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Harmonic Producing Loads in an Electrical Distribution Network

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ABSTRACT

There has been an increasing demand for power electronics non-linear devices to mitigate energy crisis in the recent time. This paper evaluates this growing trend and call for concerted efforts to mitigate the problems. As a case study, series of survey were carried out at selected parts of Ilaro. They include Information Technology Centre (ICT) and Engineering blocks of the Federal Polytechnic Ilaro Ogun State, an environment dominated with the non-linear devices with a view to ascertain the level of penetration of these devices in the distribution system. Other places covered are religious centre and office building. Data on all electrical appliances in these places were gathered and classified into linear and nonlinear loads. Percentage of each was found and presented using pie chart. The result shows that the residential building has lowest percentage (5%) while religious centre has the highest percentage (79%) of non-linear and thus confirms that nonlinear loads are increasing which calls for attention. The stakeholders in electricity industries and market will find this information useful for planning and regulation purposes.

Key words: Non-linear devices, Harmonics, Power quality, Distribution network, Standards.

Aims Research Journal Reference Format:
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1. BACKGROUND TO THE STUDY

This paper is an extended version of paper "Mitigating the growing trend and threat of nonlinear devices in power system" Ogunyemi (2019). An attempt was made in the paper to identify the non-linear loads at a particular location. Addressing this problem becomes necessary because an electrical power system as a whole has continued to witness involvement of electronics devices in the utilization of electrical energy which has led to development of arrays of power electronic devices and emergence of Power electronics field. It is now of concern that summation effect of nonlinear device (NLD) in residential areas may exceed the required limit on distribution feeder (Olatoke, 2011). As the number of non-linear loads has increased within the network, power quality issues have continued to attract attention in the power industries (António, José, and Helder, 2011; Rao, et al, 2011; Witherden, 2012; Hota, and Nanda, 2014; Balasubramaniam, and Prabha, 2015).

Today, from flexible ac transmission system (FACTS) devices to custom power devices for distribution system, electronics devices continue to be the solution to power problems. Intelligent Electronic Devices that provide monitoring and controlling capabilities are on increase for security surveillance, data gathering, health monitor and host of others. (Design Guide for Rural Substation, 2001). Thus, there is an increase in the distortion of the distribution network due to continuous demand in the utilization of all kinds of electronic devices. Today, the call for power quality in the face of modern electronic devices very sensitive to poor power quality is becoming global affair. bBefore the advent of electronic, non-linear devices in power system was minimal and of no issue. However, since the electronics revolutions of fifties and sixties, electrical network has continued to witness growth of non-linear devices in electricity industries.

Sankara, (2002) estimated that more than 70% of the loading of a facility by year 2010 will be due to nonlinear loads. It has been reported that between 15-20% of the utility distribution load consists of NLLs in the USA (Mayoral, et al, 2017). The major concern is that this growth in the number of electronic devices has not been accompanied, in many cases, by an improvement in the quality of the electronic designs (Canteli, 2007). These devices have been reported to have twin effect of being affected by poor power quality and at the same time causing power quality problem Kuskos (2007). Of growing concern in power network is harmonic distortion level as these nonlinear loads are emerging as solutions to energy utilization and sustenance. Energy-efficient appliances such as microprocessor-controlled devices, CFL, SMPS, Uninterrupted Power Supply (UPS) and power-electronic interfaced loads which are finding increasing applications in electricity market are usually source of high odd harmonics. Any of these equipment installed anywhere in the system have an inherent property to generate continuous distortion of the power source that puts an extra load on the utility system and the components installed in it. CFLs with electronic gear are new on the scene of harmonic generators characterised by extremely distorted current with high THDI. They cause a significant distortion in electrical installations, when large quantities are installed in Commercial buildings. Figure 1 shows the deviation from the normal sine wave of a distorted waveform. Their maximum permissible share should not exceed the 10% limit as laid down by the International Standards. Table 1 shows the comparison between linear and nonlinear loads in terms of their strengths and weaknesses.

