Assessment of Growing Trend of Non-Linear Devices in Electrical Power System's Applications

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ABSTRACT

The application of electronics non-linear devices in the utilization of electrical energy has continued to witness unprecedented growth. To conserve energy, reduce cost and environmental pollution; electronics solutions are employed globally. However, the negative impact of these devices on the power system as a whole has been attracting attention. This is because they degrade the quality of the power network by distorting the waveforms. This paper highlights this growing trend and call for concerted efforts to mitigate the problems. As a case study, a survey was carried out at the Information Technology Centre (ICT) 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. The result shows that the percentage of non-linear loads is increasing and calls for attention. Adequate measures to mitigate their impacts are highlighted.

Keywords: Non-linear devices, Harmonics, Power quality, Distribution network, Standards

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1. INTRODUCTION

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. This has continued to attract attention in the power industries (António, José, and Helder, 2011; Rao, Reddy, and Ram, 2011; 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. FACTS device is to enhance power transfer capabilities of transmission network by making them electronically controllable. 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).

The spectacular growth that has occurred during the last two decades in the utilization of in almost all kinds of electronic devices has given rise to an increase in the distortion of the distribution network. Today, the call for power quality in the face of modern electronic devices very sensitive to poor power quality is becoming global affair. Before 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. 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. Their maximum permissible share should not exceed the 10% limit as laid down by the International Standards.

2. NON-LINEAR DEVICES IN POWER SYSTEM

Sine wave power is thought to cause fewer problems and is generally preferred for sensitive electronic equipment. Non-linear devices are devices which draw non-sinusoidal waveform current and thus leading to distortion in the network. This is popularly referred to as electrical pollution as it degrades the quality of the power. The output waveform of non-linear device must be considered when evaluating their use. The THD of an output waveform can be used as a tool for evaluating a power source. Fig 1 shows the waveforms for sinusoidal and distorted signal.

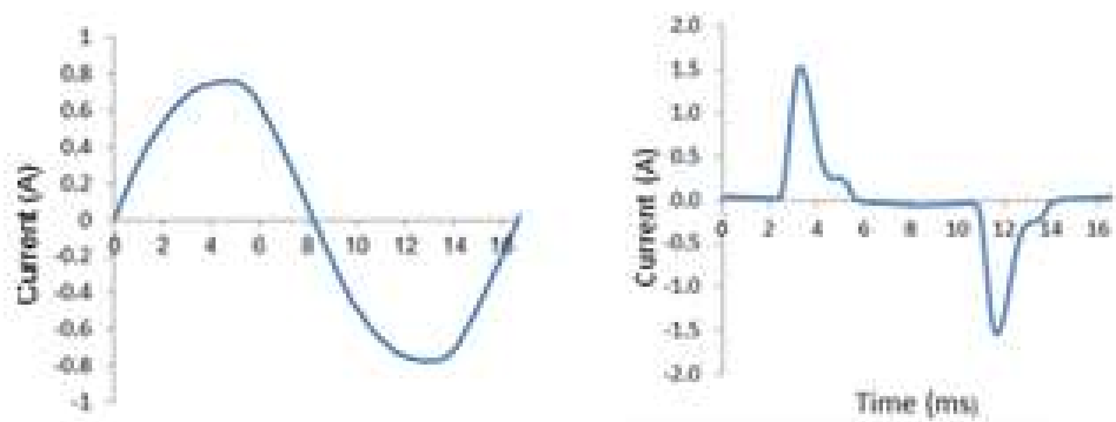

Fig 1: sinusoidal wave vs distorted wave

Table 1 summarizes the pros and cons of linear and non-linear devices in power system applications.

