GSJ: Volume 10, Issue 9, September 2022, Online: ISSN 2320-9186

www.globalscientificjournal.com

Conceptual analysis of infrastructural requirements for automated power theft tracking system in Ghana

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Abstract

Electricity usage has become one of the key attributes to socioeconomic and environmental development worldwide. It has led to touch many sectors of the economy, since its growth is highly reliant on the development of the power sector. Hence the aim of this study is to investigate infrastructural requirements for tracking power theft in NEDCo-Ghana. This study endorsed a cross-sectional survey plan and also employed a random study method. The research formed part of a bigger study which started in March, 2019 and ended in May 2021. Structured questionnaire which consisted of open ended and close ended were designed for consumers to answer. A total of 140 questionnaires were deployed to all the selected which falls within the NEDCo area of operation. On the basis of strategy of the research team, we divided the regions in to 2 equal halves thus (Savanna and Upper West) representing the Northern belt and whereas the other 2 regions (Bono and Bono East) were also known to be the Middle belt. This study demonstrates inefficiency relating to infrastructural deficit in the energy sector of Ghana and the need to embrace new technologies to help fight power loses in the energy sector. This will lead to give accurate measures to revenue mobilization issues and also account for power supplied to consumers.

Keywords
Technical & Non-technical loss Power theft, Advanced Metering Infrastructure, Northern Electricity Distribution Companys' Automated Tracking System, postpaid and prepaid meters.

Introduction

Infrastructural requirements satisfaction is needed to promote growth in any organization. Like most developed and underdeveloped countries demand for electricity has become essential to prove success in socioeconomic and environmental development (IEA, 2019). In the 21st century, one of the tool most developed nations have relied upon is the application of computer technology. The use of digitization technology like the introduction of real-time data has quickened the operational moves of most organizations to function highly (Accenture, 2013). According to (Morales & Palma, 2010), their study revealed that, the application of real-time systems will enable electricity companies to obtain data and transmit it reversely. This is because it positions effective communication features, accurate speed to detect locations. To help boost infrastructural systems in the power sector by means of operation, there should be a fore knowledge to every activity such as meter installation, new service extension which will heighten monitoring system (Morales & Palma, 2010). A good projection of materials in infrastructural stocks perhaps contribute to more realistic set-ups on the energy system, simultaneously improving the understanding of its environmental impacts (Sodersten et al., 2018). The basis of a sustainable economic development of every country depends on ensuring uninterrupted and sustainable electricity distribution (Zeshan, 2013). Globally, the use of computerized system in a way tracking electricity theft is in a way gaining acceptance to support monitoring systems and remote control by providing real-time information on usage, security and physical state of the devices, equipment or infrastructure.

In Ghana, the supply limits in the electricity sector have demonstrated to be the most important development challenge for the country. Amidst the supply constraints, Ghana continues to struggle with high reported cases of electricity theft and other illegal activities, leading to approximately 30% loss of electricity supplied by the companies (Ackah et.al, 2014).

Although, the sole aim of the utility company is to move completely consumers in both urban and rural areas to prepaid electricity metering system in order to fast-track and restore revenue and high administrative costs of unpaid paid bills by consumers using post-paid services.

Electricity theft is the fundamental cause of the financial crisis facing distribution companies in Ghana, and the high rate of electricity theft is worrisome and needs to be curbed. It is noted that the high NTL is commonly associated with customers using a post-paid metering system (Pless *et al*, 2016). Detecting electricity theft involves conducting regular on-site visual inspections to identify illegal meter connections. Doing so is a very tedious exercise and is very expensive for utilities. Most residential consumers indulge in unlawful connections at night when utility workers are not working. Another method of checking electricity theft involves studying a consumer’s consumption patterns to identify very low or zero energy recordings and then following up at the consumer’s premises to ascertain what the cause may be. These approaches and many others used to detect electricity theft are cumbersome, and the expected gains or results are unsatisfactory. Hence the aim of this study is to investigate the infrastructural requirements for automated power theft tracking system in the electricity system of Ghana.

Methodology

Description of Study area

The Bono East region is a fresh region which currently separated from Brong Ahafo Region. The Bono language is their main dialect. It has a vegetation which is made up of timberland and rich soils between December and April is the dry season. The showery season is amid July and November with usual once yearly rainfall of near 750 to 1050 mm. The main occupation of the inhabitants is mostly farming. They have a total population of 2,142,211.

Succinctly, the Savanna Region is one of the newest regions in Ghana and yet the largest region in Ghana. The Savanna Region is accommodated to be on the north by the Upper West region and west by Ivory coast. The vegetation mostly entails of Sahel and savanna. The

Upper West region is situated in the north-western turn of Ghana and to Upper East Region to the east and on the west by Burkina Faso. They have a total population of 1,554,322. The major occupation is mostly farming.

