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A CRITICAL LITERATURE REVIEW ON THE IMPACT OF ELECTRICITY SUPPLY INTERRUPTIONS ON BUSINESSES AND PREVENTION IN CAMEROON.

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ABSTRACT

Electricity interruptions have become a great concern for consumers of electricity and for electricity utility companies in many countries of the world. Many businesses have shot down due to the recurrence of prolonged electricity supply, especially in Africa. Hospitals, companies, households, schools etc. have all suffered due to electricity supply interruptions.

This paper seeks to review available literature on the impact of sporadic, chronic and momentary electricity interruptions. Publications around the world on these distinctive electricity interruptions types were researched and synthesized critically to provide information about the impact of electricity interruptions that can be applicable to small and medium size businesses.

Since electricity interruptions are associated with economic costs which can be of severe magnitudes, the paper also provides findings on preventive measures against electricity interruptions that can help reduce the occurrence of electricity interruptions.

Key words: Sporadic, chronic, momentary, electricity, interruptions, network, maintenance

Background

Electricity is one of the most essential requirements to function in modern life. In the days of old, the early man depended on fire to obtain light, heat and for cooking. As recorded by the Institute for Energy Research, IER (n.d.), one of the first major breakthroughs in electricity occurred in 1831, when British scientist Michael Faraday discovered the basic principles of electricity generation, by inducing electric current through moving magnets inside coils of copper wire. Today, there are various modern technologies used in producing electricity. In most developed countries today, electricity is generated through steam turbines using fossil fuels, nuclear, biomass, geothermal, as well as solar photovoltaic and wind turbines which are gradually becoming popular. In many developing countries, hydro turbines and gas turbines are the most principal sources. In Cameroon, mainly hydro and thermal stations are used to generate the electricity transmitted and distributed to supply electricity consumers.

The smooth functioning of homes, schools, business centers, work places and industries require the supply of electricity. The various devices we use today like mobile phones, tablets, computers, equipments in households like fridges, freezers, television sets, electric irons require electricity to function. The necessity of electricity supply applies both for industrial and local purposes, which in this modern times, is obtained by just turning on a switch. However, for electricity dependent operations like small and medium size businesses (SMBs) considered in this research to function optimally, there is need for a reliable and uninterrupted supply of electricity.

The interruption of electricity supply has become a big problem for users. SMBs in many countries around the world today are affected by electricity supply interruptions. These interruptions can be momentary, sporadic or chronic. According to Sinan (2015), momentary interruptions last for a very short time, typically some seconds. Sporadic interruptions are caused by harsh weather conditions such as thunder storms or floods which pose a great threat to electricity networks since they cause long lasting interruptions associated by significant economic losses for the consumers. Chronic interruptions on the other hand, are mostly caused by poor electricity network planning and operation, insufficient power generation, overloading of the system components, as well as faults in the electricity network due to aging or lack of maintenance.

Particular indicators are universally used in measuring the interruption level and reliability of electricity distribution networks. Typically, the System Average Interruption Duration Index (SAIDI), the System Average Interruption Frequency Index (SAIFI) and the Undistributed Energy (END) are used. According to current World Bank statistics (http://www.enterprisesurveys.org/), Pakistan has the worst levels of average electricity interruption frequency in the world today, while Cameroon is ranked at the twenty fifth position. However, for average interruption durations of electricity outage per year in Africa, according to the recent publication of Sönnichsen (2021), Nigeria recorded the worst with 4600 hours, followed by Niger 1400 hours, DR Congo 830 hours, Cameroon & Ghana 790 hours each, Angola 760 hours, Tanzania 670 hours, Ethiopia 570 hours, Kenya 420 hours, Zimbabwe 280 hours, Ivory Coast 20 hours, Zambia 180 hours, Senegal 130 hours, Mozambique 80 hours, South Africa 50 hours. The ranking reflects Cameroon at the fourth position in Africa with poor average duration of electricity outage per year. Cameroon, being at this rank is a big concern that directly reflects the state of its electricity distribution network of today. According to ENEO (2021), the frequent electricity outages in the South West Region from ENEO Cameroon's electricity interruption Server (http://tableau/#/workbooks/83/views), reveal the region at the third rank nationwide with low electricity interruptions from "*1762 registered interruptions in 2020,* to *1281 registered interruptions so far in 2021.*"

Many scholars have researched on the impact of electricity interruptions. For the purpose of this research, a critical review on available literature on the impact of Electricity Supply Interruptions on SMBs will be investigated and analyzed. Further, the research will seek to identify the gabs in literature, as well as the underlining factors contributing to the frequent electricity interruptions to be addressed with the ultimate goal of developing future strategies to help the electricity utility company of Cameroon (ENEO) compete with the better performers in the African continent so that electricity consumers and SMBs in particular could be reliably supplied with electricity void of regular interruptions.