Table1: Comparison between linear and non-linear devices

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

2.1 Examples of non-linear devices

Among the types of equipment that both can cause power quality problems, and are susceptible to them, are i) High efficiency energy saving lamp ii) Adjustable speed drive (ASD) or variable frequency drive (VFD) iii) Switch mode power supply (SPMS) iv) Microprocessor controlled devices v) Industrial equipment (welding machines, arc s, and other arc devices, furnaces) vi) Uninterruptible Power Supplies (UPSs) vii) Rectifiers viii) Office equipment (computers, photocopy machines, fax machines, etc.) ix) Home appliances (television sets, micro-wave ovens, fluorescent lighting) x) Certain devices involving magnetic saturation (transformers), xi) Battery Chargers xii) Electronic Dimming Systems, Lighting Ballasts (esp. Electronic) xiii) Medical Equipment, e.g. MRIs and X-Ray Machines

2.2 Harmonics and their impacts

Harmonics are a distortion of the normal electrical current waveform, generally transmitted by nonlinear loads are often the cause of poor power quality. Some equipment and appliances are affected by significant levels of harmonics. Single-phase non-linear loads are prevalent in modern office buildings, while three-phase, non-linear loads are widespread in factories and industrial plants. A large portion of the non-linear electrical load on most electrical distribution systems comes from SMPS equipment. For example, all computer systems use SMPS that convert utility AC voltage to regulated low voltage DC for internal electronics. These non-linear power supplies draw current in high-amplitude short pulses that create significant distortion in the electrical current and voltage wave shape—harmonic distortion, measured as total harmonic distortion (THD). The distortion travels back into the power source and can affect other equipment connected to the same source.

Most power systems can accommodate a certain level of harmonic currents but will experience problems when harmonics become a significant component of the overall load. As this higher frequency harmonic currents flow through the power system, they can cause communication errors, overheating and hardware damage, such as: overheating of electrical distribution equipment, cables, transformers, standby generators, etc.) High voltages and circulating currents caused by harmonic resonance) High neutral currents that generate heat and waste energy) Equipment malfunctions due to excessive voltage distortion) Increased internal energy losses in connected equipment, causing component failure & shortened life span) False tripping of branch circuit breakers) Metering errors) Fires in wiring and distribution systems) Generator failures) High crest factors and related problems) Lower system power factor, resulting in less usable power (kW vs. kVA) and penalties on monthly utility bills.

One of the effects of the harmonic distortion is that it reduced service life of equipment. For voltage distortion of 10%, the reduction in service life of equipment has been estimated at 32.5% for single-phase machines; 18% for three-phase machines and 5% for transformers and also, generator supplying non-linear loads (NLDs) must be de-rated by 10% for 30% of NLD (Schneider Electric, 2010). Perhaps this explains why many of the generators in the Business centre may not last when the percentage is exceeded.

3. STANDARDS & REGULATIONS ON POWER QUALITY

Standards exist to regulate the impacts of electronics devices. The development of standards can help to keep the disturbances due to these non-linear devices within the limits. There are various standards and regulations across the globe on power quality. Fig 2 shows modern power system with electronic solutions and standards for regulation as well. Obviously, in standards, the tendency in the setting up compatibility levels, e.g. for the voltage harmonics, shows a direct convergence to the increasing number of harmonic sources. The stakeholder in power system -utilities, equipment manufacturers and system designers all share responsibility for power supply conditions (GAPS Guideline, 2015). There are several standards that describe power quality requirements for utilities, including IEEE 1150-1995 and IEC 61000, the average household is unaware of the quality of power.

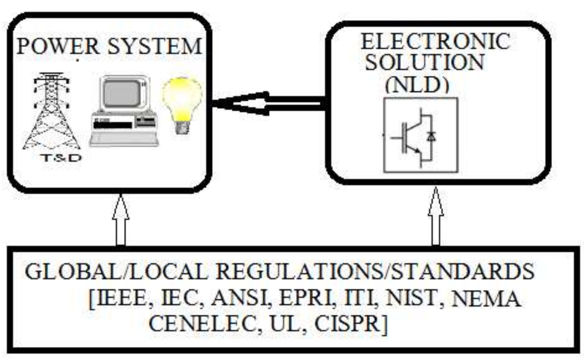

Fig 2: Modern Electrical Power System solutions (Ogunyemi & Adetona, 2018)

Some of the Power Quality Related Standards of the IEEE are shown in table 2.