Selection of Study area

Four Regions were earmarked for this study, on this note, the selected regions divided into 2 regions, each representing the northern belt (Savanna, Upper West) and middle belt (Bono, Bono-East). These regions were selected because they fall within the regions of operation of the Northern Electricity Distribution Company (NEDCo).

Study Design and Population

This study endorsed a cross-sectional survey plan and also employed a random study method. The research formed part of a bigger study which started in March, 2019 and ended in May 2021. The cross-sectional research was purposefully achieved in June, 2019.

Research Method

The research team were driven to task to the goal of this study. In view of this, poring over of existing documents, field observations and conducting of interviews were the solid grounded factors that motivated this qualitative study. At the same time, adjourning Staff from NEDCo in the selected regions were interviewed and asked questions related to infrastructural requirements for automated power theft tracking systems in Ghana and their impact on the economy. These participants readily opined answers to them.

Respondent's survey

Structured questionnaire which consisted of open ended and close ended were designed for consumers to answer. A total of 140 questionnaires were deployed to all the selected which falls within the NEDCo area of operation. On the basis of strategy of the research team, we divided the regions in to 2 equal halves thus (Savanna and Upper West) representing the Northern belt and whereas the other 2 regions (Bono and Bono East) were also known to be the Middle belt. The questionnaires consisted of social demography of participants, knowledge on infrastructural requirements, servicing and maintenance and knowledge of computing. In all 140 questionnaires were administered to study participants. We administered 70 questionnaires to technical personnel working in NEDCo in the Middle belt as well as same of 70 questionnaires applied to staff of NEDCo in the Northern belt. This was done so as to compare their knowledge and understanding to technicalities in electrical power sector.

Inclusion criteria

A Participant who has worked with NEDCo and has lived in the said regions for more than 5 years, proved to be more than 25 years and willing to contribute to research were involved.

Exclusion criteria

Persons who were not identified to be familiar citizen in the study regions, not a worker from the NEDCo company and were either less than 25 years or who did not consent to partake in research were not allowed to join this research.

Analysis of Statistical Data

Analysis for this research was completed by using Graph Pad Prism statistical software© (Version5). Completed questionnaires received from research participants were entered manually using Microsoft excel 2021 version. Answered questionnaires were verified in simple frequency, p=value and odd ratio.

Results

The research constituted male and female participants working in NEDCo from both middle and northern belt of Ghana. The ages of participants of NEDCo workers in this study ranges from 25 to over 40 years. There were a higher number of age category 36-40 of participants in the northern belt (33%) compared to the middle belt (31.43%) who responded to this questionnaire Majority of participants from the study area had formal education and were skillful in some professional programs such as electrical and electronics engineering, computer engineering, telecommunication engineering etc. in the middle (38.5%) and northern belt (34.3%) of Ghana as shown in Table 1 below. Further analyses of bio-data from participants in this study with admiration to gender, revealed that there were greater males (60%) from the northern belt who availed themselves for this study compared to their middle belt counterpart (49%) which was not statistically significant (p>0.05) (Table 1). This study also took notice of marital status of participants in the study area. The married constituted (46%) from the middle belt while (47%) represented participants from the northern belt.

Table 1: Social demographic of Participants in the study community

Variable	*%number of cases examined (140)*	*%middle Belt (70)*	*%northern Belt(70)*	*p-value*	*odd ratio*
Age					
20-25	35(25.0)	21(30.6)	14(24.3)	0.722	3.5
26-30	31(22.14)	12(17.14)	19(27.14)	1.54	0.6
36-40	45(32.14)	22(31.43)	23(32.86)	0.86	0.94
>40	29(20.72)	15(21.43)	14(20.0)	0.84	1
Gender					
Male	76(54.23)	34(48.57)	42(60.0)	0.175	0.63
Female	64(45.71)	36(51.43)	28(40.0)	0.175	1.59
Marital Status					
Married	93(66.43)	46(65.71)	47(67.14)	0.86	0.94
Single	32(22.86)	15(21.43)	17(24.29)	0.69	0.85
Divorce	6(4.29)	2(2.86)	4(5.71)	0.4	0.49
Separated	2(1.43)	1(1.43)	1(1.43)	1	1
Widowed	7(5.0)	6(8.57)	1(.43)	0.053	6.47
Educational Status					
Jhs	3(2.14)	3(4.23)	0(0)	0.08	7.31

Shs	42(30.0)	15(21.43)	27(38.57)	0.03	0.43
Diploma	44(31.43)	25(35.71)	19(27.14)	0.275	1.49
University	51(36.43)	27(38.57)	24(34.29)	0.598	1.2

Footnote Norther belt region refers to Upper west and savanna whiles the Middle Belt regions refers to Bono East and Bono; OR refers to Odds ratio , p<

was considered significant at 95% confidence intervals.

