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The Effects of Technical and Non-Technical Losses on Power Outages in Nigeria

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Abstract - Adequate and reliable electricity supply is widely accepted as a sine qua non for the rapid socio-economic development of any nation. Researchers, over the years, have attributed electricity supply failures mostly to dilapidated electrical equipment, poor maintenance culture etc. Only a few considered the contributions of transmission and distribution losses to frequent power outages. This paper fills the gap by focussing on the effects of technical and non-technical losses on power outages in Nigeria. This study emphasizes the need for more radical measures than are currently being applied to reduce system losses and make the nation's electric power system holistically more efficient.

Index Terms— Distribution losses, Electricity supply, Power outage, Power system, Transmission losses,

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1 Introduction

The primary function of an electric power system is to provide adequate electricity to its customers efficiently and reliably [1], [2]. Adequate and uninterruptible electricity supply is vital to the rapid socio-economic development of any nation. Power outage frequency and duration indicate the reliability, quality and indeed the efficiency of an electric power system [3]. Despite the billions of dollars invested in the Nigeria's power sector, power outages persist to the extent that about 95% of Nigerians cannot boast of 16 hours of electricity availability daily [4], [5].

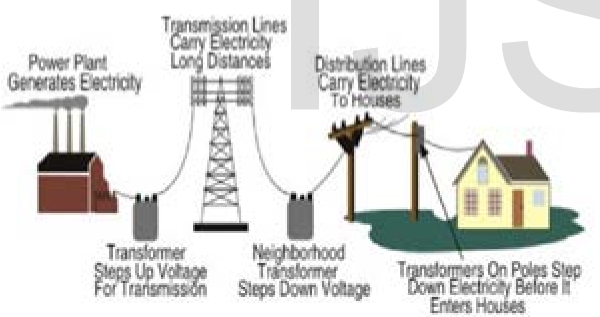

Fig. 1: Typical Electric Power System

The Nigerian power system, particularly the national grid, is weak and unreliable. This has resulted in much system losses and rampant power outages which increase the operating costs of electric utilities, the cost of electricity and impact negatively on the nation's socio-economic development and industrialization [6], [7]. Electricity losses refer to the electricity injected into a transmission and distribution network that is not paid for by the end-users and therefore represent an economic loss for the country [8]. Due to the high technical and non-technical losses in the Nigerian power system, potential investors are discourages from coming in to strengthen the system and make it deliver adequate and reliable electricity supply in the country. Fig. 1 is a typical power system showing some infrastructural facilities. A power sector should be financially sustainable by generating adequate revenues to cover costs and be able to continuously provide reliable and sufficient electricity to the end-users as well as make investments to meet changing future demands [9]. This has not been the case, however, with the utilities in Nigeria as much of the anticipated revenue get swallowed up by system losses. To reverse the trend by advocating for more radical means of reducing system losses and minimizing power outages occurrence rate in Nigeria is the main focus of this work. Over the years, scholars and researchers have attributed power outages in Nigeria to: Weak grid and outdated power stations, equipment overloading, inadequate compensation equipment on the system, weather and tree related factors, vandalism, poor maintenance culture, etc. [10], [6], [11]. See Fig. 2. Only a few have hitherto considered the contributions of transmission and distribution lines losses to electricity supply failures. This paper fills the gap by focussing on the effects of technical and non-technical losses to frequent power outages in Nigeria.

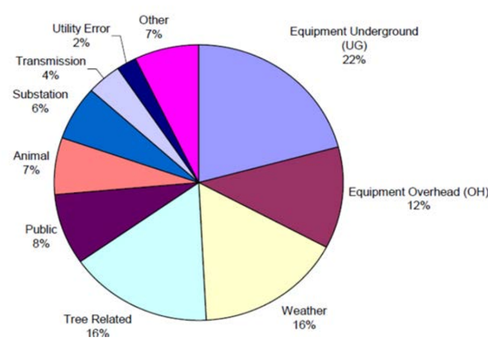

Fig.2: Causes of Power Outages. Source: [11]

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2 TECHNICAL AND NON-TECHNICAL LOSSES AND POWER OUTAGES

Two types of losses occur in an electric power system: (1) Technical losses are due to deficiencies in operations arising from the physical properties of the components of the systems and occur naturally in the form of power dissipation in transformers, transmission and distribution lines. A technical loss could be calculated. (2) Non-technical or commercial losses resulting from actions outside of the physical power system e.g. electricity theft, non-payment of bills, defective meters, errors in meter reading, estimating un-metered supply of energy, poor recordkeeping etc. [8], [12], [15]. Non-technical losses are often difficult to measure. But it is possible to calculate a non-technical loss if the technical loss is known.

We can derive an expression for the energy lost in the electrical network:

$$\boxed{P_{losses} = [P_{in} - P_{out}](W)} \quad \text{......................................} \ (1)$$

Where P_{losses} is the power lost (W) in the network, P_{out} is the electrical output power (W) in the network and P_{in} is the electrical input power (W) in the network.