Table 2: Common IEEE Standards on Power Quality

S/N	Standard	Description
1)	IEEE 1433	Power Quality Definitions
2)	IEEE 1159	Monitoring Electric Power Quality
3)	IEEE P1564	Voltage Sag Indices
4)	IEEE P1453	Voltage flicker
5)	IEEE 519	Harmonic Control in Electrical Power Systems
6)	IEEE 446	Emergency and Standby Power
7)	IEEE 1001	Interface with Dispersed Generation
8)	IEEE 1100	Power and Grounding Electronics
9)	IEEE 1250	Service to Critical Loads
10)	IEEE 1346	System Compatibility in Industrial Environments
11)	IEEE 1366	Electric Utility Reliability Indices

4. CASE STUDY

In this case study, survey of various loads in the ICT buildings was carried out. Statistics of all the loads with classification into either linear or non-linear were done. Two sites were chosen at the West Campus of the Federal Polytechnic Ilaro. The wattage rating of each load was taking and percentages of both linear and non-linear loads were calculated. Measurements of the waveforms were done with Power and harmonic analyser (DW 6095).

5. RESULTS & DISCUSSION

Table 3 and 4 show the equipment rating at the two location with the pie chart illustration in figure 3 and 4 respectively.

Table 3: Number of equipment and their power ratings

S/N	Equipment	Quantity	Type of load	Power rating(W)	Total Power (W)
1	Long double florescent	14	Non-linear	80	1120
2	Energy Saving Light(CLF)	46	Non-linear	26	1196
3	Incandescent bulb	11	Linear	100	1100
4	Electric Ceiling Fan	27	Linear	90	2430
5	Panasonic outdoor AC	13	Linear	1750	22750
6	System unit(C.P.U)	95	Non-linear	120	11400
7	Monitor	95	Non-linear	150	14250
8	Projector	2	Non-linear	650	1300
9	Small florescent bulb	2	Non-linear	40	16
10	Server room C.P.U	1	Non-linear	180	180
11	Server room Printer	1	Non-linear	600	600
12	Laptops	2	Non-linear	75	150
Total					56,524

$$\% \text{ of Linear load} = \frac{1100+2430+22750}{56,524} \times 100$$

$$= 46.5\%$$

% of Non-linear Load = (100- 46.5) % = 53.5%

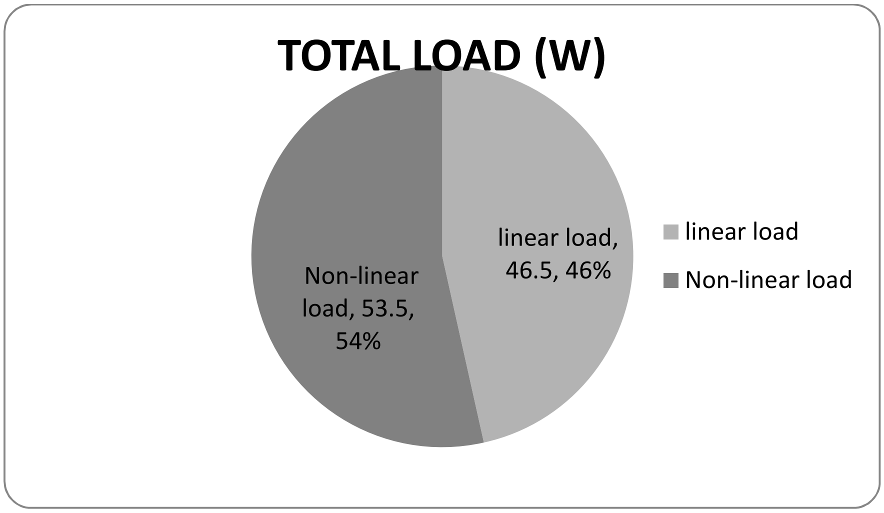

Fig.3: Percentage of linear and Non-linear loads in the PTDF ICT centre

Table 4: Equipment and their Power Ratings

s/n	Device	Quantity	Type of load	Power Rating (W)	Total Power (W)
1	Air Conditioner	18	Linear	1100	19800
2	Fan	60	Linear	90	5400
3	CLF	32	Non-linear	26	832
4	Thin Client Comp.	200	Non-linear	45	9000
5	Monitor	71	Non-Linear	180	12780
6	C.P.U	74	Linear	120	8880
7	Stabilizer(500VA)	72	Linear	25	1800
8	U.P.S (500VA)	72	Non-linear	25	1800
9	Laptop	3	Non-linear	75	225
10	Switch	2	Non-linear	7	14
11	Router	1	Non-linear	12	12
12	Fluorescent	30	Non-linear	40	1200
Total					61,743