The knowledge of participants on infrastructural requirements regarding automated power theft tracking service was asked during this section. Our research team resolved to know from participants working in the study area if probably there is a device used to detect power theft from their system. A higher number of participants from the northern belt (90%) expressed that thus, the company has not yet made an advancement to such technology compared in the middle belt (79%). We delved further to ask participants (NEDCo Staff) from both regions how then do they assess power theft cases. It was worth revealing that greater majority of participants in the northern belt (65.71%), (25.71%) expressed that power theft is assessed by effective monitoring and "tip-off" given by third-party consumers compared to their middle belt counterpart (55.71%), (33%) It was also questionable to know from our study how the electricity company is able to determine the actual amount of electricity stolen by a consumer. They answered that it was calculated based on the average units the consumer uses. Unreservedly, it was observed by the team that, greater participants from the middle belt (88.5%) had knowledge on devices for tracking power theft compared to the northern participants (84%) and this was found to be statistically significant with p- value<0.00001. We also found out if their company had instituted the use of management information system as part of their work. The middle belt participant (60%) believed that management information system was working effectively in their company compared to their northern group (45%) and this information was however not statistically significant. Further analysis of answered questionnaire was done to ascertain whether their company has enough logistics to help fight power theft crimes. On this note study participants from both regions indicated the already preparedness of their company with only (90%) participants from the middle belt as supported by their northern belt group (77%) and this was not found to be statistically significant as shown in table 2 below. We sought to analyzed whether the installation of automated tracking system meters has commenced in Ghana. Analyzed results showed that were about 5 times participants from the northern belt (4.3%) who did not show consent and understanding to ATS compared to their middle belt group (17%) and this was found to be significant with p=0.014. Also, participant from the middle belt (50%) reacted that the best way to move in combating crime for power theft incident is through the establishment of ATS as shown in Table 2 below.

Table2: Participants knowledge of infrastructural requirements on Automated Tracking System

Variables	%number of cases examined	%middle belt(70)	%northern belt(70)	p-value	odd ratio
Does your company have a device used to detect power theft?					
Yes	18(12.86)	13(18.57)	5(7.14)	0.043	3
No	118(84.29)	55(78.57)	63(90.0)	0.0632	0.41
Not yet	4(2.86)	2(2.86)	2(2.86)	1	1
How do you detect power theft?					
Monitoring	41(29.29)	23(32.86)	18(25.71)	0.4	1.4
Informants	85(60.71)	39(55.71)	46(65.71)	0.23	0.7

Tracking devices	14(10.0)	8(11.43)	6(8.57)	0.6	0.3
Have you heard about automotive tracking device?					
Yes	121(86.43)	62(88.57)	59(84.3)	<0.0001	42
No	19(26.15)	8(11.43)	11(15.71)	<0.0001	0.24
Do third parties report theft incidences?					
Yes	103(73.57)	48(68.57)	55(78.57)	2.7	0.4
No	37(26.43)	22(31.43)	15(21.42)	0.18	0.6
Do you work with management information software?					
Yes	74(52.86)	42(60.0)	32(45.17)	0.094	1.8
No	66(47.14)	28(40.0)	38(54.29)	0.09	0.6
Does NEDCo have enough logistics to combat power theft?					
Yes	117(83.57)	63(90.0)	54(77.14)	0.04	2.7
No	23(16.43)	7(10.0)	7(10.0)	0.04	0.4
Do your company embark on seminars relating to technology?					
Yes	135(89.29)	61(87.14)	64(91.43)	0.41	0.64
No	13(9.29)	9(12.86)	4(5.71)	0.15	2.43
Don't know	2(1.43)	0(0)	2(2.86)	0.15	0.2
Have you heard about AMI?					
Yes	18(12.86)	12(17.14)	6(8.57)	0.13	2.21
No	112(l87.14)	58(82.86)	64(91.42)	0.13	0.5
Does your company have ATS meters?					
Yes	49(35.0)	38(54.29)	11(15.71)	0.0001	0.4
no	76(54.39)	20(28.57)	56(80.0)	0.0001	0.1
Don't know	15(10.71)	12(17.14)	3(4.29)	0.014	4.6
Can ATS be the best tool to combat electricity theft?					
Yes	21(15.0)	10(14.29)	11(15.71)	0.83	0.9
No	60(43.0)	50(14.29)	10(14.29)	0.9	1
Don't know	99(70.29)	10(71.49)	50(71.42)	1.5	1.1

