CFLs. It employed the usage of survey questionnaire to select most commonly used CFL Bulbs using likert approach so as to have the broad view of the usage of the selected bulbs and to establish the effect of Power Quality Disturbances on CFL bulbs, in such a way that cause and effect relationship could be developed. The questionnaires were mapped per locality within Ibadan metropolis on three (3) strata; High, Medium and Low Income Areas

Regression analysis was carried out between the independent variable: Power Voltage (Voltage swell/voltage sag) and the dependent variables; Energy Saving Bulbs (CFLs) used to test the research hypotheses shown that the effect of Power Quality Disturbances were very minimal on Compact Fluorescent Lamp (Energy Saving Bulb) while high income areas consumed more energy compared to medium and low income areas with the number of CFL Bulbs and frequency of replacements. However, there was no significant effect on the usage of the item and its life span.

***Index Terms*— CFL, Energy, Reliability, Quality, Power, Validity.**

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I. Introduction

The rate of load growth in Nigeria is higher than the power supply network expansion, in some areas the available power cannot be successfully distributed to consumers due to overloading of the distributing transformers. High system losses, inefficiency of overloading equipment and old transformers in the highly populated communities have resulted in much lower energy being distributed to consumers than what has been generated. The disequilibrium in electricity demand and supply which results in the current erratic power supply in Nigeria is therefore hinged on low generating capacity and poor distribution network. Hence, the result is frequent interruption and power fluctuation to the consumers, which eventually lead to voltage surge/sag and under/overvoltage.

Incessant electric power supply interruptions/variations in most parts of the country, especially at the residential consumers end, have become a normal feature of electricity supply throughout Nigeria. The power supply interruptions/variations cause serious inconveniences and economic loses to industrial, commercial and domestic consumers. The frequent voltage surge/sag to residential consumers may have direct and indirect consequences on consumers. Some of the effects such as damaged equipment, and spoiled food may be quantified in monetary values but effects such as discomfort, injury and loss of life are difficult to estimate. Frequency of under/overvoltage could be frequent, momentary or long depending on the nature of cause. Electric power supply interruption could either originate from the utility as a result of disturbance on supply network or from outside the utility company.

In our daily lives, we enjoy the service of thousand of devices and systems that have made our lives easier and more comfortable. Bulb, iron, electric fan, blender are most popular used systems. However, all these appliances are powered by three-phase A.C. supply which consists of 3-phase voltages of 120degree out of phase with identical magnitude which is expected to be sinusoidal and continuously available, in which diversion from these requirements is considered as poor quality of power, perhaps, under/ overvoltage and voltage surge or voltage sag. The resulting effect has been having adverse effect on the reliability of household appliances, because most of new equipment is too fragile to sustain the effect of power quality variation, as this creates a periodic down time of the equipment and eventually results into unavailability of the appliances. Today, exorbitant amount are allocating by consumers to repair all these basic needs. On this platform this work proposes to understudy the reliability of the Compact Fluorescent Light (CPL) Bulb to variation in voltage values.

The Compact Fluorescent Lamps (CFL) with integrated ballast was developed as an alternative to the incandescent light bulb specifically for this purpose. CFLs consume a 1/4th to 1/5th of the energy used by the incandescent light bulbs to provide the same level of light. About 25% of energy consumed by CFL converted to visible light compared with just 5% for a conventional incandescent lamp. CFLs also have much longer lifetimes with rated life spans of 5,000 to 25,000 hours compared to Incandescent Lamp of 1,000hours. Globally incandescent lamps are estimated to have accounted for 970 TWh of final electricity consumption in 2005 and given rise to about 560 Mt of CO2 emissions. About 61% of this demand was in the residential sector with most of the rest in commercial and public buildings. If current trends continue Incandescent Lamps could use 1610 TWh of final electricity by 2030. (OECD /IEA, 2006). However, it has been established that the CFL bulbs generate substantial harmonic distortions (Charles Ndungu et al)

II. LITERATURE REVIEW AND THEORETICAL KNOWLEDGE

The quest to have new household electrical appliances has increased tremendously which led to astronomical increase in the number of consumers and load demands. The utilities provider could not generate, transmit and distribute steady, regular and uninterrupted power supply to its consumers. In Nigeria, the supply to most domestic appliances is at 220V, 50Hz single – phase and it is usually alternating current. Frequent electric power supply outages have been blamed on what is described as consumer wastage which occurs whenever consumers use appliances or processes that are inefficient or anytime they leave electrical appliances on due to outage, selection of decentralized systems instead of centralized alternatives, such as specifying individual room air conditioning, use of appliances and processes with high reactive power demand without adequate compensation.