The paper is structured in seven sections. The first is on planning for the literature review. The seond section is on conducting the literature review, while the third section deals with the reporting of findings. The fourth section is on prevention of electricity supply interruptions, while the fifth section looks at gaps identified in the literature. Section seven outlines the limitations of the literature, followed by discussions on the seventh section.

Chapter 1: Planning for the Critical Literature Review

1.1 Review questions

Through available literature, this review seeks to establish what the impact of electricity supply interruptions on businesses in Cameroon are.

The specific review questions to be addressed are;

- ✓ What is the impact of *sporadic interruptions* which occur suddenly during weather storms on small and medium size businesses (SMBs)?
- ✓ What is the impact of *chronic interruptions* caused due to poor electrical networks on small and medium size businesses (SMBs)?
- ✓ What is the impact of *momentary interruptions* with short durations on small and medium size businesses (SMBs)?

1.2 Inclusion criteria

This review considered all studies that involve electricity supply interruptions on electricity distribution networks. However, the review seeks to focus on their impact on small and medium size businesses (SMBs).

The particular interest of the review is on the impact of momentary, sporadic and chronic interruptions on small and medium size businesses (SMBs).

1.3 Types of outcome

The primary outcome of interest is the impact of electricity supply interruptions on businesses. Particularly, outcomes on the impact of momentary, sporadic and chronic interruptions on small and medium size businesses (SMBs) are of fundamental interest. The secondary outcomes include electricity supply interruption reduction through electricity network maintenance.

Chapter 2: Conducting the Critical Literature Review

2.1 Search Strategy

The search strategy was designed to access both published and unpublished materials and comprised of three stages:

The first stage was a wide search of on Google Book Search and Google Scholar to identify relevant articles. At the second stage, articles or books identified and the synonyms used by respective databases were used in an extensive search of the literature. At the third stage, reference lists and bibliographies of the articles collected from those identified in stage two above were obtained.

The initial search terms were “momentary electricity interruptions”, “sporadic electricity interruptions”, chronic electricity interruptions”, ‘electricity interruption’, “impact of electricity interruption” and “electricity network maintenance”. A total of 16 articles published in the last 10 years in English were found and detailly examined.

The full copies of articles identified by the search, and considered to meet the inclusion criteria, based on their title, abstract and subject descriptions, were obtained for data synthesis. Articles identified through reference lists and bibliographic searches were also considered for data collection based on their title.

Identified studies that met the criteria were grouped into one of the following categories: case studies, interpretive studies, economic impact studies.

2.2 Data collection and synthesis

Following assessment of methodological quality, the papers were grouped according to whether they are quantitative or qualitative. A data extraction form through an organized spreadsheet was prepared as seen in table 1 to enter data and categorized under momentary interruptions, sporadic interruptions, chronic interruptions or general interruptions.