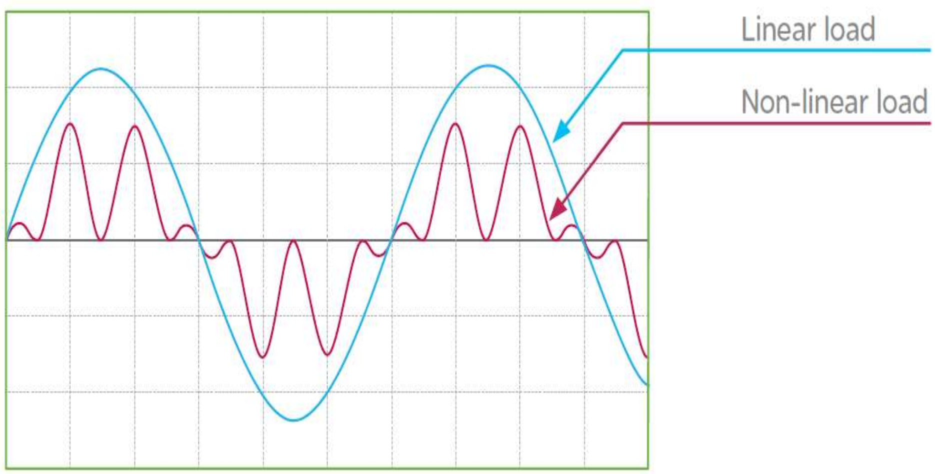

Figure 1: Linear and non-linear loads waveform (Schnieder, 2008)

Table 1: Linear versus Non-linear loads with disadvantages italicized (Ogunyemi, 2019)

S/N	Parameter		Linear	Non-linear
1	Load (Wattage)		*High*	Low
2	Efficiency		*Low*	High
3	Speed		*Low*	High
4	Size		*Bulky*	Compact
5	Weight		*Heavy*	Light
6	Economic cost	Initial	Low	*High*
		Overall	*High*	Low
7	Waveform	Sine wave	Pure	*Distorted*
		Quality	Good	*Poor*
8	Environmental impact		*Increasing pollution*	Reducing pollution
9	Power quality		No effect	*Degrade*

1.1 Statement of Problem

The increase in nonlinear devices in Nigerian's power system has not been fully address to ascertain their level of penetration for proper mitigating methods. Harmonic producing loads causing distortions of the normal electrical current waveform have not been fully assessed and characterized in Nigerian electricity distribution network.

1.2 Objective

The main objective of this paper is to identify and classify the harmonic producing loads in a distribution system

2. METHODOLOGY

As an extension of earlier work of Ogunyemi (2019) in which only one place was considered, this work examines three more locations in addition to the previous one. A comprehensive load survey of the area of study was carried out. Table 2 shows the grouped areas where loads surveys were carried out and types of loads in each area. The loads were also classified as linear and non-linear. The power consumptions were also analysed and presented. This involves evaluating the existing loads in each area of the study such as moving from one place to another, including the residential area, and an office to see composition of loads utilized in their daily activities.

2.1 The Research Design

The design is based on the load pattern of the distribution system which mainly consists of air conditioners, CFL, fluorescent lamp, PCs, etc (Table 2).

Table 2: Loads Classifications in the studied areas- NLLs shown in italics.

S/N	Location	Common loads	Major/Peculiar loads
1	Data Center (ICT) Fed Poly Ilaro	Lightings (*CFL*, FT INC), fans, A/Cs, *stabilizers, UPS, laptops*	*Computer systems, Server, Monitor/Projector, battery chargers for inverter*
2	Residential	Lightings (*CFL*, FT INC), fans, A/Cs, *stabilizers, UPS, laptops*	Oven, *Freezers*, Cookers, Electric kettles, *Television, Sound system, Satellite receiver, Radio, Chargers, Blenders/Mixers, Washing machines*
3	Offices/Biz Centre	Lightings (*CFL*, FT INC), fans, A/Cs, *stabilizers, UPS, laptops*	*Computer systems, Printers, Photocopier*
4	Religious Centre (Church)	Lightings (*CFL*, FT INC), fans, A/Cs, *stabilizers, UPS, laptops*	*Amplifier, Mixers Charging units, wireless mic &transmitter, Projector/Monitor, Satellite Receivers, stabilizer, UPS*

3. DATA PRESENTATION

3.1 Results of Load Survey

Table 3: ICT Centre's Loads estimation

Device	Qty	Type of load	Power Rating (W)	Total Power (W)
AC	18	Linear	1100	19800
Fan	60	Linear	90	5400
CFL	32	*Non-linear*	26	832
Thin Client Comp.	200	*Non-linear*	45	9000
Monitor	71	*Non-Linear*	180	12780
C.P.U	74	*Non-Linear*	120	8880
Stabilizer (500VA (9p5% efficiency)	72	*Non-Linear*	25	1800
U.P.S (500VA) (i.e. 95% efficiency)	72	*Non-linear*	25	1800
Laptop	3	*Non-linear*	75	225
Switch	2	*Non-linear*	7	14
Router	1	*Non-linear*	12	12
Fluorescent lamp	30	Linear	40	1200
Total				61,743
Load characteristics				

	Linear Loads (W)	Nonlinear loads (W)	
	26,400 (43%)	35,343 (57%)	

