

Electric Power Outage Cost to Electricity Distribution Companies in Nigeria.

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Abstract: Over the years, customers and distribution companies have suffered psychological and social-economic losses due to power outages. These have led to a reduction in living standards, an increase in production cost, and stagnated national economic growth. However, little study exists to show the impact of power outages on the distribution companies. Hence in this work, the financial implication in terms of potential revenue loss to the distribution companies as a result of outages on their distribution feeders was analyzed. To achieve this, an important energy index such as Energy Not served (ENS) was used to estimate the consequent lost revenue based on the prevailing electricity tariff. From the analyzed outage data (from 2015 to 2018 for Ehor, Ubiaja, and Uzebba 33kV feeders of Irrua Transmission Station), it was discovered that the feeders experienced 4520 interruptions during the time under review. As a result, a total energy of 164,398,401.67kWh was not served which amounted to a loss of 4,415,428,094.48 Naira to the distribution company. Therefore, it was suggested that vandalizers of power equipment should be sanctioned to avoid the outages that are caused by such act. Also, the distribution companies should always carry out routine preventive maintenance and capacity increment on their network. The off-peak electricity tariff should be specially reduced to encourage people to use electricity in the nights to remove the interruptions caused by system overloading during peak load times of the day. Contrary to some public opinions, it is hoped that this study will make the populace to appreciate the fact that it is never in the best interest of distribution companies to allow/cause power outages. Also, it will serve as a guide for policy makers in the regulation of the power industry.

Keywords: Energy not served, Outage Cost, Power Outages, Electricity Cost, Nigeria Power Sector, NERC, NEMSA.

I. Introduction

Cost is the price paid in exchange for a product or service rendered. However, the price paid for power outage includes the psychological and social-economic inconveniences suffered by customers and the utility providers as a result of power cut. These customers may be industrial, commercial, or residential types [1]. The inconveniences they will have to bear as a result of power outages vary from the extra cost required to maintain back up power generator, insecurity, reduced productivity, underemployment, unemployment to deprivation of functional entertainment, and recreational facilities. These can cause boredom and may lead to frustration and depression. On the other hand, the utility providers also feel the negative impact of outages in the cost required to fix any damaged equipment responsible for the outage and loss of probable revenue within the outage period [2], [3]. Outage has a way of impacting the security status of an area. The vandalization of power equipment and some other social vices are perpetuated during such time.

Power outages have become a worldwide issue. The claim by Telson [4] that the power in the United States of America was too reliable has been overtaken by recent events judging by the incidence of power outage on August 14 -15, 2003 which affected Northern US and Canada [5], [6] and subsequent prediction of increased outages events in America by Short [7]. However, the most affected nations are the under-developed countries of the world [8].

Different steps have been taken to avert power outage menace, and also to be able to meet up with the increasing demand for stable power systems which are required to maintain critical power-dependent facilities such as automated industrial production processes, health care facilities, and institutions. [9]. The ownership of the various power infrastructures has changed from that of public to private business entities through privatization and deregulation processes in many nations. Such deregulation is supposed to open up the market for the participation of multiple private investors spurring up positive competitions and increase of efficiency in the generations, transmission, and distribution of electricity to the end-users. The effects of these activities have greatly influenced the planning, operations, and pricing in the power industry which often lead to reduction in downtime and improvement in the power quality.

The distribution of power costs a lot of money hence these private utility providers depend on prompt energy bill payment from Customers for them to remain in business and continue to provide improved power supply. To this end, the customers are expected to do away with the old notion that power is an essential social commodity to be provided by the government.

However, the privatization of the Nigerian power sector has not been able to provide the expected improvement in the power sector [2]. This could have been due to lack of foreknowledge of basic challenges of the sector by the investors, lack of financial and technical resources to tackle prevailing issues in the sector, and poor regulation of the industry by the regulators such as Nigerian Electricity Regulatory Commission (NERC) and Nigerian Electricity Management Services Agency (NEMSA).