Table 1: Summary table of data extraction form for electricity interruptions

SN	AUTHOR	RESEARCH TITLE	PUBLIISHED YEAR	COUNTR	RESEARCH AREA	RESEARCH QUESTIONS	RESEARCH ARGUMENTS/ THEORIES	RESEARCH OBJECTIVES	RESEARCH CONCLUSIONS	PUBLISHING JOURNAL	CITING	Type of Interruption Momentary, Sporadic, Chronic, General
1	Sinan Küfeoğlu	Economic Impacts of Electric Power Outages and Evaluation of Customer Interruption Costs	2015	Finland	Economic Impact of electricty interruption	(1) What are the direct economic impacts of power outages (2) What are the indirect economic impacts of power outages	(1) Electric power transmission and distribution planning cannot be done without a clear idea of the economic worth of the continuous electric power. Even though the smart grid technologies are being installed in the electric power infrastructure, the power reliability has been in an alarming state. (2)The climate change brought and increased frequency of the extreme weather events and natural disasters. This poses a great threat to the electric power system	To provide Customer Interruption Cost (CIC) estimations which will be: (1) Customer specific (2) Utilizing publicly declared and objective data (3)Demanding less time, less money and less effort (4) Easy to duplicate in any part of the worl (5) Providing credible and	(1)The direct impacts of electricity interruptions cover loss of manufacturing and production, interruption of services such as transportation, telecommunication and so on, loss of sales, damages on the equipment, spoiled goods, damages on the electronic data, accidents and injuries. (2)The indirect impacts of electricity interruptions include public disorder, looting, other crimes seen upon blackouts, property losses and so on	Aalto University publication	Sinan, K. (2015).*Economic Impacts of Electric Power Outages and Evaluation of Customer Interruption Costs* . (Aalto University publication series 131/2015) [Doctoral Dissertation, Aalto University].Retrived from https://core.ac.uk/download/pdf/301131449.pdf	Sporadic
2	Steve Mathewman and Hugh Byrd	Blackouts: a sociology of electrical power failure	2014		Impact of electricty interruptions	What are the effectes of electrical supply interruptions	Eletricity interruptions have adverse effects on economy, food safety, crive rates, accidents in transportation	To provide an understanding to the patterns of Electrical network failure, i.e. the accidental loss of electrical power referred to as blackouts	(1) Modern societies are dependent on an uninterrupted supply of electricity.The continuing sophistication and prevalence of electrical appliances only serves to increase our dependence. (2)In the digital world interruptions and disturbances less than 1 cycle (1/60th second) can have catastrophic effects. Servers and computers crash, life support machines become their opposite, intensive care operations are compromised, as indeed are all manner of automated machines and micro-processor based devices (3) Western societies now face a significant social problem. They are becoming ever more dependent upon electrical power yet supply will struggle to meet demand. Increasing numbers of people are living longer and enjoying rising living standards (4) Power outage is asscociated with economic cost, food safety and increased crime rates	No Publisher	Mathewman, S. & Hugh, B. (2014).Blackouts: *a sociology of electrical power failure.* (n.p.).Retrieved from https://www.researchgate.net/publication/264985468_Blackouts_a_sociology_of_electrical_power_failure	Chronic
3	Mao Shua et al.	Review on Economic Loss Assessment of Power Outages	2018		Economic Impact of power outages	What are the economic impacts of power outages	Power outages cause huge economic loss to the social economy	To explain; (1) Economic impact caused by blackout (2) Influence factors that cause power outage (3) Assessment method to evaluate directt and indirect economic loss	(1) The economic impact of power outages can be divided into the direct economic impact of power outages and the indirect economic impact of power outages (2) There are many studies on the direct economic loss of power outages, but few studies have been made on the indirect economic loss of power outages	Elsevier B.V.	Mao, S. et al.(2018).*Review on Economic Loss Assessment of Power Outages.* Amsterdam, Niederland: Elsevier	General
4	Ali Fakih, Pascal Ghazalian and Nancy Ghazzawi	The Effects of Power Outages on the Performance of Manufacturing Firms in the MENA Region	2020	Middle East and North Africa (MENA)	Effects of power outages	What are the consequences of power outages	(1) Power supply in developing countries is often characterized by unreliability and inefficiency, resulting in disruption costs for operating firms (2)The extents of power outages in the Middle East and North Africa (MENA) region are more significant compared to other geo-economic regions.	To examine the effects of power outages on the performance of manufacturing firms in the MENA region using a firm-level dataset derived from the World Bank's Enterprise Surveys (WBES) database	(1) Firm performance is represented by sales, employment, and productivity growth rates (2) The results emphasize the adverse consequences of power outages for the performance of manufacturing firms in the MENA region. (3) Different patterns of power outages have varying implications for firm performance, and that the effects of power outages exhibit variations with firm size.	De Gruyter	Ali, F.,Ghazalian,P. & Ghazzawi, N.(2020).*The Effects of Power Outages on the Performance of Manufacturing Firms in the MENA Region.* Berlin, Germany : De Gruyter. https://doi.org/10.1515/rmeef-2020-0011	General
5	Otuekong Ekong , Anthony Etim & Anietie Ekong	Automated Real-Time Electricity Supply Monitoring System	2021	Nigeria	Electricty supply calculation	(1) How can the duration of electricity supply be calculated such that the readings so obtained can be used as the basis to generate consumption bills (2)How can electicity consuption readings be made available online on an open visualization platform for the evaluation of the load scheduling program effected for a given household, community, or region without the need for	(1)There is gross insufficient energy to be distributed to the approximately 180 million population of Nigeria. As such, Distribution Network Operators DNOs resort to constant load scheduling, overloading, under-voltage, and in extreme cases cutting off some communities (Blackouts) so as to balance the load in their network. (2)Acute electricity problems hinder development regardless of the availability of vast natural resources in any country	(1) To propose a system that measures the duration of supply such that the readings so obtained can be used as the basis to generate consumption bills (2)To propose a system capable of making the readings available online on an open visualization platform for the evaluation of the load scheduling program effected for a given household, community, or region without the need for physical visits.	(1) In many developing countries where many households are yet to be metered, it is not uncommon to find consumers complaining about outrageous electricity bills which they feel do not necessarily reflect the situation on ground (2)In this model, the date, time and location information of the POWER ON status of a building is automatically monitored and reported form the moment the power supply was switched on. (3) For the mobile version, the location coordinates of the building is automatically acquired using the smart phone's GPS sensor.		Otuekong, E., Etim,A. & Ekong, A. (2021). *Automated Real-Time Electricity Supply Monitoring System* . Proceedings of the 27th iSTEAMS Multidisciplinary Innovations & Technology Transfer (MINTT) Conference. Academic City University College, Accra, Ghana. June, 2021. Pp 10-16 www.isteams.net/ghana2021. DOI - https://doi.org/ 10.22624/AIMS/iSTEAMS-2021/V27P2	General