The percentage power loss in the network can be expressed as:

$$\boxed{\%Losses = \frac{P_{in} - P_{out}}{P_{in}} \times 100\%} \quad \text{…………………………….} \ (2)$$

The efficiency of the network is given by:

$$\boxed{\eta\% = \frac{P_{out}}{P_{in}} = \frac{P_{out}}{P_{out} + P_{losses}} \times 100\%} \quad \text{………………} \ (3)$$

To calculate the energy input and the energy lost in the network respectively, we write:

$$\boxed{E_{in} = P_{in} \times t} \quad \text{……………………………………………..} \ (4)$$

$$\boxed{E_{losses} = P_{losses} \times t} \quad \text{……………………………………} \ (5)$$

Where: E_{in} is the energy (J) delivered in the network, t is the time (s) taken for energy transfer and P_{losses} is the energy lost (J) in the network.

The number of power outages per year is an indication of the efficiency of power supply even as consumer dissatisfaction with electricity service is often linked to high level of outages [13]. Since the more the number of power outages, the less efficient the power system, it follows that given higher system losses (technical and non-technical), there would be more power outages indicating the inefficiency of the system. Table 1 and Fig. 3 show the results of an investigation of the impact of power quality problems on the efficiency of a ring distribution network conducted by [14]. The 11 kV ring distribution network was modeled and simulated in DigSilent PowerFactory 14.0.512 software package so that five case studies were conducted on the network for normal operation conditions and abnormal conditions (outage and harmonics).

Table 1: Powers obtained for all case studies

Network	Units	CS1	CS2	CS3	CS4	CS5
P in	MW	9.7	9.64	9.67	9.67	9.69
P out	MW	9.56	9.45	9.5	9.51	9.54
Cable losses	KW	54.76	98.2	75.86	71.304	56.545
	KW	90.2	89.49	89.81	89.49	90.14
Total Losses	KW	145	187.69	165.67	160.80	146.685
Losses Increase	%	0	29.44	14.26	10.89	1.16
Efficiency	%	98.56	98	98.2	98.3	98.45

Source: [14]

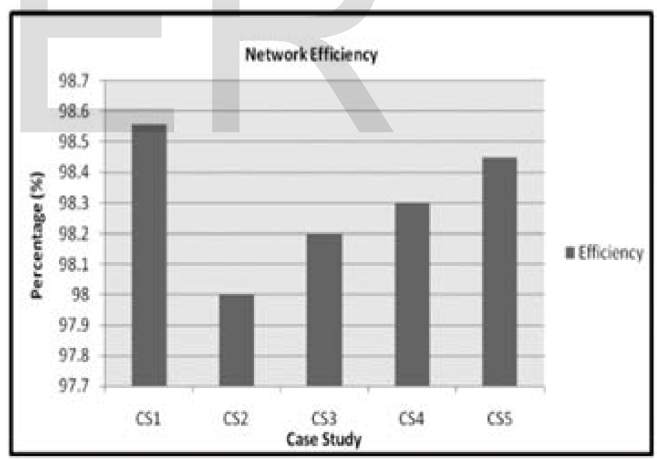

Fig. 3: Efficiency of Network obtained in case studies
Source: [14]

The power losses obtained from CS3 and CS4 increased normal operating condition (CS1) power losses by 14.26 % and 10.89% respectively. The highest power losses in the system were experienced in CS2, in which case the system technical losses increased by 29.44%. It can be seen in Table 1 that the technical power losses in the cables for CS2 to CS5 are higher. There are increases in the cables power losses for CS2 to CS5 viz. 79%, 38.54%, 30.22% and 3.3% in the respective cases, with CS2 giving the highest percentage due to the increase in current which forced the remaining cables in the network to take the extra load current from the lost feeder. When a feeder is lost from the network, the network configuration changes and

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so the network efficiency also changes.

From Tables 2 and 3, we observe that a technical loss can cause a blackout just as an uncontrolled non-technical (commercial) loss could result in huge loss of revenue which could have been channelled into strengthening the electrical system network against frequent power outages.

Table 2: Technical Losses

Nature of Technical Loss	**Where it takes place**	**Potential Effect**
Line loss	1. Loss in conductors/ cables where lower size conductors are used. This causes sags and temperature rise in conductors which further aggravate the loss. 2. Loss in higher loaded phase wires due to unbalanced loading. 3. Losses due to current in neutral for cases of unbalanced where neutral wires of lower size are used (like 3 ½ core cables, and neutral wires of size lower than phase wires) 4. Loosening of strands (in multi-strand conductors like ACSR, AAC, AAA, etc.).	Power Outage
Losses in mid-span joints (or any joint) at terminations	1. Contacts of joints due to improper installation and looseness. 2. Contacts of joints due to inadequate surface area of contact.	Power Outage
Losses in transformers (typically DTs)	1. Loose connections at brushings. 2. Bend in jumpers at connectors where the strands are not tightly held. 3. High no-load loss depending on type of core used. 4. High no-load loss in repaired transformers, where the core has not been properly tightened. 5. No-load loss in case a large number of lightly loaded DTs. 6. High copper loss for transformers operating at sub-optimal loading which is not commensurate with the designed optimal loading.	Power Outage
Losses in service cables and connections	1. Under sized service cables. 2. Loss in joints of service cables at the poles or junction boxes. 3. Use of inappropriate fasteners without spring washer at the crimped joints.	Power Outage
Loss due to high impedance faults	1. Tree touching, creepers, bird nesting. 2. Insulator breakages and tracking on the surface of the insulator.	Power Outage
Losses in re-wired fuses/ jumpers	1. Loose connection. 2. Inadequate size of fuse wires – often a source of hot spots.	Power Outage