Footnote Norther belt region refers to Upper west and savanna whiles the Middle Belt regions refers to Bono East and Bono; OR refers to Odds ratio, p<0.05 was considered significant at 95%

When issues relating to technical services and maintenance was asked from Participants regarding how their company respond to technical faults. (50%) participants from the middle belt gave the option that during fault complains some field Technicians in charge of the operational area are deployed to the scene to help fix the problem compared to (32%) of their northern counterpart as found in Table 3 below and this was also known to be statistically significant with (p=0.002). In terms of labour force the organization needs to run the utility service effectively, (85%) of middle belt group explained that more technical staff needs to be recruited to help bring the desire results the company needs as likened to those in the northern belt (54%). Meter accessories and its related questions were asked during this study and analysis of results however showed that greater proportion of middle belt (33%) admitted that the only way to mitigate power theft is that NEDCo as matter of urgency procure and install smart meters having AMI features because it is another way to help reduce power theft crises in surrounding environment. Though current meters do possess some functions of smart detection features, yet NEDCo have not fully activated those functions and as a result customers are using that to cause great harm of theft to the company anytime one feel like practicing theft compared to their northern belt compatriot (26%). The researchers also further investigated into NEDCos' response to faulty gadgets. On this note we sought to know the exact periods NEDCo conducts maintenance services. It was amazing to hear NEDCo workers from the northern belt (90%) agreed to monthly servicing by their company compared to their middle belt NEDCo workers (70%). This was also noticed to be statistically significant with p=0.03 as shown in Table 3 below.

Table3: Participants knowledge on maintenance and servicing of electrical components

Variable	%No of cases examined (140)	%middle belt region (70)	%northern belt region (70)	p-value	odd ratio
Do your company have an office for automated tracking system?					
dispatch technical team	82(58.57)	32(45.71)	50(71.43)	0.002	0.34
wait for several complaints	8(5.71)	6(8.57)	2(2.86)	0.15	3.2
wait for report from field officers	37(26.42)	21(30.0)	16(22.86)	0.34	1.45
software detection	13(9.27)	11(15.71)	2(2.86)	0.003	13
Do NEDCo have enough labor force in line with technical activities?					
Yes	42(30)	10(14.29)	32(45.71)	<0.0001	5.1
No	98(70.0)	60(85.71)	38(54.29)	<0.0001	0.2
Do current meters have AMI functions					
Yes	41(29.29)	23(32.86)	18(25.71)	0.4	1.4
No	14(10.0)	8(11.43)	6(8.57)	0.6	1.4
don't know	85(60.71)	39(55.71)	46(65.71)	0.23	0.7
Does your company have computer for every office?					
Yes	15(10.71)	12(17.14)	3(4.29)	0.014	4.6
No	112(80.0)	49(70.0)	63(90.0)	0.003	0.26
Don't know	13(9.29)	9(12.86)	4(5.71)	0.15	2.43

Footnote Norther belt region refers to Upper west and savanna whiles the Middle Belt regions refers to Bono East and Bono; OR refers to Odds ratio, p<0.05 was considered significant at 95% confidence intervals.

Discussion

This study is set out to be the first published work on infrastructural requirements for tracking power theft systems in the Northern Electricity Distribution Company of Ghana. Henceforth, its discoveries will help direct infrastructural requirements and its associated power theft leakages in the electricity sector of Ghana. Also, this will help to address several materials related to the growing demand for electricity (Deetman et al., 2020). First of all, our study revealed that, the rampant theft practices occurring in NEDCo- Ghana, was due to inadequacy of field Technicians in NEDCo operational areas to help monitor electricity supply and services effectively and was visualized to be paramount leading to rampant increase of power theft practices in some of its operational areas. These outcomes are similar to a study conducted by (Watari et al., 2019) that made similar observation on the need for more technical strength demand in the power industry.