A synthesis of the data was made after the critical literature review was concluded which is reported in chapter three.

Chapter 3: Reporting on Critical Literature Review on electricity supply interruptions

3.1 General situation on electricity supply interruptions

The reliability of electricity supply has become a fundamental requirement for the functioning of modern societies (Schröder & Kuckshinrichs, 2015). Power outages or electricity interruptions are increasingly becoming of great concern in Africa particularly, as well as other parts of world. As pointed by Anselm (2016), in the study titled "*Power Outages and Production Efficiency of Firms in Africa"*, power generation capacity in sub-Sahara Africa is lower than that of any other region in the world and capacity growth has also stagnated such that the continent currently faces major electricity shortages with a number of power outages which has the tendency of rendering many firms less efficient in their production. As a result of power generation capacity deficit, many electricity utility companies are forced to ration the supply selectively and in doing so keep selective areas unsupplied with electricity. This process is usually rotational such that almost every consumer suffers the effect of electricity supply interruption.

According to Anselm (2016), the number of power outages or electricity interruptions experienced in a typical month has a negative impact on the production efficiency of firms in Africa. In terms of interruption cost as far as the impact of electricity supply interruptions are concerned, according to Schröder & Kuckshinrichs (2015), a distinction can be made between two types of cost impacts. To these authors, on the one hand, there are costs that can be termed damage costs and on the other hand, end users incurred costs that can be better described as mitigation costs. Damage costs can be broken down into direct and indirect costs. Direct damage costs are taken to mean those that are incurred directly by the company or the individuals affected. For example, the loss of production can be regarded as direct damage for the manufacturer. This loss of production then makes itself felt as indirect damage for other companies in the form of delayed deliveries. Mitigation costs are understood, for example, as costs for the procurement and operation of standby generators

3.2 Literature Review on Sporadic electricity interruptions

Sporadic electricity interruptions are caused by extreme weather conditions and this has been a major area of concern for many countries in the world. Such interruptions usually take a very long time and can bring extensive cost to electricity consumers in the way of spoiling perishable materials, food, damaging equipment, causing production loss, income loss, health impact, and extra expenses (Qin, Tatjana & Mladen, 2016).

Many authors have come up with the real circumstances that lead to sporadic electricity interruptions. Within the doctoral dissertation of Sinan (2015) at Aalto University in Finnland titled "*Economic Impacts of Electric Power Outages and Evaluation of Customer Interruption Costs*" climate change was found to be the underlining reason that brought an increased frequency of the extreme weather events and natural disasters that poses a great threat to the electricity power systems which leads to sporadic electricity interruptions. In the same way, the authors Qin, Tatjana & Mladen (2016) in their study titled *"Predicting Impact of Weather Caused Blackouts on Electricity Customers Based on Risk Assessment"*, pointed at severe weather conditions as the foundation that can cause damage to electricity delivery system and power infrastructures, leading to power interruptions to large number of customers. Also as underscored by Klinger, Landeg & Murray (2014), in their study titled *"Power Outages, Extreme Events and Health: a Systematic Review of the Literature from 2011-2012. PLOS Currents Disasters"*, it was premised that *e*xtreme events (e.g. flooding) in western countries threaten critical infrastructure including power supplies and that many interlinked systems in the modern world depend on a reliable power supply to function effectively. The findings of all these researchers are real and are realities that apply to many countries in the world that face extreme weather conditions.