Source: [15]

Table 3: Non-Technical (Commercial) Losses

Nature of Non-Technical Loss	**Where it takes place**	**Potential Effect**
Loss at consumer end meters	1. Poor accuracy of meters. 2. Large error in capital CTs / PTs. 3. Voltage drop in PT cables. 4. Loose connection in PT wire terminations. 5. Overburdened CT.	Loss of revenue that would have been invested to strengthen the system against power outages.
Tampering / bypass of meters	1. Where meter without tamper-proof-tamper-deterrent/tamper-evident meters are used. 2. Poor quality sealing of meters. 3. Lack of seal issue, seal monitoring and management system. 4. Shabby installation of meters and metering systems. 5. Exposed CTs/ PTs where such devices are not properly securitized.	Loss of revenue that would have been invested to strengthen the system against power outages.
Pilferage of energy	1. From overhead 'bare' conductors. 2. From open junction boxes (in cabled systems).	Loss of revenue that would have been invested to strengthen the system against

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	3. Exposed connection/ joints in service cables. 4. Bypassing the neutral wires in meters.	power outages.
Energy accounting system	1. Lack of proper instrumentation (metering) in feeders and DTs for carrying out energy audits. 2. Not using meters with appropriate data login features in feeders and DT meters. 3. Lack of a system for carrying out regular (monthly) energy accounting to monitor losses. 4. Errors in sending end meters, CTs and PTs. 5. Losses connections in PT wires (which results in low voltage at feeder meter terminals. 6. Energy accounting errors (by not following a scientific method for energy audits).	Loss of revenue that would have been invested to strengthen the system against power outages.
Errors in meter reading	1. Avoiding meter reading due to several causes like house locked, meter not traceable, etc. 2. Manual (unintentional errors) in meter reading. 3. Intentional errors in meter reading (collusion by meter readers). 4. Coffee shop reading. 5. Data punching errors by data entry operators. 6. Lack of validation checks. 7. Lack of management summaries and exception reports on meter reading.	Loss of revenue that would have been invested to strengthen the system against power outages.
Error in bills	1. Errors in raising the correct bill. 2. Manipulation/ changes made in meter reading at billing centres – lack of a system to assure integrity in data. 3. Lack of system to ensure that bills are delivered.	Loss of revenue that would have been invested to strengthen the system against power outages.
Receipt of payment	1. Lack of system to trace defaulters including regular defaulters. 2. Lack of system for timely disconnection. 3. Care to be taken for reliable disconnection of supply (where to disconnect).	Loss of revenue that would have been invested to strengthen the system against power outages.

Source: [15]

3 Measures to reduce Technical and Non-Technical Losses

The following measures would help minimize losses on Nigeria's electric power system and therefore reduce the frequency of power outages so that the system can become more efficient and reliable:

1. The power system network must be properly designed taking into consideration contingency needs.
2. There should be programmes to sensitize the public to safeguard electrical installations and equipment in their domains from vandals.
3. There should be strict implementation of the laws against the illegal use of electricity.
4. Electricity meters should be upgraded to meet standard accuracy. Smart card technology should be adopted. Smart metering would enable utilities monitor usage and detect tampering and theft more quickly.
5. Integrated billing system and prepaid energy meters must be installed and implemented. There is need for statistical monitoring of energy consumption and for statistical evaluation of meter readings.
6. Utilities must ensure proper training for their personnel engaged in energy metering and should motivated them with sufficient employee loyalty packages.
7. There is need for preventive maintenance programmes and for periodic inspection of electrical infrastructural facilities.
8. Thermal limits of transmission and distribution lines should be closely monitored to ensure that they are never exceeded. Distribution transformers and all electrical equipment and infrastructure must be protected against overloading.

4 CONCLUSION

This study will make utilities, system engineers and energy planners become more conscious of the fact that the higher the system technical and non-technical losses, the more power

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outages. As technical and non-technical losses are radically reduced, utilities become further encouraged to invest more into strengthening and extending the existing electricity infrastructure being reassured of increased revenue on their investments. In addition, reduced system losses would make the nation's power industry more attractive to outside investors when they are assured of seeing returns on their investments through strong and secure grids, stable supply and reliable payment systems. The need is hereby emphasized for the Nigerian governments and the power industry stakeholders to urgently work in synergy to reduce the losses and minimise the power outages currently prevalent on the nation's electric power system.

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