One of the ways to understand the shortcomings in the power sector (and subsequently profound probable solutions) is to carry out studies on the economic impact of power outages. A lot of studies have been done in this field [2], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18], [19]. However, most of them mainly considered the financial loss suffered by the customers while very little or nothing has been done in the evaluation of the cost borne by service providers as a result of power outages. Also, most of the works based their findings on information from administered questionnaires to customers. However, feedback from customers with the help of questionnaire in this field of study is highly subjective because customers may over-bloat their power outage related losses just to weed sentiment [1], [10]. The major reason responsible for the lack of researches in the study of financial cost suffered by the utility provider is the herculean task of gathering outage data with the technical variables needed to determine the equivalent monetary cost [1]. From available information at our disposal, it was only Izuegbuna, *et al.*, [3] that has carried out a study that evaluated the revenue loss incurred by power distributors in Nigeria. However, a review of the work showed that the outage financial loss was not the focus of the article. Hence, the issue was unsatisfactorily handled. This was the major reason that prompted LaCommare & Eto [1] to argued that more works need to be carried out in this field of study to analyze the significance of outage cost.

Nevertheless, the assessment of financial losses by any company is necessary for many reasons. such information will go a long way in helping the government in policy formation and sector regulation guide. Current and potential investors are better guided on their investment decision and management of their resources. Such information can also go a long way in ameliorating the power outages related rifts between customers and utility providers.

In this article, the financial costs of power outages to the power provider as a result of revenue loss due to energy not served (ENS) during blackouts will be considered by analyzing outage data obtained from Irrua transmission station.

The rest of this work will be divided into different sections to achieve the set objectives coherently. Section II will focus on the theoretical framework. The methodology will be presented in section III while the result will be displayed and discussed in section IV. The conclusion and suggestions will be done in section V.

II. Theoretical Framework

2.1 The Place of Electricity in National Development

National industrialization and economic prosperity require reliable source of electricity for smooth operations. This is as a result of the fact that most critical modern processes depend on electrical energy [19]. Power is required to run the industries, government parastatals, institutions, hospitals, small and medium scale industries, etc. It enhances personal comforts, the standard of living, security, gross domestic products (GDP), information dissemination, transportation, etc. Therefore, any interruption may result in catastrophic consequences. However, Power outages have become an integral part of the power industry causing damages of diverse magnitude to dependent facilities.

Outages can occur as a result of faults, insufficient power infrastructure (capacity shortage or system inadequacy), emergencies such as fire outbreak, or reduction in water reservoir in the case of hydro power source [11]. However, the most difficult outage scenario that the utility provider can respond to is when the event is as a result of system inadequacy. Such instances require the installation of new infrastructures to meet up with the system demands and this usually requires time and funds. The only palliative measure is to engage in the practice of regimented load management. Therefore, power producers should have adequate capacity reserve to meet up with any abrupt surge in load demand due to the unpredictable nature of customer demand for electricity. It has been observed that one of the major causes of the inadequate power in

Nigeria (which is one of the major causes of outages) was as a result of lack of funding in the 90s by the federal government [20], [21].

The burden of an outage can be influenced by some factors such as prior notification of the event, the time of occurrence, the affected processes, the duration of the outage, etc. (Anderson & Taylor, 1986). Furthermore, it has been discovered that the negative impact of outage is more aggravated by the number of events compared to the duration [11].

2.2 Implications of Power Outages

According to LaCommare & Eto [1], the gains and motivation for investment in the power systems may not be fully appreciated until the negative implications of power outages are well analyzed. Also, the effect of outages on industry performances may not be properly felt in the short run but the long run [19]. Furthermore, the impact of power outage on the users can be measured in terms of discomfort, the loss in production, or the cost of arranging for an alternative supply [12].

To start with, it is important to note that all outages affect the quality of power supply, though those events that last more than 5 minutes are specially treated as reliability issues [22], [23]. On a global perspective, the third world countries such as Nigeria and Ghana are the worst hit by the menace of outages. Hence, industries in these countries suffer more from the inadequate power supply and expensive power tariff when compared to developed countries [24]. This has caused a situation whereby most firms in Nigeria have accepted the inclusion of provision of alternative power sources as part of their overhead cost [25].