Since sporadic electricity interruptions is now an accepted reality, further studies have been necessary to understand how they apply to consumers, governments and electricity utility companies, as well as how they could be contained and minimized. In the qualitative study by Sinan (2015), with objectives to provide Customer Interruption Cost (CIC) which will be customer specific and based on publicly declared objective data that demands less time, money

and efforts, it was premised that electricity power transmission and distribution planning cannot be done without a clear idea of the economic worth of a continuous and uninterrupted electricity supply. Even though smart grid technologies are being installed in the electricity network infrastructure, electricity supply reliability and interruptions have still been in an alarming state. As augured by Abdelgani (2020) in the study titled *"Customers Interruption Costs in Power Systems"*, extreme weather conditions in Finland adapted the electric power system to withstand extreme conditions. However, according to Abdelgani (2020), although Finland has a forceful infrastructure that enabled it to have a high level of reliability until the years before 2010, in late July 2010, when Finland was hit by severe storm along with thunders which caused the Finnish authorities to start making improvements in their electricity power systems to make it resilient towards extreme weather events. From the inputs of these authors, it is evident that major stakeholders in the electricity sector need to find ways to adjust in a way that any sporadic electricity interruption could be contained and their effects minimized.

In a study conducted in the USA by Ricky & William (2001), rolling brown-outs and black-outs have been commonplace in parts of California during the spring and early summer of 2001 with problems resulting from structural and legal failures, inefficiencies and diseconomies in power production and distribution that continued to plague California and other areas of the USA. According to these authors, sporadic power interruption first hit industries with interruptible power contracts, while others are similarly vulnerable when power is scarce with damages and losses that follow the interruption. It follows that there is a legal aspect attached to such electricity interruptions where consumers consider an interruption of supply as a breach of contract between them and the electricity utility company.

The impact of sporadic electricity interruptions can be very severe with devastating consequences. According to Sinan (2015), the impact of electricity interruption is classified into both direct and indirect; the direct impacts cover loss of manufacturing and production, interruption of services such as transportation, telecommunication and so on, loss of sales, damages on the equipment, spoiled goods, damages on the electronic data, accidents and injuries. The indirect impacts include public disorder, looting, and other crimes seen upon blackouts,

property losses and so on. These impacts are real and can be duplicated in any part of the world. In their own way, Qin, Tatjana & Mladen (2016), classified the direct impact to utility assets as the type of impact that includes all the situations where severe weather conditions directly caused the component to fail, such as lightning strikes to the utility assets, wind impact making trees or tree branches come in contact with lines, etc. In this case the outage occurs during the time of impact. When post fault analysis is performed these types of outages are marked as weather caused outages. The Indirect impact to utility assets as recorded by Qin, Tatjana & Mladen (2016), are the type of impact that accrues when weather didn't directly cause the outage but instead created the situation in the network that indirectly caused components to fail.

The impact of thunderstorms on electricity networks often cause damages that lead to sporadic electricity interruptions. According to Abdelgani (2020), thunderstorms in Finland reached a high record of 170.000 registered ground flashes, which is considered 20% higher than the long term average and these storms led to excessive damage, such as falling trees on the aerial distribution lines leading to extensive blackouts such that out of 3.2 million electricity customers, around 481,000 experienced electric power interruptions. These customers cut across various domains of electricity consumption. For example, within the framework of a systematic literature review conducted by Klinger, Landeg & Murray (2014), from 20 relevant articles found, Power outages were found to impact health at many levels within diverse settings, where the recurrent themes included the difficulties of accessing healthcare, maintaining frontline services and the challenges of community healthcare with 52 power outages identified in 19 countries that were the direct consequence of extreme events during the first three months of 2013. In a similar and more intense scenario, a sporadic electricity interruption occurred on 30th September 2021 that caused the whole of the Fako Division of the South West region of Cameroon to go without electricity supply for over twenty hours. As recorded in the ENEO Fako customer forum on the 1st October 2020, the Regional hospital director wrote, *"Regional hospital Buea topped their fuel reservoirs yesterday for the generator. But as we all know the generator has been running since last night and we are running short as I write. Ironically we can't buy gas anywhere now. Heading towards catastrophe with 25 patients on oxygen who depend on power for oxygen supply to stay alive"*. This means that the impact of sporadic electricity interruptions is a very

serious cause for concern for electricity utility companies because not only businesses depend on it, but the lives of a population as well.

The financial impact of sporadic electricity interruptions do not only apply to individual businesses, but also to the economies of countries. In the case of the United states of America, Qin, Tatjana & Mladen (2016) indicated in their study titled *"Predicting Impact of Weather Caused Blackouts on Electricity Customers Based on Risk Assessment"*, that estimated annual cost from storm-related outages to American economy is between $20-55 billion and the trend is still growing and that the historical blackout data from 2012 to 2014 in Texas shows 33% of the historical outage events caused by weather/ falling trees. In contrast to the financial impact to the American economy, the study of Abdelgani (2020) on Customers Interruption Costs in Power Systems, made no direct mention on the impact on economy with figures. However, other impacts of the sporadic electricity interruption according to Abdelgani (2020) were that daily life was somehow set on a pause as food was getting spoiled, automatic doors in hospitals stopped working, and the social activities were canceled.