Table 4: Residential Loads estimation

S/N	Items	Qty	Type of load	Rating (W)	Total Power (W) Installed
1	Refrigerator	1	Linear	120	120
2	Freezer	1	Linear	400	400
3	Incandescent Bulb	13	Linear	60	780
4	Ceiling Fan	3	Linear	60	180
5	Hot plate	1	Linear	1500	1500
6	Blenders	1	Linear	500	500
7	Computer system	1	*Non-linear*	120	120
8	Laptop	1	*Non-linear*	65	65
9	Pressing iron	1	Linear	1000	1000
10	DVD player	1	*Non-linear*	20	20
11	Monitor	1	*Non-linear*	150	150
12	C-way water dispenser	1	Linear	600	600
13	Water pump	1	Linear	750	750
14	Washing machine	1	Linear	500	500
	Total				**6930**
	Loads characteristic				

	Linear loads (W)	Nonlinear loads (W)	Total (W)
	6330 (95%)	355 (5%)	6685

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Table 5: Office building Load's estimation

S/N	Items	Qty	Type of load	Rating (W)	Total Power (W) Installed
1	Incandescent Bulb	8	Linear	60	480
2	Ceiling Fan	1	Linear	60	60
3	Computer system	3	*Non linear*	120	360
4	Laptop	3	*Non-linear*	65	175
7	DVD player	1	*Non-linear*	15	15
8	Monitor	4	*Non-linear*	120	480
10	Printer	1	*Non-linear*	50	50
11	Water pump	1	Linear	750	750
	Total				**2370**

Loads characteristic

	Linear load (W)	Nonlinear loads (W)	**Total (kW)**
	1290 (54%)	1,080 (46%)	**2370**

Table 6: Religious Centre Loads estimation

S/N	Items		Qty	Type of load	Rating (W)	Power (W) Installed
1	CFL	Small	3	*Non-linear*	11	33
		Medium	17	linear	26	442
2	Fan	Ceiling	4	linear	75	300
		Standing	2	linear	60	120
		Wall	4	linear	20	80
3	Computer system		1	*Non-linear*	120	120
4	Laptop		2	*Non-linear*	65	130
7	DVD player		1	*Non-linear*	15	15
8	Monitor	Plasma 32'		*Non-linear*	160	320
		LED 15'		*Non-linear*	65	65
10	Rechargeable lamps*		10	*Non-linear*	5	50
11	Phone chargers	2A		*Non-linear*	7	140
		1A	30	*Non-linear*	4	120
12	Amplifier	Big	1	*Non-linear*	250	250
		Small	1	*Non-linear*	150	150
13	Receiver		5	*Non-linear*	5	25
	Total					**2360**

Loads characteristic

	Linear loads (W)	Nonlinear loads (W)	**Total (W)**
Operating	315	1258	1573
Installed	**500**	**1860**	**2360**

4. DISCUSSION OF FINDINGS

From the survey carried out, the percentage of the nonlinear loads and that of the linear loads could be easily seen. Apart from residential with lowest percentage of nonlinear loads, others have significant nonlinear loads. The highest is that of religious centre with 79% nonlinear loads. This is expected because most of the equipment are electronics nonlinear loads including lighting. Obviously due to poor power supply, many worshippers are quick to find any available means to recharge their appliances. The second on the list is ICT section with nonlinear loads of 57%. This is also expected as some of the loads are known for harmonic production. A good example is that of switch mode power supply (SMPS) which is very rich in third harmonics. Next and third on the list is that of an office building with 46% nonlinear loads. The least load of residential reflects low level of automation and applications. These scenarios are represented in the figures below:

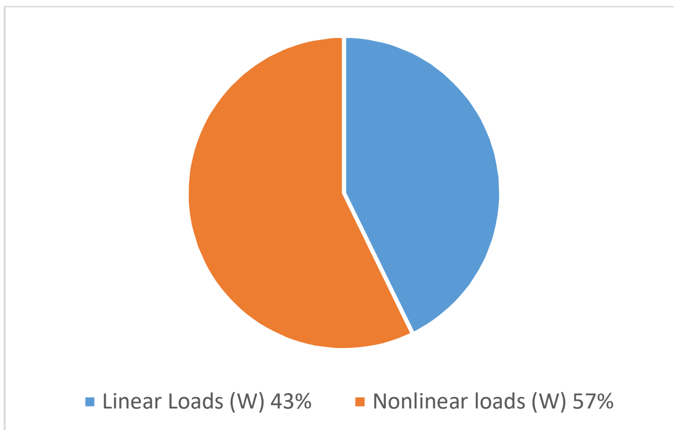

Figure 2: ICT center

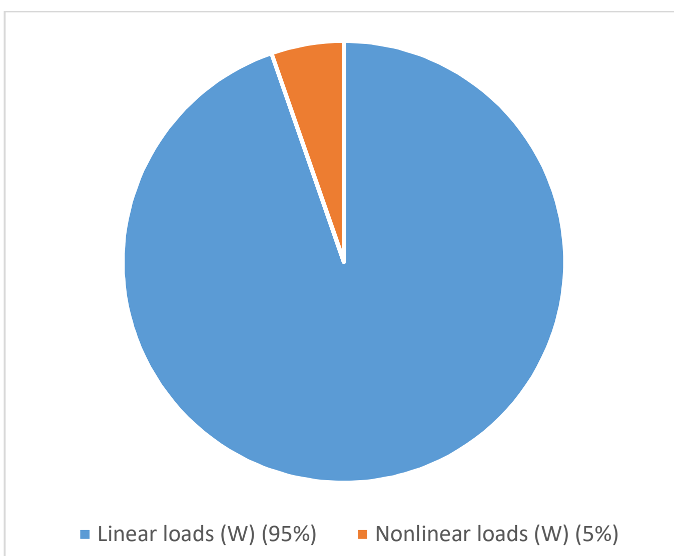

Figure 3: Residential building

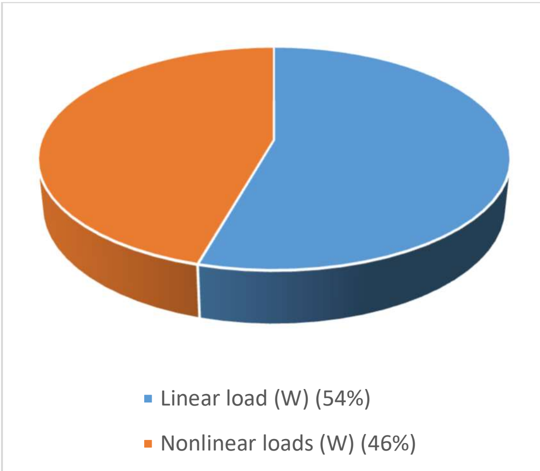

Figure 4: Office building

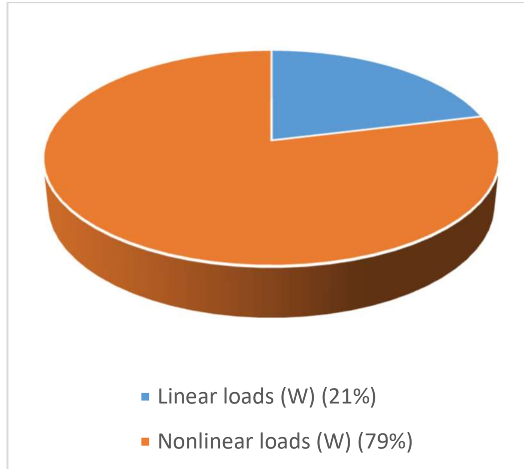

Figure 5: Religious centre

The ratio of nonlinear loads in this study can be approximated as 5: 50: 60:80 for residential, office, ICT and religious center respectively. In simplest term, it is 1:10:12: 16. Neglecting that of the residential and considering only the rest; the ratio is 5:6:8. It should be noted that there is potential for more nonlinear loads in these places of study. For instances, one of the reasons while the religious centre has the highest value is because all the lighting loads are energy saving. Places like residential and office with 780W and 480W incandescent lamps respectively could have been replaced with energy saving equivalent of 338W and 208W using 26W CFL to replace 60W. This could have increased the nonlinear to 11% and 61% respectively. Similarly, some of the motorized appliances has potential for increasing percentage of nonlinear loads as they are now driven by variable speed drive (VFD) a major source of pollution in industrial loads.

5. CONCLUDING REMARKS

The large-scale introduction of active power electronic devices in distribution network is considered to be posing a threat to electric power system (EPS). The old traditional electrical power system which is an interconnection of generating sources and customer loads through a network of transmission line, transformer and ancillary equipment are witnessing the entrance of power electronics devices to address salient issues. There is therefore need to be properly monitored and regulated to reduce their side-effects as well. This paper has examined the penetration of these devices in a distribution network. The results obtained from the sites show that these non-linear devices are increasing and can become threat to power system in the nearest future if not mitigated. There is need therefore for more action to address the problem. As recommendation, there is need for data gathering and continuous monitoring of power quality to ensure healthy power system

6. CONTRIBUTIONS TO KNOWLEDGE

This paper has been able to identify the depth of penetration of energy saving electronic devices which are nonlinear in nature in a distribution network. Such knowledge is very important for planning and control of power quality.

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