The over-reliance of the Nigerian economy on alternative power supply results in the wastage of several man-hours in queuing for the purchase of fuel in Petrol stations [2]. Things usually become worse in times of fuel scarcity which has characterized the petroleum product industries in Nigeria [26]. Apart from the extra financial costs involved in such activities, there is also the safety implications that can result to fire outbreaks.

Records showed that Nigeria has the highest economic cost of power outages in Africa [27]. This is attributable to the poor power availability in the country despite all the available energy resources. Consequently, the cost of production in Nigeria is as high as 9 times compared to China [28]. This has made it very difficult for local industries to compete with foreign ones. Also, this has discouraged investors from setting up businesses and also made the populace to lose confidence in the power sector [15].

Power outages have slowed down the pace of development in many parts of the country. For instance, MAN claimed that that power outages cost their members up to 11.3 million dollars per week as a result of fueling and maintenance of generators [29]. Consequently, more than 800 manufacturing firms were closed down in Nigeria between 2000 and 2008 due to poor power status in the country [30].

Another country in Africa (beside Nigeria) that has also felt the bite of power outage in their economy is Ghana. As a result, the SMEs in Ghana have been losing US \$686.4 Million in sales yearly since 2009 [8]. If nothing is done to stem the tide of the continuous collapse of the SMEs due to intermittent power outages, the economy of Ghana which highly depends on them will suffer. To buttress this point, it was observed that the contribution of the manufacturing industry to the GDP in Ghana reduced from 10.2% in 2006 to 6.7% in 2011 mainly as a result of reduction in power availability [19].

The power outage implications are not limited to the developing nations alone. For instance, LaCommare & Eto [1] discovered that power outages in the US could cost as much as between \$22 billion and \$135 billion annually. In general, it is estimated that outage costs vary between \$1.27 to \$22.46/kWh of unserved electricity for the industrial sector, while that or residential vary between \$0.02 and \$14.61/kWh unserved in the industrialized world [9].

According to Lee and Anas [31], about 25% of the total initial cost for setting up a business in areas with unreliable power supply is used for making provisions for power back up in case of power failure. This is because lack of stable power supply leads to the underutilization of industrial assets [17]. Power outages can lead to loss of raw and processed goods, equipment damage, and reduction in production and sales [8], [13].

Another implication of power outage is unemployment because many companies do close down as they cannot afford the rise in production cost as a result of epileptic power supply [18]. Long run outage cost (LROC) of energy has a way of increasing the pricing of electricity [12].

Anderson & Taylor [11] have made it clear that the distribution companies are not immune to losses as a result of power interruption. They lose potential revenue as a result of energy not served within the outage period. Also, the follow-up maintenance cost required to restore any circuit that went out as a result of fault is a source of financial burden to the companies.

2.3 Related works

Scholars have adopted different methods to quantify the short and long-run cost of power outages. These have helped in unveiling the implications and possible solutions to the menace.

Izuegbunam, et al. [3] discovered that the revenue loss suffered by the distribution company within Onitsha could be as high as 61 Billion Naira per annum due to power outages. To avoid this, the work then recommended that the distribution company should engage in thorough maintenance activities to arrest the ugly trend.

The cost of power outages on the business sector of the Nigeria economy was analyzed by Adenikinju [15] using both survey and revealed preference approaches. Findings from the study showed a significant financial increase in the cost of production due to the loss of power from the power utility company. Due to this, the authors advocated for the reformation of the structure of the power system in Nigeria.

Anderson & Taylor [11] investigated the different methods used by scholars in the analysis of the social cost implications of unsupplied electric energy in Sweden and other advanced countries of the world. The authors carried out a proper review of existing works as regards the different techniques that were adopted for evaluating the cost of unsupplied power. However, the work needs lots of updates due to the changes that have occurred over the years in terms of the power industry structures, technological advancements, and industry standards.

Bental & Ravid [10] Presented a method for evaluating the marginal cost of unsupplied energy to industrial customers by the use of questionnaires. To achieve this, the authors considered the ability of firms to mitigate the effect of power outages by purchasing back-up generators which ensures minimal impact on factory production in the advent of power outage incidence. However, feedbacks from questionnaires could be easily influenced by the state of mind of the respondents, hence the work suffers integrity checks.