As a way to reduce the storm-related outages, Qin, Tatjana & Mladen (2016) proposed possible methods including tree-trimming schedules, reliability-centered maintenance regulations, distributed generation support, grid redundancy improvement, underground cables construction, and mutual assistance agreement. However, all these methods are for long-term purposes. In a short-term view, if the utilities are aware of an upcoming severe weather scenario and the estimated severity of the related customer impact, preventive measures can be deployed to mitigate the customer vulnerabilities ahead.

3.3 Literature Review on Chronic electricity interruptions

Chronic electricity interruptions are those that cause consumers not to rely solely on the existing electricity grid for their electricity needs. This is so because electricity consumers that suffer chronic interruptions have no guarantee for a reliable supply due to dilapidated and poorly planned electricity networks.

The importance of a steady flow of electricity is important to every consumer of electricity. As put by Mathewman & Hugh (2014), in their study titled, "*Blackouts*: *a sociology of electrical power failure"*, modern societies are dependent on an uninterrupted supply of electricity as the continuing sophistication and prevalence of electrical appliances only serves to increase our dependence on it, especially as in the digital world, interruptions and disturbances of less than 1 cycle (1/60th second) can have catastrophic effects. Servers and computers crash, life support machines become their opposite, intensive care operations are compromised, as indeed are all manner of automated machines and micro-processor based devices (Mathewman & Hugh, 2014). According to these authors, chronic electricity interruptions have adverse effects on economy, food safety, crime rates, and accidents in transportation. This is in accordance with the study by Elie & Assad (2016), titled "*The Lebanese Electricity Woes: An Estimation of the Economical Costs of Power Interruptions"*, that pointed access to a reliable and continuous supply of electricity, as a major element of infrastructure services, which is essential to all economic activities that contributes to the enhancement of the standard of living standards of citizens, as well as the technological and scientific advancement of societies. According to Elie & Assad (2016), in Lebanon, ensuring such access has remained a major challenge because since the end of the civil war in the early 1990s, Lebanon has never enjoyed an acceptable degree of electricity supply security due recent figures show that electricity consumption per capita has grown at an average rate of 7% per year, whereas electricity generation has always lagged behind.

Chronic electricity interruptions come along with severe cost impact. In the case of Cameroon, the study of Dipoma & Tamo (2013), titled "*Power interruption costs to industries in Cameroon"* with objective to estimate the average outage cost for industries, the percentage reduction of average outage cost if suspension notice is given by the electricity utility company, as well as to estimate the cost of running generators during outages, it was found that the cost of electricity outages are high for Cameroonian industries, as well as the cost for running Generators during outages. This is true for most countries, particularly in Africa that suffer from dilapidated electricity networks.

The effects of privatization of electricity utility, especially in Africa is important in the subject of dealing with chronic electricity interruptions. In the case of Senegal, according to Lassana &

Abdoulaye (2013), in their study titled, "Electric *Power Outages and the Productivity of Small and Medium Enterprises in Senegal',* the Senegalese economy has undergone a major crisis in the electricity sector due to failed privatizations with the increased cost of fuel, and lack of public investments as the main factors that led to a poor electricity supply that shows in the daily occurrences of power outages which are chronic. In their objective to find out the effect of power outages on cost and technical efficiencies on Small and Medium size Enterprises (SMEs) , results based on survey data from 528 businesses indicate that power outage frequency and duration has a significant negative effect on cost and technical efficiencies on SMEs and larger businesses. This finding applies to many countries where the electricity sector has been privatized since investors are more concerned with making profits than re-investing to improve the electricity networks.

The relationship between the economic impact of chronic electricity interruptions and the costs of the interruptions at the utility and customer level has not been investigated widely. Akpeji et al. (2020) augured in their study titled "*Economic impact of electricity supply interruptions in South Africa"*, that high impact events like power system collapse affect large numbers of customers, often for extended periods. According to these authors, in the past, some authors had assessed the costs to some of South Africa's electricity customer segments using customer surveys which typically were based on chronic electricity interruptions, while other authors preferred the use of macroeconomic models for assessing the cost of un-served energy and the economy-wide cost of hypothetical nation-wide blackouts. Rotational load shedding, as experienced during more than a decade in South Africa, shares many characteristics with chronic interruptions and large system collapse scenarios (Akpeji et al., 2020). The finding fits squarely with the way chronic interruptions are managed in many other countries.

