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Electricity Theft and Power Quality in Nigeria

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***Abstract*— There are two component of losses in power system (technical and non technical). The technical losses consist of losses from the transmission line, losses from transformer, measurement systems, etc. There are other losses that are outside the control of the utility provider comprising of electricity theft, non settlement of bills by customers, error in accounting and record keeping. Electricity theft is difficult to estimate. The regulatory instrument (Electricity Theft and Other Related Offences Regulations) was formulated by Nigeria Electricity Regulation Council in 2013 to deter electricity theft, and the destruction of electricity supply infrastructure but this has not have any effect on the rate of electricity theft and electricity vandalism in Nigeria. Electricity theft can be in the form of fraud (meter tampering), stealing (illegal connections), billing irregularities, and unpaid bills. The importance of the eradication of electricity theft cannot be over-estimated especially given our power generation and transmission deficit and the need to attract significant capital investments in order to improve availability, access and service delivery in the industry. The theft of electricity poses significant dangers to all concerned. It can damage equipment and cause power outages, and it costs everyone who is paying for the power they use. This paper discusses the effect, consequences and measures to control electricity theft to improve power quality.**

Keywords: Electricity theft, Metering, Technical, Non-Technical and Power quality

I. INTRODUCTION

Power theft is one of the most prevalent issues which not only cause economic losses, irregular and inadequate supply of electricity but also lead to poor power quality. It hampers functioning of equipment, industries and factories, and shortage of power supply to homes due to shortage of power supplied to them. It leads to loss of revenue by Government as individual enterprises and reliability on other source of power supply which are either more expensive to set up or expensive to maintain.

The Managing Director, Frontier Oil and Gas Limited, Thomas Dada, has said 40 per cent of generated electricity in the country is lost to theft and that a lot of people who use electricity do not pay for it [1]. He called for the regional distribution system, saying that part of the problem of the sector is that there is huge amount of power loss due to the centralization of the grid system as well as transmission.

He said: "If we can address the centralization of the grid system, by decentralizing the transmission system to be regional rather than central, we should go back to regional distribution system and people can offload to another system if they got excess capacity in their region. Again, we need to stop electricity theft by prosecuting those who steal electricity, those who by-pass meters, and those who use it without paying for it."

According to him, these energy thieves are not only shortchanging the distribution companies but also the entire nation. He added that it is affecting everybody that has invested in the power sector

Dada accused the workers of complicity in the sabotage, adding that they are responsible for sending out estimated bills and colluding with customers to steal electricity.

According to a recent study, with the adoption of the Smart Grid and smart meters, though, utilities are introducing new technologies to detect meter tampering and reduce electricity theft global losses from electricity theft in 2015 totaled US$89.3 billion. India led the way ($16.2 billion in losses), followed by Brazil ($10.5 billion) and Russia ($5.1 billion) [2]

Electricity stealing acts will not only bring economic losses to the state and the power sector, interfering with normal supply order, but also cause fire, destroy power supply units and cause widespread power outage, threatening power grids and public security [3, 4].

A large percentage (perhaps, 50-60%) of these losses can be attributed to energy theft - people consuming power without paying for it. This can happen either inadvertently or deliberately. Inadvertently because the power companies are not metering and collecting the payment. This is usually a smaller percentage because the power companies simply use estimated billing to cover for the unmetered consumers. The deliberate stealing of electricity is widespread and happens through various schemes including - direct connection to the overhead low tension distribution cables, bypassing the meter so that only a small load is connected to it while the rest are connected directly to the supply behind the meter or tampering with the meter to make its reading inaccurate. The deliberate stealing of electricity is more often than not aided and abetted by experienced (current or past) technicians who understand how the systems work [5].

Electricity thieves can be found in nearly every country across the globe, including the U.S. Whether it's performing illegal hookups or tampering with meters over $200 billion in electricity is lost each year due to equipment failure or electricity thieves. In the U.S. alone, this crime costs roughly $6 billion annually, which makes it the third most stolen commodity following credit card information and vehicles [6].

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In these instances, the uses of smart meters which are able to send their status readings to a central server are easily outfoxed. The smart meter will only have records of the electricity passing through the network it is connected to. If it is bypassed, or the connection is directly to the distribution line, the smart meter is unable to detect and report the anomaly. When the meter is itself tampered with by experienced technicians, they may also be able to fool the meter into not reporting the breach. Smart meters depend on being able to communicate their status to a central server which can then analyze the information and hopefully be able to infer thefts using different algorithms. Considering the amount of data each meter produces, few organizations can afford the computing power needed to execute these algorithms in near real time.