The power supplied to the domestic consumer is sometimes interrupted and these interruptions may be due to switching operations, faults on lines (high and low voltage lines or extra high voltage lines), lightning or overloading. These interruptions which can be momentary, frequent, temporary or long–term constitute the problems causing breakdown of household appliances. When these interruptions occur at a frequent interval, active components are burnt out depending on the severity of the cause(s) of power supply interruption. This has direct or indirect effects on industrial, commercial and residential consumers are the largest customers on any power utility company. Individual consumer demand is relatively small but on the aggregate the residential load is large and has the most daily variations. While the demand is low in the morning, it increases until it peaks at night between 8.30pm and 10pm. This variation is as a result of the work pattern of residential consumers. Residential loads are mostly connected to single phase supply and they may be purely resistive or inductive-resistive load. The most important electrical domestic appliances are CFLs, electric cookers, electric fans, refrigerators, freezers, heaters and small motors for pumping water, television set, water heater, dish washer and room air conditioner. Most of these appliances use single-phase voltage. Most electrical appliances can be categorized into Non Linear (such as CFL Radio, television, computer) and Linear (i.e. iron, bread toaster, electric cooker and fan). These devices are basically switching power supplies that eliminate the large, heavy, 'iron' ballast and replace it with an integrated high frequency inverter/switcher. Current limiting is then done by a very small inductor, which has sufficient impedance at the high frequency. Properly designed electronic ballasts should be very reliable. Whether they actual are reliable in practice depends on their location with respect to the heat produced by the lamps as well as many other factors. Since these ballasts include rectification, filtering, and operate the tubes at a high frequency, they also usually eliminate or greatly reduce the 100/120 Hz flicker associated with iron ballasted systems. However, this is not always the case and depending on design (mainly how much filtering there is on the rectified line voltage), varying amounts of 100/120 can still be present. **Under normal operating condition, the capacitor is essentially charged closed to the peak of the A.C. line voltage Vp $+\delta V/_2$ (Ashish et al) .And for a 60cycle period**

$$\Delta v = \frac{I_0 T_{60}}{2C_{dv}} \qquad (1)$$

While the resonant frequency between line voltage and rectification i.e. $X_s = X_c$ is given by

$$F_{LC} = \frac{1}{2\pi\sqrt{L_s C_{dc}}} = \frac{1}{T_{LC}} \qquad (2)$$

And for any true practical rectifier circuit, resonant frequency is assumed to be much larger than the line frequency (Ashish et al)

Since line voltage $\quad V_s = I_s X_s \qquad (3)$

Neglecting the R_s and if the current at the load terminal is I_0 then, short circuit ratio $SCR = \frac{V_s}{W_s L_s}\Big/ I_0 \qquad (4)$

For overvoltage, when there is power interruption, for the cycle of N = 1/2 , 1, 1½ , 2 … the voltage would increase by 2NδV giving an end voltage of $V_p + \left(2N + \frac{1}{2}\right)\delta V$.

During the sag or under-voltage, the voltage would drop by 2NδV, giving and end voltage of $V_p - (2N - \frac{1}{2}\delta V)$. At the sag end the voltage reverts instantly back to normal, if assumed to occur at the peak, under these condition, a large initial current pulse flows from line into the capacitor would be given by

$$i_{(t)} = I_p Sin(W_{LC} t) \qquad (5)$$

While I_p deducted from equation (2) and (4) is

$$I_p = \frac{\left(2N - \frac{1}{2}\right)DV}{\sqrt{L_s/C_d}} = \frac{\left(2N - \frac{1}{2}\right)DV}{Z_0} \qquad (6)$$

For the reversed, the capacitor voltage jumps up to $V_p + \left(2N - \frac{1}{2}\right)\delta V$.