The impact of chronic electricity interruptions can affect not just individual businesses, but also the economy of a country. A good example, according to Elie & Assad (2016 is Lebanon, where the country has always suffered from a significant supply & demand imbalance in the regulated electricity market. According to these authors, with almost 100% electrification rate, an electricity shortage in Lebanon could hold back both economic and social development. However, the study of Dipoma & Tamo (2013) in Cameroon "*Power interruption costs to industries in Cameroon"* did not only conclude that power interruptions have a significant

negative effect on industries in Cameroon, but using the direct method for assessment, these authors found that the average outage cost varies from €3.62/kWh to €5.42/kWh for a 1-h interruption and from 1.96/kWh to €2.46/kWh for a 4-h outage and with the indirect method, the total capital costs and total running costs of generators are approximately €180,040,180.08 and €4,305,510.6, respectively. These figures reflect great losses that are generated through electricity interruptions which need to be carefully addressed.

3.4 Literature Review on Momentary electricity interruptions

In electricity distribution networks, momentary interruptions are usually caused by short automatic reactions of interrupters in power stations, as response on short duration failures on medium voltage networks. Since the inception of the electric power industry, the utilities protection practices have focused on reducing the frequency of sustained interruptions. Today, the increasing sensitivity of customer loads to brief disturbances has forced the utilities to find ways to reduce the number of momentary interruptions that occur on their systems (Gustavo, Arturo & Mario, 2011). This has resulted in increasing popularity of the associated indices, such as MAIFI (Momentary Average Interruption Frequency Index)

Generally, momentary electricity interruptions occur mainly during strong windy periods, where on return of the electricity supply, voltages often fluctuate with voltage sags. According to Tosak, Somchai & Mark (2005), voltage sags and momentary interruptions are the most significant power quality problems encountered by many industrial and commercial customers, where whether or not voltage sag causes a problem will depend on the magnitude and duration of the sag and on the sensitivity of the equipment of the consumer. Such interruptions can cause process interruptions in businesses that have very high costs. Therefore, options for improving the performance of businesses during momentary interruptions and voltage sags should always be considered. In the study of Chaitusaney & Yokoyama (n.d.), titled *"Influence and Prevention of Voltage Violation and Momentary Electricity Interruption Resulting from Renewable Energy Sources"* to investigate the causes of voltage fluctuations, and voltage violations in the electricity systems with integrated renewable sources, it was found that the more frequent bus voltages violate their limits, the more momentary electricity interruption tends to occur. However, this

particular source of momentary interruptions is not common in Africa, since tying electricity to the grid is not a common practice. They apply mostly to western nations with a well-developed renewable energy mix tied to normal grids.

As a result of frequent momentary interruptions and paradoxically high electricity consumption bills, there have been arguments on how duration of electricity supply can be measured such that the readings so obtained can be used as the basis to generate consumption bills. In the study of Otuekong, Etim,& Ekong (2021) in Nigeria on *"Automated Real-Time Electricity Supply Monitoring System"*, a proposed system was arrived at that measures the duration of supply such that the readings so obtained can be used as the basis to generate consumption bills. According to Otuekong, Etim,& Ekong (2021), in many developing countries it is not uncommon to find consumers complaining about outrageous electricity bills which they feel do not necessarily reflect the situation on ground because they mostly go for long with several electricity interruptions. Therefore, the system these authors came up with, in which the date, time and location information of the consumer is automatically monitored and reported from the moment the power supply was switched on helps to solve the problem of billings.

Chapter 4: Prevention of electricity supply interruptions

4.1 Maintenance of electricity networks

Maintenance of electricity networks are the main requirements that can help reduce the interruptions of supply, which requires specific maintenance philosophies. A maintenance philosophy is defined as the *"system of principles for the organization and execution of the maintenance"* (ISO/IEC 2002), which is a high level description of the overall principles for the maintenance management (Nordgård et al. 2005).

In a good electricity distribution network, there should be rankings of critical network components, network sections or feeders that may fail. In the study of Gross et al.(n.d.), titled *"Predicting Electricity Distribution Feeder Failures Using Machine Learning Susceptibility Analysis"*, a Machine Learning (ML) System known as ROAMS (Ranker for Open-Auto

Maintenance Scheduling) was developed to create failure-susceptibility rankings for almost one thousand 13.8kV-27kV energy distribution feeder cables that supply electricity to the boroughs of New York City. According to these authors, in Manhattan, rankings are updated every 20 minutes and displayed on distribution system operators' screens, while additionally; a separate system makes seasonal predictions of failure susceptibility. The implementation of such systems can greatly guide the practical activity of maintenance in order to reduce interruptions on electricity networks.