Consequently, our study observed the unpreparedness of NEDCo in the involvement of technology in most of their system. This act was another factor seen to be causing a great havoc to power sector of Ghana. Detection of electricity theft by power utilities can be done using technological and non-technological approaches. In the 21st century, detection of electricity stealing can be done using computerized advancement and non- computerized advancement. Most electricity companies do not implore the no-real-time monitoring system. By convention, the use of zero-low purchase monitoring can be applied when a consumer has paid for a small unit but in reality, uses more than what he has bought or can be timed for a specific period he is supposed to buy units and actually that time elapsed. Sometimes the use of load/purchase technique can be applied when the company for example in area it supplies electricity, the consumption rate is higher than the purchased rate. For the non-computerized method, utilities can adapt periodical monitoring of meters after its installation. To detect power theft is not easy. Utility companies throughout the world are confronted with some operational and technical problems. In a previous study conducted by (Geib, 2012) investigated that the top most technical challenges encounted include data integrity. In rare cases information of a consumer who has acquired a meter will not be captured in the data base system of the electricity company. In this case, it will be difficult tracking the consumer stealing the electricity. Another issue is that, culprits who steal power does so mostly at night and this situation cannot safeguard the electricity companies since their monitoring occurs in the day time. Hence, we found this information to be in line with our study.

We also esteemed that shortage of electricity installation materials to new service or areas receiving rapid population growth due urbanization is the main cause leading to extremely demand power theft practices Since the laid down processes for consumers to be supplied with power from NEDCo is somehow devastating. One could easily contract a contractor and by- pass the main process to have access to the electricity. In this situation, he/she will be left no option done to steal electricity. A study shown internationally predicts yearly material demand of electricity linked to various sectors (Morimoto et al., 2019). The study continues to explain that the yearly material demand of electricity is generally small likened to the current total global production for materials such as concrete, steel and glass, but for other materials such as copper and aluminium the electricity sector represents a considerable fraction of the total global demand. As the annual demand of the sector is expected to increase, so does the relevance with respect to the current production.

Thirdly, our study realized the inability on the part of NEDCo to use technology to assess or monitor power theft practices. Of late one of the best tools to make things happened is the use of technology but however NEDCo-Ghana has abandoned the use of these tool in order not make their work productive. In the power sector, the assembling of smart meters like the AMI could help curb power theft practices in Ghana. In recent years, smart metering has gained popularity in the energy sector, especially in electricity and gas, as it eliminates NTLs by inhibiting customers’ cheating behaviours that are common with non-innovative meters. Often, the introduction of smart metering aims to change customers’ consumption behaviour toward energy saving (Sonderlund et al., 2014). Conversely, in developing countries where electricity cheating is common, the introduction of this technology tends to benefit utilities through electricity theft management rather than energy saving management. These suggest that any increase in the reported amount of electricity consumption from smart metering constitutes (the lower bound of) the reduced NTLs (Otchere-Appiah,2021). Electricity theft in prepaid metering system is one of the new challenges confronting the power utilities. It has become a world-wide concern in the transmission and distribution supply of electricity, more so in recent years where most utilities are adopting prepaid electricity metering systems (Pandey et al., 2013; Selvapriya, 2014). Most developing countries are estimated to be losing between 20% and 45% of revenue through electricity theft (SARPA, 2013), while those in the developed world loses between 3.5% and 30% (Balasubramanya, 2014). The estimated losses run from the period 2008 to 2014. One of the challenges in preventing electricity theft is the difficulty in detecting the actual location of electricity theft in real-time (Tasdoven, Fiedler & Garayev, 2012). The implementation of real-time technology to track and monitor communications between the consumer and utility should be the best tool to help fight electricity power theft. There is a need to detect electricity theft at the exact location, in real-time and transmit the information through mobile technologies to the back-end system for decision making. Mobile technologies offer a real-time platform in achieving the required information. They also provide the capability to monitor individually installed infrastructure. The use of mobile technologies is central in detecting electricity theft. However, most power utilities world over are still lagging behind in this regard (Pargal, 2014).

Conclusion

In this study, our results practically show that, power theft and still exist in some of the NEDCo operational areas where this study was conducted. Although some losses in the power sector could be not be done without, there are myriads of loop holes of losses in the power sector which could also be lessened. First, inadequate monitoring and improper technical observations, less stringent administrative policies, yearly biased routine organizational workshop training to equip staff knowledge on power theft handlings were noted

to be some root causes to addressing this problem. Again, this study demonstrates inefficiency relating to infrastructural deficit in the energy sector of Ghana and the need to embrace new technologies to help fight power loses in the energy sector. This will lead to give accurate measures to revenue mobilization issues and also account for power supplied to consumers. This initiative application and stringent measures will end confidently electricity theft technics used to steal power by culprits.

Acknowledgment

The team is grateful to all and sundry we work tireless to enable this research reached this far. To the outmost is our key respondents and community leaders who made things so easy for the success of this study.

Funding

The Researcher declare that no research grant was received in the course of this work.

Availability of data and materials

The datasets analyzed during the immediate study are available from the research team on the basis of reasonable request.

Competing interests

The authors affirm that we have no competing interests.

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