Considering the end result of voltage swell and voltage sag, both peak voltage and peak current can cause CFL malfunctions .

III. METHODOLOGY

Location and Population of the Study, this study was carried out among the households and apartments in fifteen localities from five local governments areas selected for this study in Ibadan, Oyo State. The fifteen localities and the five (5) Local Government Areas within Ibadan, mapped for the study are shown in table 3.1

Sampling Technique; The selection of the CFLs was based on sampling techniques called stratified random sampling, in which required that the population to be divided into strata or sub-population i.e. high, medium or low income earner before a random sampling took place within each stratum, while the data collection instruments used for this study were questionnaires. In order to have a rich data to be analysed in such a way that cause and

Table 1: Mapping of Data Collection

LOCAL GOVERNMENT AREA	HIGH INCOME	MEDIUM INCOME	LOW INCOME
IBADAN NORTH	BODIJA	MOKOLA	OKE AREMO
IBADAN SOUTH WEST	OLUYOLE ESTATE	CHALLENGE	ISALE OSI
IBADAN SOUTH EAST	FELELE	ADESHOLA(ORITA APERIN)	LABO/ ORANYAN
IBADAN NORTH WEST	IDI-ISHIN	ELEYELE	NALENDE
NORTH EAST	AKOBO	BASHORUN	KOLOKO

effect relationship could be developed using variable, a survey questionnaire titled Survey on usage of household appliances in dwelling was developed based on the following conditions:

- **Target population and samples**

Targets are Low income and high income housing for the experiment

- **Who may answer the questionnaire?**

Questionnaire may be answered by any person who is a dwelling's tenant or landlord and is familiar with usage of house hold appliances.

- **Location:** Ibadan Metropolitan Areas

A Data Collection Methods

Data for this study was collected using the quantitative approach. The instrument for data collection was questionnaire. Twenty (20) copies of the questionnaire were distributed per locality. Questionnaire was adopted for this study because it is a cost effective tool for gathering data from a large number of respondents within a short period. The questionnaire was carefully designed and the questions were structured in sections based on the variables the study intended to measure. Some of the questions were finally removed while some reframed.

B Data Validity and Reliability of the Instrument and its Analysis

In order to determine the validity and reliability of the instruments for data collection, the instrument underwent face

validation. That was in order to make sure that they were subjected to thorough scrutiny by the data analyst and necessary modifications were made based on the assessments. Analysis was based on describe pattern of usage of some selected

Table 2: Percentage/Frequency Distribution of the pattern of usage of CFLs in High Income locality (Akobo), Ibadan North-East

Energy savings light bulbs	Response (%)			
	Quantity	Working Duration hr/day	Life Span	Cause of Replacement
0-4	40.0	55.0		
5-9	20.0	25.0		
10-14	25.0	20.0		
15-19	0	0		
20-Above	15.0	0		
Weeks			10.0	
Months			75.0	
Years			15.0	
Voltage				60.0
Fail				40.0

Household. Energy Savers Bulbs; CFLs hypotheses and to determine if the particular independent variable influences the dependent variables and extent of influence. returned copies of the questionnaire, responses from the questionnaire were coded and Statistical Package for Social Science (SPSS) 22 Software was used for the analysis Descriptive statistics was used to describe pattern of usage of some selected household Energy Savers Bulbs; CFLs across the fifteen localities of the five local government areas. Simple linear regression analysis was used to test the formulated hypotheses and to determine if the particular independent variable influences the dependent ones and extent of influence.

Table 3: Percentage/Frequency Distribution of the pattern of usage of CFLs in Medium Income locality (Bashorun), Ibadan North-East

Energy savings light bulbs	Response (%)			
	Quantity	Working Duration hr/day	Life Span	Cause of Replacement
0-4	50.0	65.0		
5-9	25.0	25.0		
10-14	15.0	10.0		
15-19	0	0		
20-Above	10.0	0		
Weeks			5.0	
Months			70.0	

Years			25.0	
Voltage				65.0
Fail				35.0

Table 4: Percentage/Frequency Distribution of the pattern of usage of CFLs in Low Income locality (Koloko), Ibadan North-East

Energy savings light bulbs	**Response (%)**			
	Quantity	**Working Duration hr/day**	**Life Span**	**Cause of Replacement**
0-4	45.0	55.0		
5-9	15.0	25.0		
10-14	25.0	20.0		
15-19	0	0		
20-Above	15.0	0		
Weeks			10.0	
Months			75.0	
Years			15.0	
Voltage				55.0
Fail				45.0

IV. DATA ANALYSIS AND DISCUSSION

Descriptive Analysis

The pattern of usage of household appliances and variables in the research were described through the use of statistical frequency counts, percentages and results are presented with the use of tables.