II. POWER QUQLITY

Power Quality is often confused with the supply disturbances, which are not the only factors that characterize the Power Quality issue. “Power Quality Supply” is a complex term and indicates the Power Quality industry has come a long way in the past years with identifying power quality problems. The first hurdle needed to overcome was defining exactly when power quality problems occur and how to define them. The IEEE is the most often used source for electrical standards when dealing with power quality. The IEEE stands for "The Institute of Electrical and Electronic Engineers".

Power quality is defined in the IEEE 100 Authoritative Dictionary of IEEE Standard Terms as The concept of powering and grounding electronic equipment in a manner that is suitable to the operation of that equipment and compatible with the premise wiring system and other connected equipment Utilities may want to define power quality as reliability [7].

Power quality can be defined by some normative terms described with the following parameters

i. Power frequency
ii. Magnitude of the supply
iii. Supply voltage variation
iv. Rapid voltage changes
v. Supply voltage dips
vi. Short interruption of supply voltage
vii. Long interruption of supply voltage
viii. Temporary power frequency over-voltages between live conductors and earth
ix. Transient over-voltages between live conductors and earth
x. Supply voltage imbalance
xi. Harmonic voltage
xii. Inter-harmonics voltage
xiii. Mains signaling voltage of the supply voltage.

Therefore, the IEEE uses specific terminology to define power quality problems. They are the following: Over voltages, under voltages, Sags, Swells, Transients, Noise, Harmonics, and Grounding as shown in figure 1.

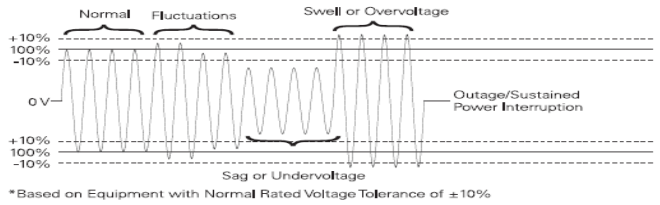

Figure 1: Disturbances

Electricity theft creates situations where power flows through the lines is not as expected. This creates power surges, sag, swell, outages and system failures due to high loads which can also lead to greater possibility of fires and even explosions. Electricity theft can cause any of the listed power quality issue shown in figure 1.

Sag: A sudden decrease in voltage that lasts less than a minute.
Swell: A sudden increase in voltage that lasts less than a minute.
Overvoltage: A voltage greater than that at which a device or circuit is designed to operate.
Under voltage: A voltage which is below the optimum, operational, or rated value of a component, circuit, device, piece of equipment, machine, or system. Such a voltage may produce, for instance, distortion, a malfunction, or failure. In computers and similar devices, under voltages can lead to data losses.
Harmonics: Electric voltages and currents that appear on the electric power system as a result of non-linear electric loads. Harmonic frequencies in the power grid are a frequent cause of power quality problems.
Transient: A temporary excess of voltage and/or current in an electrical circuit which has been disturbed.
Noise: Any electromagnetic disturbance that interrupts, obstructs, or otherwise degrades or limits the effective performance of electronics and electrical equipment.
Grounding: Providing a conductor that directs excess electric current to the Earth to dissipate the buildup of hazardous voltages that would otherwise result in damaging electrical shock to people, property & equipment.

Fig. 2 illustrates mutual responsibility sharing on power quality aspects among the network operator, the customer and the equipment manufacturer.

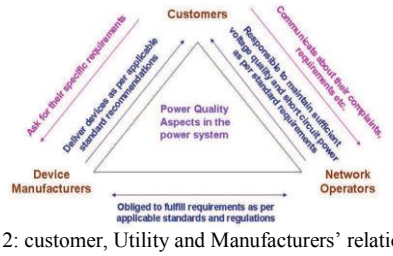

Figure 2: customer, Utility and Manufacturers’ relationship

Customers are those consumers who have a commercial relationship with the electricity supplier within the applicable regulatory framework. Users of electricity, on the other hand, include customers as well as those who are not customers but nevertheless consume electricity through theft or by unofficial diversion from another customer

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III. WHAT IS ELECTRCITY THEFT?

In electricity supply to final consumers, losses refer to the amounts of electricity injected into the transmission and distribution grids that are not paid for by users. Total losses have two components: technical and non-technical. Technical losses occur naturally and consist mainly of power dissipation in electricity system components such as transmission and distribution lines, transformers, and measurement systems. Non-technical losses are caused by actions external to the power system and consist primarily of electricity theft, non-payment by customers, and errors in accounting and record-keeping. Electricity Theft is the use of power without a contract with the supplier with total or partial bypassing metering system. Theft of electricity is also the criminal practice of stealing electrical power. It is a crime and is punishable by fines and/or imprisoned.