It takes good planning to effect maintenance on electricity networks with the help of relevant softwares. The study of Stanislav, Radomir & Vladimir (2006), titled *"Application of reliability centered maintenance in electricity Distribution Company"* deals with description of basic principles of reliably centered maintenance and software for the maintenance optimization of equipment in electric power engineering. According to these authors, the reliability centered maintenance is a more effective maintenance strategy of equipment where the inputs are databases of outages, maintenance, equipment condition, financial flow and software that connects optimal maintenance intervals and equipment maintenance. As stated by Stanislav, Radomir & Vladimir (2006), the software provides data for responsible and logical decisions and data for efficient maintenance strategy and feedback system.

According to (Nordgård et al. (2005), in order to have clear primary goals and visions when working with establishing and implementing maintenance strategies, the following principles have been identified as guidelines for the network companies' work: Firstly, the maintenance activities shall be based on risk evaluation, meaning that the activities shall be seen in light of the probability for and the consequence of the incidents they are intended to control. Secondly, the maintenance activities and (re)investments shall be closely coordinated, meaning that the maintenance activities must be seen in context to potential renewal of the grid. The maintenance shall be performed in compliance with existing rules and regulations.

In the study on electricity network management by Hamed et al. (2017) titled *"Distribution System Maintenance Budgeting: A Reliability-Centered Approach"*, maintenance management was pointed at as a part of the asset management policies which plays a vital role in enhancing the reliability of the electricity distribution system (EDS). It means that electricity utility companies need to devote a considerable effort to allocate their financial

resources to critical parts of the system in order to achieve higher efficiencies. According to Dark, Rodrigo & Dragan (2009), many systems require the periodic undertaking of major preventive maintenance actions (MMAs) such as overhauls in mechanical equipment, reconditioning of train lines, resurfacing of roads, etc. In the long term, these actions contribute to achieving a lower rate of failure occurrences, though in many cases they increase the intensity of the failure process shortly after performed, resulting in a non-monotonic trend for failure intensity.

Chapter 5: Gaps identified in the literature

5.1 Specification gap on electricity consumer group

The available literature does not specify the impact of electricity supply interruptions on a specific group of electricity consumers. All the available literature is on the impact of the various types of interruptions on the general consumers of electricity. This constitutes a gap in the literature.

5.2 Geographical gap

The available literatures are from articles from different parts of the world. There is no article available on the impact of electricity interruptions conducted in Cameroon. This constitutes a geographical gap that requires a study attempt to fill.

Chapter 6: Limitations of the review

The limitations of this study were that very limited research had been done on the impact of electricity supply interruptions on businesses, and no books exist in the subject. However, a number of articles are available on Google Scholar, from where the materials in the paper were obtained.

Chapter 7: Discussions

As synthesized in this paper, electricity interruptions are serious areas of concern for electricity utility companies, governments and various users of electricity. The contribution of this research is that Research and publications of the causes of electricity interruptions and impacts are good starting points of awareness, but more important are practical solutions to minimize or stop their occurrences.

One possibility of enhancing the sustainability of electricity supply that can be applied in African countries is the integration of solar electrification. In a country like Cameroon, where the electricity access rate is about 65–88% for urban areas and about 14% for rural areas (Erasmus, Sofiane & Fouzi, 2017), the rich solar resource of the country could be of great importance to boost the current electricity access rate.

In the report of Ntungwe (2019) on "*Cameroon's Rural Solar Energy Drive to Save Disappearing Forest*", the government of Cameroon is now encouraging the construction of solar energy projects in the electricity-starved rural communities across the country as part of its ambitious plans to become an emerging economy by 2035. According to Ntungwe (2019), the rural solar power drive that has already taken off in some local councils is geared at bringing new development stimulating perspectives to change the livelihood of rural communities. This is the way forward in ensuring an improved access of electricity in the country which needs plenty of support, especially from the government in tax reduction of solar electricity components.

Historically, to boost the development of renewable energy (RE), Cameroon had relied on reforms on the electricity sector, led by hydroelectricity which is largely developed compared to other RE sources such as wind, solar and biomass. According to Kidmo & Bogno (2021), initially, the law n°98/022 of 24 December 1998 governing the electricity sector, focused on hydroelectricity development only. Afterwards, the electricity Law 2011/022, governing the electricity sector and promulgated on 14th December 2011, clearly defined Renewable Energy (RE) sources. As recorded by Kidmo & Bogno (2021), this new law precisely shapes the legal and institutional supervision for RE promotion, by creating the Department of Renewable energy within the Ministry of Energy and Water Resources. To cope with the growth of electricity

demand, several government plans and programs for energy development have been announced and deliverables are highly expected. The involvement of the government in Renewable Energy (RE) sources is the foundation for the prosperity of the sector.

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