B Test of Hypotheses

The results of the regression analysis carried out between the independent variable: Power Voltage (Over-Voltage/Under-Voltage) and the dependent variables CFL (Energy Savers) to test the research hypothesis. Constructs were computed because the computation was required so as to convert the variables into scalar form which would be suitable for the regression analysis. With the level of significant set to 5%, when P obtained < 0.05, the null hypothesis was rejected, else (when P obtained > 0.05) the null hypothesis was not rejected.

he results in Table 5 reveal that there is a negative and low correlation between power voltage and energy saving bulbs (β = -0. 078). It also indicates a positive but insignificant slope ($p = 0.355 > 0.05$). The null hypothesis is therefore not rejected; hence, there is no predictive relationship between power voltage and energy saving bulbs

Coefficients[a]

Table 5 Simple Linear Regression Analysis for Power Voltage (Over--Voltage/Under-Voltage) and Household Appliances (Energy Saving Bulbs)T

	Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
Model	B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1 (Constant)	7.986	1.957		4.081	.000		
Power Voltage	-.478	.515	-.078	-.928	.355	1.000	1.000

a. Dependent Variable: EnergySavers

H01: There is no significant relationship between Over-Voltage/Under-Voltage and Household Appliances (Energy Savers

Bulbs)

C Discussion of Findings

Figure shows Graphical representation of the Simple Linear Regression Analysis for OverVoltage/UnderVoltage of Household Appliances (Energy Saving Bulbs in some of those Localities

Results obtained indicated that over/under-voltage has a negative and insignificant correlation with energy saving bulbs (β = -0. 078). This implies that for energy saving bulbs to function effectively, over/under-voltage is neither important nor to be considered.

V. CONCLUSION AND RECOMMENDATIONS

.This work assists to know the extent of effect of under voltage/overvoltage supply on selected Compact Fluorescent over a period and the damaged effect of unstable power supply on the consumers economically and otherwise. The effect of Power Quality Disturbances is very minimal on Compact Fluorescent Lamp (Energy Saving Bulbs). This work elaborates the effect of under/over voltage on the consumers; however, there are other voltage variations in which this research can be further expanded such as momentary voltage dip, short-time interruption, voltage transients, voltage flicker, voltage unbalance, and Frequency variation and Harmonics each of the voltage variation will have a different effect on load devices. These Appliances under observation can also be subjected to varying voltages and their response measured to generate data, for analysis.