B. Causes Of Electricity Theft

i. Irregularities in the billing system
ii. Absence of accountability
iii. Inadequate and ineffective enforcement of law
iv. Political protection of employees and influential customers
v. Customer attitude: "Immoral to steal from neighbour".
vi. Unemployment

C. Types of Electricity Theft

There are various types of electrical power theft, including Tapping a line or bypassing the energy meter. Electricity theft occurs in private dwellings, on commercial and industrial premises. The various types of electrical power theft include:

i. Direct Hooking/Tapping from Line

Hooking/tapping is the most used method as shown in figure 3.1a. The consumer taps into a power line from a point ahead of the energy meter. This energy consumption.

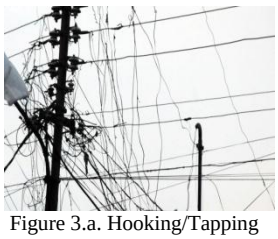
Figure 3.a. Hooking/Tapping


Figure 3.b. Tampering with the meter

ii. Tampering With the Meter (Bypassing the energy meter, Injecting foreign element into the energy meter and Physical obstruction)

In this method, the input terminal and output terminal of the energy meter is short-circuited, preventing the energy from registration in the energy meter [5] as shown in figure 3.1b

Meters are manipulated via a remote by installing a circuit inside the meter so that the meter can be slowed down at any time. This kind of modification can evade external inspection attempts because the meter is always correct unless the remote is turned on.

This type of tampering is done to electromechanical meters with a rotating element. Foreign material is placed inside the meter to obstruct the free movement of the disc. A slower rotating disk signals less energy consumption.

iii. Billing Irregularities by the meter readers

iv. Unpaid bill by individuals, government institution and very important persons (Very Important persons)

IV. DANGERS OF ELECTRICITY THEFT

Dangers to people: Illegal connections to power lines are never safe, as they haven't been installed by professionals. They're a danger to anyone who may come into contact with them, especially young children.

In emergency situations, such as fires, electricity needs to be shut off to permit firefighters and other emergency personnel to do their jobs safely. Power lines that have been compromised by theft measures can stay energized even when emergency responders think they've been shut off. Employees who work on the power lines are at risk from electricity theft.

Dangers to property: Power surges due to electricity theft can damage the wiring in your home and can lead to electrical fires. The overloads can also harm your electrical equipment and appliances.

Dangers to the electrical system: High loads that occur with electricity theft cause power surges and electrical system failures. This damages transmission equipment and infrastructure, what we call the grid, and can lead to the premature failure of expensive electrical transformers and system collpase**.**

Danger to the Economy: When the distribution companies who are at the end of gas to power value chain are not making sufficient income, they are unable to make profit which implies, ultimately, that part of the value chain that is the gas producers who produce the gas that is used by the generation companies to generate the power that is sold to the people, don't make enough money. The adversely affect the economy of the state and the entire nation.

V. CONSEQUENCES OF ELECTRICITY THEFT

Poor power quality, Network infrastructure challenges (Overloading of the transmission line, feeders and transformer), Fire, Loading Shedding/ Grid energy insufficiency and instability, Equipment failure/ damages, Death, Irregular supply, Fault, Tariff challenges and revenue shortfalls (non-cost reflective tariffs, low collection efficiency, Metering challenges (huge metering gap, estimated billing, poor meter maintenance, etc.), Operational challenges (long

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feeders, quality of workforce, large operational areas, etc.), Funding challenges and Unemployment.

VI. WHY ARE WE CONCERNED

Electricity theft is a threat to the entire value chain. Although its impact is borne substantially by the Discos (Distribution companies) in terms of loss of revenue, the overall effect of theft of electricity affects the value chain in totality. Distribution companies recently published that it loses N21 billion annually to theft of power, thus amounting to an estimated average of N231 billion for the entire industry. The impact of such criminal activities robs legal customers of available electricity and ultimately, returns on investment to the companies. The quality of power being delivered to the users is affected due to this illegal activity, someone tampering with the connections either on the transformer, at the metering point or on the transmission line. The losses caused by these electricity related offenses are resulting in distortions which are of significant magnitude, such that distribution companies are unable to property account for the energy allocated to them

VII. SUSPICIOUS SIGNS OF ELECTRICITY THEFT

You can help identify electricity theft by being aware of your neighbours and your neighbourhood. Notice strangers who may be hanging around and recognize suspicious activity and objects.
Signs of electricity theft are usually found on electrical wires and electricity meters:

Is the metal tag on the meter broken?, Are there cut wires sticking out of the meter?, Are there numerous wires or cables coming out of the meter?, Are there strange objects or tools jammed in the meter?, Is the meter missing?, Is a meter being worked on by someone who's not a Utility provider's staff?, Are there wires that are cut or hanging off the power line itself? And Are there lots of extension cords snaking across a property for weeks at a time?