Percentage of Linear Loads = $\frac{5400+19800+1800}{61,743}$ X 100 = = 43.7%

% of Non-linear Loads = (100 – 43.7) % = 56.3%

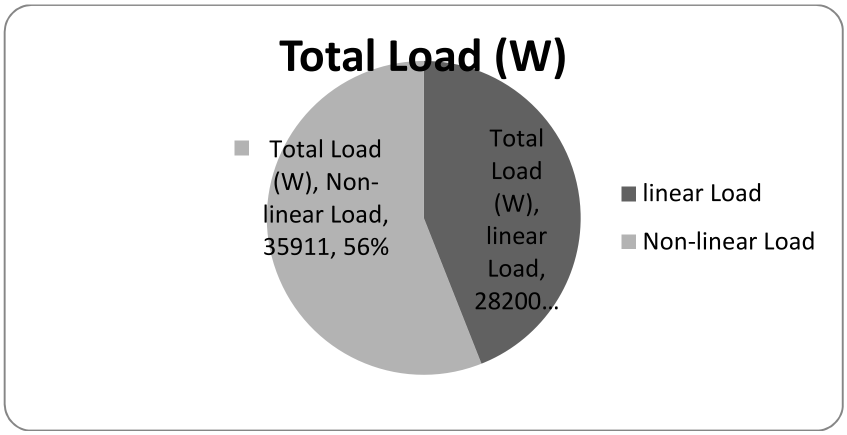

Fig.4: Percentage of Linear and Non-linear Load in the Multimedia Centre

Fig 5 shows the waveform display due to a single laptop measured with power and harmonic analyser DW 6095. The highly distorted waveform with crest factor of 5.247 is far from ideal pure sinusoidal waveform. The resultant effect of many of such devices is shown in fig 6. The linear load in the system reduces the overall distortion in the system

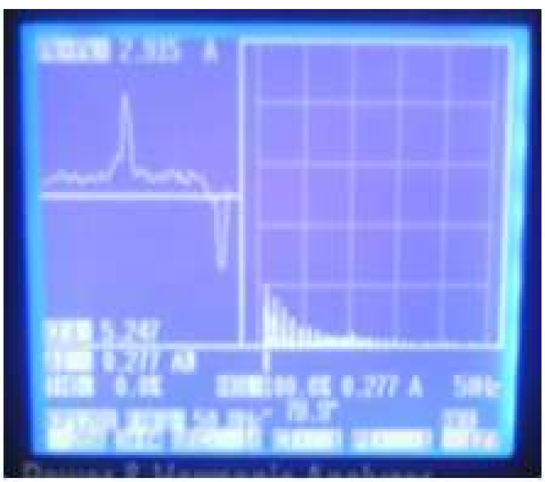

Fig.5: Waveform & Harmonic distortion of a single laptop **Fig. 6: Wave distortion due to multiple NLD**

6. CONCLUSION

The old traditional electrical power system which is 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. However, these devices need to be properly monitored and regulated to reduce their side-effects as well. This paper has examined the distribution network to ascertain the impact. The results obtained from two sites measurement that these non-linear devices are threat to power system in the nearest future if not mitigated. There is need therefore for more action to address the problem

7. RECOMMENDATIONS

i. There is need for continuous monitoring of power quality to ensure healthy power system
ii. There is need for data on increasing influx of electronics non-linear loads and their distributions in the power network for analysis and policy formulation.
iii. Derating of existing transformer supplying large number of non-linear devices. When it is necessary to maintain the service lives corresponding to the rated load, equipment must be oversized.
iv. The use of special transformer in highly dense non-linear devices environments to replace normal conventional ones
v. Local standards should be strengthened to complement the international standard on power quality. Statistical approach to reliability monitoring will also assist the regulators to set more optimum performance standards.

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