Forkuoh & Li [8] faulted previous outage cost estimation works in Ghana for not considering any case study in their studies. Hence the work focused on cold-store in Asafo markets in Kumasi Ghana as a case study. The findings showed that the cost of operation for these SMEs usually increase significantly as a result of power interruptions. Assets could be damaged as a result of incessant power outages. Power outages can also result in loss of sales. The work advocated for medium to have a common generator for clusters of SMEs as a way of reducing the cost of alternative sources of power.

Quarshie et al. [19] investigated the performances of the stocks of some manufacturing firms in Ghana based on the pattern of power outage trend from 2007 – 2013. The impact of the outages on the return on equity (ROE) was found to be insignificant. However, the Return on asset ratio (ROA) was found to be better with lower numbers of power interruptions.

Ukpong [33] studied the financial impact of inadequate power on the industrial commercial sector in the greater part of Lagos Nigeria between 1965 and 1966. As a form of follow up, Nnanna & Uzorh [16] studied the impact of power outages on the major industrial areas in Nigeria comprising Kano/Kaduna, Lagos/Ibadan, and Anambra/Abia industrial axis. The outcome reveals that outages significantly increases the cost of production. This was as a result of the low performance of the then government-owned NEPA/PHCN which were ineffective in supplying power to the local industries that rely on electricity for production [32].

Adenikinju [14] Examined the financial implications of inadequate power supply on the manufacturing sector in Nigeria using a nationwide survey feedbacks from different manufacturing firms. It was discovered that the cost of providing and running a backup generator takes up to 3 times the cost of normal electricity bills. The authors posited that it cost as much as 20% - 30% of the total initial investment to set up an alternative power supply and this does have a negative effect on the ability of a firm to compete with other established competitors in the market. The work suggested liberalization of the power sector as a way of improving their services.

Ahmed and Mallo [2] observed that the most affected sector by power outages is the small-scale subsector of the economy because they do not have enough funds to acquire back-up facilities to mitigate the negative impact of power outages. This prompted the examination of the impact of inadequate power supply on the small-scale industries operating in the northeastern parts of Nigeria. The results showed that the subsector has suffered heavy financial losses as a result of poor power availability in the country. As a way of compensation and deterrent for such losses, Uchendu [13] suggested that the company owners should be legally empowered to sue for damages from power providers in the advent of loss in production as a result of power outages.

LaCommare & Eto [1] emphasized that the major costs of outages are borne by the industrial and commercial sector and very less by the various individual residential customers and also noted that momentary outages are more frequent than the sustained outages.

III. Methodology

The data used for this study were obtained from Irrua Transmission Station in the central part of Edo state. These include four years outage records (2015-2018) of their 33kV feeders such as Ehor, Ubiaja, and Uzebba. A sample of the detailed report of each event (which includes the time of outages, interrupted load (Amps), and the duration (hours) of each outage) is presented in Appendix I - III. The total interruption records are presented in Table 1. The energy lost (Popularly referred to as energy not served (ENS)) during each outage was calculated and summed using equation 1. The equivalent lost revenue as a result of these outages was determined by equation 3. The unit cost of electricity (for residential customers) during the time under consideration is found in table 2. The residential tariff was chosen because they form the majority of the customers in that part of the area supplied by these feeders. Also, the tariff disparity between these customer classes is very minimal (NERC, 2015). Hence, the final result will not be significantly distorted by this tariff class choice.

$$ENS = \sum_{i=1}^N P_i * O_{di} \tag{1}$$

Where;

$$P = \sqrt{3}IV \cos \phi \tag{2}$$

ENS = Energy Not Served

P = Electric Power/Load lost (kW) due to outage

O_{di} = Outage Duration

I = System load current (Amps) before the outage

V = System Voltage (33kV)

$\cos \phi$ =Power factor taken as 0.85

$$RL = ENS * T_A \tag{3}$$

RL = Revenue Lost

T_A = Electricity unit Cost

IV. Results and discussions

The yearly power outage records of Ehor, Ubiaja, and Uzebba 33kV feeders are presented in Table 1 while the cost for a unit of electricity is shown in Table 2. The resulting lost energy and equivalent revenue forfeited during the outages are presented in Table 3.