VIII. POWER THEFT MODEL

Power loss can also be expressed as the difference between the transmitted power and received power. i.e.

Ploss (Technical and Non Technical)= PowerSent– PowerReceived (1)

Ploss (Theft))= Ploss (Technical) – Ploss (other non Technical) (2)

VII. MEASURES TO CONTROL ELECTRICITY THEFT

The measures can be divided into two, technical and non technical.

A. Non Technical measures are:

Consumer Education and Enlightenment**:** There is a need to educate electricity consumers on the fundamentals of the electricity sector and the importance of fighting the crime of electricity theft. The preconceived notion by the average Nigerian consumer that power is a social good has to be erased from the minds of consumers via enlightenment initiatives in order to wean them off the entitlement mentality that drives power theft.

Laws and Regulations prohibiting Electricity Theft**:** The Laws and Regulations frown against electricity theft and impose stiff penalties for [8].

National Anonymous Tip Line**:** Customers must also be actively engaged and provided with opportunities across multiple communication channels to report incidences of electricity theft anonymously.

Publicity of cases of theft detected through inspection. This has been shown to be a very effective tool, as large consumers are in general well known and have much to lose if their fraudulent behavior is exposed. They steal electricity until the utility decides to "name and shame" the customer, because the cost of social condemnation far exceeds the savings from not paying fully for electricity consumption.

Training Programmes and Workshops for Judges**:** Organised training programmes should be developed for Judges that will be designated to handle such electricity related matters in order to help acquaint judges with the commercial, legal, regulatory and certain technical framework peculiar to the electricity industry.

Engagement with Security Agencies**:** Active engagement of the distribution companies with the relevant security agencies within their respective distribution zones needs to be undertaken to ensure collaborative efforts in tackling electricity theft.

B. Technical measures

Implementation of Advanced Metering Infrastructure: Remote metering, reading, and monitoring of electricity consumption referred to as advanced metering infrastructure (AMI).

Smart Meter**:** Smart meters consist of two units: the metering device and a display unit that is at the consumer's place. Smart meters are good for the distribution firms, as they can detect unusual and heavy demand powers, which may point to a tapping of wires.

Make the supply lines, underground. It has lots of pros, in a place which is not prone to frequent erosion or landslides etc.

Alternate, isolated and green sources of power (solar, wind hybrid) should be developed and encouraged.

Make the process to get a new electrical connection very simple and prompt by ensuring proper survey is carried out before hooking up any household to the national grid.

Customer load analysis should be carried out regularly.

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The use of Global mobile system to read and communicate electricity to the central server which help in monitoring the electricity consumption by the customer.

VIII. CONCLUSION

The importance of the eradication of electricity theft cannot be over-estimated especially given our power supply deficit and the need to attract significant capital investments in order to improve availability, access and service delivery in the industry. With the right signals and messages in place, consumers would be mindful of the impact of such criminal activities on the entire electricity value chain. More importantly, revenues that would accrue from the incidents of the crime would be otherwise diverted by the Discos to undertake investments that will assure stable power supply which would ultimately result in the growth and development of the Nigerian economy.

The unauthorized users of electricity fall into two general categories: those who are unable to pay; and those who are able to pay but choose not to. Strategies must therefore be developed to focus on the distinct categories. The people who can afford to pay and choose not to pay, do so for pure investment reasons. The benefits of not paying outweigh the risk of being caught and adequately penalized.

If the theft is taking place internally (namely by an owner or tenant in a complex), the Utility must take action to correct the bypass, which might require the intervention of the property owner (if he is not the tenant), the police, or even an order of court if the tenant refuses to allow the meter to be corrected.

Where a meter has been bypassed or where a meter is faulty and is not recording the consumption, the utility provider should replace the meter with one that is working, and take readings for three months of the consumption. Then consumption is then averaged across those three months, and an average monthly consumption figure arrived at, which is applied per month to the entire period during which the theft (or non-metering) took place.

Reducing, and eventually eliminating, this unlawful activity is one reason why utilities want to install more advanced power meters. Recording consumer data on a regular basis will assist utilities in detecting any unusual activity, therefore decreasing the amount of money utilities lose.

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