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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