Table 3 shows that Ehor feeder suffered 1793 outages within four years under review while Ubiaja experienced 1543 and Uzebba had 1184 outage records. These summed up to 4520 outage incidences for the three feeders within four years.

Table 1: Outage records

Feeders	2015	2016	2017	2018	Total
Ehor	378	426	416	573	1793
Ubiaja	351	415	348	429	1543
Uzebba	201	339	280	364	1184
Total	930	1180	1044	1366	4520

Table 2: Energy Cost for residential customers

Year	2015	2016	2017	2018
Cost (NGN/kWh)	14.82	24.45	34.40	34.40

Source: NERC [34].

Table 3: Energy Not Served (ENS) and revenue loss due to outages

	2015	2016	2017	2018	Grand Total
ENERGY NOT SERVED (KWH)					
UBIAJA	13,384,750.00	10,279,440.83	7,866,213.33	10,863,551.67	42,393,955.83
EHOR	11,574,253.33	17,169,640.00	10,295,702.50	17,586,194.17	56,625,790.00
UZEBBA	15,559,541.67	17,427,684.17	14,388,124.17	18,003,305.83	65,378,655.83
TOTAL ENERGY (KWH)	40,518,545.00	44,876,765.00	32,550,040.00	46,453,051.67	164,398,401.67
Revenue Loss (N)	600,484,836.90	1,097,236,904.25	1,119,721,376.00	1,597,984,977.33	4,415,428,094.48

The total lost energy due to outage for Ehor was 56,625,790.00kWh while 42,393,955.83 was lost by Ubiaja and 65,378,655.83kWh was lost by Uzebba. These resulted to a total energy loss of 164,398,401.67kWh. Though the least total lost energy happened in 2017 (32,550,040.00 kWh) and the highest 2018 (46,453,051.67kWh), yet a general observation presents a historical trend of increase in lost energy.

Records showed that the revenue loss incurred by the distribution company during the period under review increased from NGN600,484,836.90 in 2015 to NGN1,597,984,977.33 in 2018. The total revenue loss was found to be NGN1,415,428,094.48 within four years which signifies an average annual revenue loss of 1.1 Billion Naira. This shows that the power outage does cause revenues loss to the service providers. The result from this work agrees with LaCommare and Eto [1], Izuegbunam, *et al.* [3], Anderson & Taylor [11], Godfrey, *et al.* [35], Fenrick and Sonju [36], Soma and Getachew [37] and Akinloye, *et al.* [38].

V. Conclusion and Suggestions

This study focused on the assessment of the cost of outages to the power provider as a result of revenue loss due to energy not served (ENS) during outages. The negative short and long-run impacts of power outages are enormous. The hardship is felt by the commercial users of the utility in terms of increase in the cost of production. National development could be stagnated. Lives could be lost in hospitals due to the failure of critical systems and processes. These side effects are not limited to the users alone. The distribution companies spend a lot of money in the fixing of any failed equipment that is responsible for power outages. During outages, the company is not able to deliver their "unstorable" product to the end-users which result in loss of revenue to the company. The results from this study showed that Ehor, Ubiaja and Uzebba 33kV feeders of Irrua Transmission Station experienced a total of 4520 outage incidences from 2015 to 2018. This led to loss of 164,398,401.67kWh which amount to 4,415,428,094.48 Naira. This is a great loss to the company, the different classes of customers, and the nation at large. A situation such as this requires serious attention. It is therefore recommended that the government should ensure that there are more participants in the provision of additional power supply in the country by encouraging more private investors to come into the industry. This will go a long way in the industrialization quest of the nation thereby improving the living standard of people in the country.

The power sector should be further deregulated to include the Transmission Company while the federal government should focus on regulating the sector. This will help the government to be less distracted and unbiased in overseeing the affairs in the sector.

Currently, the major source of electric power in Nigeria is dependent on gas and other petroleum sources. This kind of energy is not environmentally friendly and the reservoir is non-renewable. Therefore, the development of other renewable energy sources like solar, wind, and biomass are highly required to save the country from the present condition of energy insecurity.