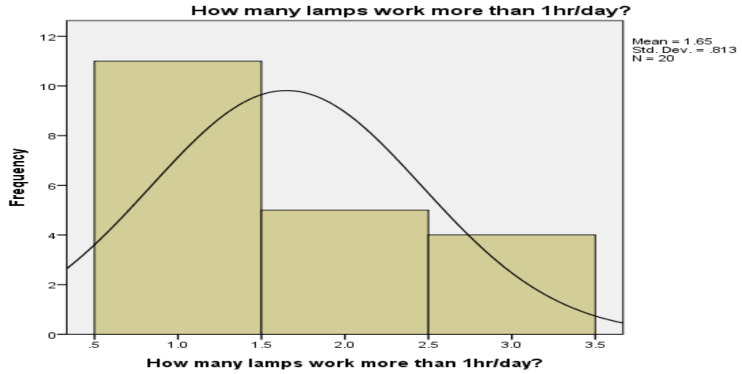

Fig. 1

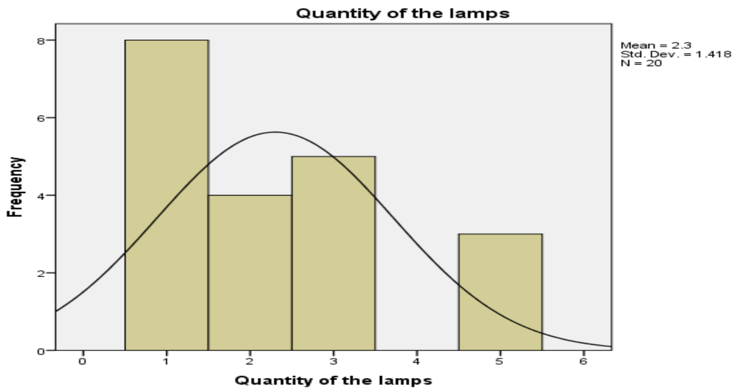

Fig. 2

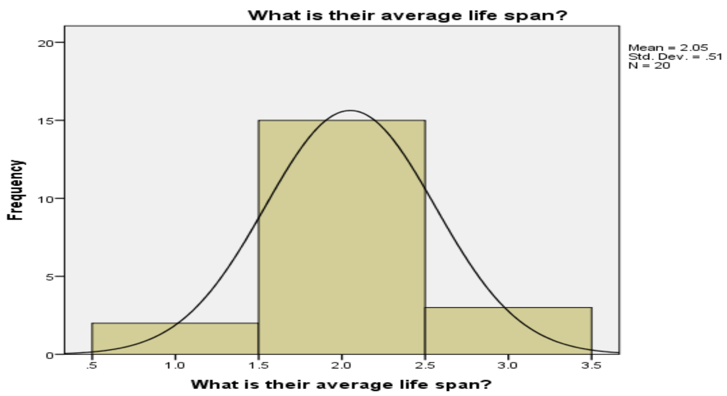

Fig. 3

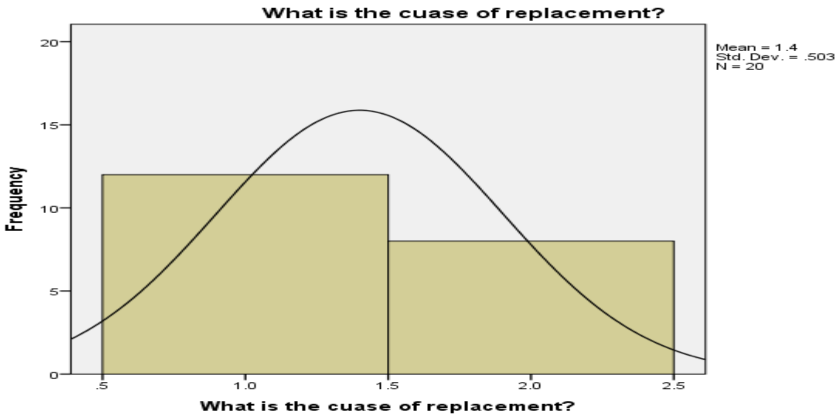

Fig. 4

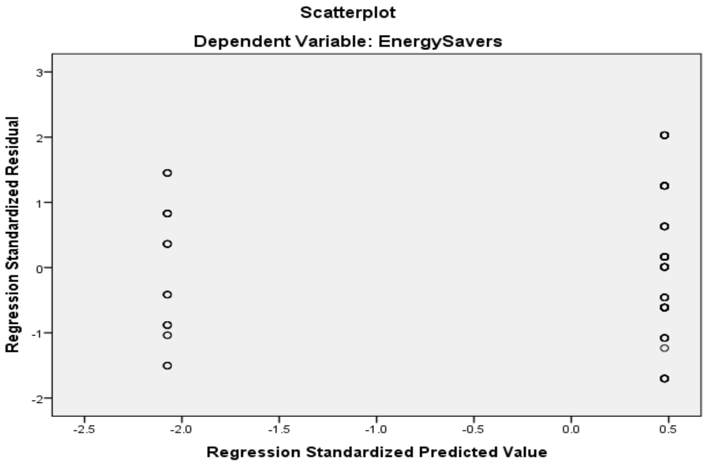

Fig. 5

Figure : ***Graphical representation of the*** **Simple Linear Regression Analysis for Power Voltage (OverVoltage/UnderVoltage) and Household Appliances (Energy Saving Bulbs)**

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