As much as possible, distribution companies should communicate any looming outage to the customers to enable them to make back-up plans for their energy requirements especially those facilities that offer critical services like the hospitals.

Industry owners can mitigate against the high cost of operation as a result of poor power supply by adjustment of working hours, reduction in manpower, usage of low power consuming equipment, outsourcing of intermediate products, and adoption of alternative power independent processes where available. Also, clusters of business or “*utility pools*” should be developed to manage the available power more efficiently.

Owners of businesses should be legally empowered to sue for damages from power providers in the advent of loss in production as a result of power outages. This will go a long way to making the distribution company sit up and be more proactive in their maintenance strategies.

On the other hand, a stiff penalty should be melted to anyone that steals energy and/or vandalize power facilities. This will eliminate outages caused by such incidents and serve as a deterrent for future occurrences because the distribution of power involves a lot of investment. The power tariff should be structured to encourage customers to use power during the off-peak period which is mainly night. This is expected to help flatten out the load curve and hence reduce interruptions due to system overloading. In all these, it is very important that the distribution companies engage in routine preventive maintenance of their system.

This work has shown that the outage related revenue loss in the distribution company is on the rise in Nigeria. This can cause psychological and social-economic damages to the industry, the customers, and the nation at large. Therefore, the highlighted strategies need to be implemented to help arrest the issues.

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Appendix

Appendix I: sample of Ehor 33kV feeder outage events record

TIME OUT	DURATION (HOURS)	LOAD (AMPS)
1/19/2015 6:34 PM	1.533333333	180
1/20/2015 7:55 AM	3.366666667	286
1/22/2015 9:32 PM	12.666666667	276
1/22/2015 12:25 AM	9.783333333	284
1/22/2015 7:28 PM	25.033333333	288
1/23/2015 7:29 PM	1.283333333	240
1/23/2015 8:46 PM	1.766666667	240
1/23/2015 11:28 PM	24.066666667	272
1/27/2015 8:11 AM	1.766666667	192
1/28/2015 1:29 AM	5.333333333	302
1/28/2015 7:39 AM	2.433333333	270
1/29/2015 6:59 PM	0.65	330
1/29/2015 6:35 PM	0.4	330
1/29/2015 5:39 AM	1.05	320
1/30/2015 9:02 AM	0.733333333	300

Appendix II: sample of Ubiaja 33kV feeder outage events record

TIME OUT	DURATION (HOURS)	LOAD (AMPS)
1/23/2015 7:30 PM	1.283333333	120
1/28/2015 10:10 AM	11.1	90
1/29/2015 8:39 AM	3.866666667	96
1/30/2015 2:19 PM	1.116666667	70
1/31/2015 5:56 PM	1.35	100
2/1/2015 6:03 PM	0.433333333	126
2/5/2015 8:39 AM	2.583333333	90
2/6/2015 2:45 AM	3.983333333	96
2/6/2015 1:54 PM	0.733333333	126
2/7/2015 1:04 AM	3.8	100
2/8/2015 7:48 AM	1.233333333	150
2/9/2015 7:27 AM	2.983333333	144
2/10/2015 4:35 AM	2.333333333	100

Appendix III: sample of Ehor 33kV feeder outage events record

TIME OUT	DURATION (HOURS)	LOAD (AMPS)
1/1/2015 12:00 AM	14.26666667	350
4/20/2015 1:36 PM	2.9	210
4/21/2015 12:03 AM	5.083333333	150
4/21/2015 7:58 AM	11.7	284
4/22/2015 1:04 PM	0.383333333	240
4/22/2015 4:25 PM	1.183333333	252
4/23/2015 1:39 AM	1.566666667	294
4/23/2015 3:19 AM	3.583333333	252
4/23/2015 7:50 AM	10.51666667	210
4/25/2015 1:04 PM	2.266666667	248
4/25/2015 7:37 AM	4.366666667	276
4/27/2015 12:45 PM	4.05	240
4/28/2015 12:42 PM	3	220
4/28/2015 12:35 AM	3.85	326
4/30/2015 11:50 AM	6.833333333	72
5/1/2015 8:24 AM	1.783333333	150
5/1/2015 11:45 PM	0.75	350

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