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Research paper

Electricity theft mitigation in the Nigerian power sector

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Abstract

Electricity theft is a pervasive problem all over the world. With electricity generation in Nigeria falling short of the required generation capacity, it is disturbing that the little power generated is also being stolen by some unscrupulous consumers. Electricity distribution companies in Nigeria (DisCos) lose about ₦30 billion every month owing to electricity theft. This amount is whopping, and if significantly reduced and spent on the power infrastructure and management, it would improve the power situation in the country. This paper proffers the deployment of Smart Grid (SG) with its inherent smart metering as a solution to the electricity theft situation in Nigeria, as a result of its improved flexibility, security and reliability. Smart Grid also supports energy diversification, by allowing the integration of various renewable energy sources into the conventional power grid. This will tend to help in improving the epileptic power situation in the country.

Keywords: *Electricity Theft; Generation Capacity; Power Grid; Renewable Energy; Smart Grid.*

1. Introduction

Electricity is one of the main drivers of any progressive economy around the world. It drives most human activities and add value to human lives. One of the factors that enhanced the developed nations in achieving such coveted status is electricity reliability. In fact, it is a common belief that any nation that aims to develop, but is still being plagued by epileptic power supply is not ready yet. Electricity attracts investments into any country of the world that could sustain its reliability, and that eventually leads to economic prosperity. Despite being referred to as the giant of Africa, the power problems in Nigeria has demystified this acclaimed status, and has made the country a hostile ground for investment. Electricity is a commodity that should be well managed and guarded jealously to make its impact fully felt in the society. Electricity is facing a major threat around the world today, and that threat is called electricity theft. Electricity theft is an age-long problem that has been plaguing the power industries for a very long time [1].

Electricity theft has hampered electricity reliability and sustainability all over the world especially in the developing countries [2], [3]. The developing or the underdeveloped status of these countries will not disappear anytime soon, because of the endemic and alarming spate of electricity theft enshrined there. This has hindered the reliability and sustainability of electricity supply in these countries and have in turn stalled economic growth.

The two types of energy losses in the electrical power system are the technical loss and the non-technical loss (NTL). Technical loss is the loss that occurs naturally, as a result of dissipation of energy in the power transmission and distribution equipment, while NTL or commercial loss [4], occurs owing to actions that are external to the electrical power system [2], [5]. Electricity theft is the main cause of NTL [6], or culminates a major chunk of NTL [7], reason the two terms are used interchangeably [8]. The losses in the electrical power system is the difference between the energy fed into the distribution system and the energy billed [5]. This difference is otherwise known as electricity theft [9].

Electricity theft causes economic loses, damages to the grid infrastructures, and this eventually leads to irregularities in power supply. The electricity situation in Nigeria is a peculiar one. The electricity that is being generated in the country falls short of the needed capacity to power the whole country [10]. Despite this shortfall, it is disturbing that the little electricity generated is also being stolen by some unscrupulous consumers. Electricity theft is a major factor that causes the epileptic and the ineffective supply of electricity in Nigeria [11]. Electricity theft has really created more havoc to the Nigerian power sector, and the stride to achieving a steady power supply in the country has been further reduced to a mere dream.

The reform process which eventually led to privatisation of the Nigerian power sector started in March 2005, when the Electric Power Sector Reform Act (EPSRA) was signed into law [12]. This signaled the beginning of the end of the monopoly of the government owned utility company, the National Electric Power Authority (NEPA). The State owned NEPA was subsequently unbundled and renamed Power Holding Company of Nigeria (PHCN) to usher in the reform process which would allow private sector to participate in the generation, transmission and distribution subsectors of the Nigerian power sector. The Nigerian government completely privatised the generation and the distribution subsectors of the power industry between November 2013 and February 2014, but retained the transmission subsector in

the electricity value chain to relieve itself of the complete monopoly of the sector. This is to enhance better and efficient management of the power sector. Despite the private sector takeover of the generation and distribution facilities of the Nigerian power industry, it is unfortunate that no significant improvement has been recorded as regards the power situation in the country [13]. Epileptic power supplies brought about by incessant load shedding is still the order of the day. Electricity theft menace is one of the major threats to the entire privatisation programme. The different companies that bought over the different generation stations across the country are called the generation companies (GenCos), while those companies that bought over the distribution stations are known as the distribution companies (DisCos). The government still owns the transmission subsector which is known as the Transmission Company of Nigeria (TCN). The ex-State owned PHCN was finally unbundled and dissolved into six GenCos and eleven DisCos [12]. The ESPRA also established the Nigerian Electricity Regulatory Commission (NERC), an independent body, to regulate the power sector [12], and the Nigerian Bulk Electricity Trading (NBET) Plc, which serves as a broker between the power producers and the DisCos [14]. The power producers consist of the GenCos, the independent power producers (IPPs), and the National Integrated Power Project (NIPP), making up currently 23 grid-connected generating plants to form the Nigerian Electricity Supply Industry (NESI) [12], [14]. The DisCos are the closest to the consumers and also serve as the retailers of the electricity product to the consumers. The DisCos are saddled with the responsibility of generating the income based on the capacity of the received transmitted power, while the GenCos and the other service providers and players in the electricity value chain are paid directly by NBET, the financial remuneration assurer and broker, from part of the revenue generated by the DisCos. However, the DisCos have been insolvent in paying (via NBET) the GenCos and others in the fold of NESI what is due to them owing to electricity theft [15], [16].

The DisCos lose about ₦30 billion monthly owing to electricity theft [17]. Electricity theft constitutes over 80% of the energy losses in Nigeria [18]. For Nigeria to take its rightful place in the committee of nations, its electricity reliability flaws which is compounded by the spate of electricity theft in the country must be dealt with. This paper is a review of the electricity theft situation in Nigeria and proffers the deployment of Smart Grid (SG), with its inherent smart meters (SMs) in the advanced metering infrastructure (AMI), as a formidable solution to ending the electricity theft problem in the country [6]. The SG allows the integration of renewable energies like wind, solar, biomass, etc. into the conventional power grid, with its demand response functionality, which would help in ending the electricity reliability impasse in Nigeria. The approach of SG deployment would improve the quantity and quality of power supply in Nigeria, and solving the perennial power problems in the country once and for all. This will seamlessly transit Nigeria into the Fourth Industrial Revolution (4IR) in the power sector.

2. Methods of stealing electricity

Electricity is being stolen by employing different methods. The two most common methods are direct connection to the power grid through the distribution lines and frauds that are related to electricity meters, otherwise known as meter tampering [19]. Meter tampering could be in the form of putting a strong magnet on top of an electromechanical meter or inserting a foreign object into the meter to impede the movement of the rotating disc inside the meter [7]. This thereby tends to slow down the reading rate of the meter, which in turn indicates false reduction in energy consumption. Damaging the pressure coil of the meter by hitting the meter and also creating a mechanical shock to the meter, so as to stop the meter from reading [20], is also a form of meter tampering. Moreover, an electricity meter could also be tampered with by bypassing the meter and connecting directly to the supply cables, just before it gets into the meter terminals. Fig. 1 shows how electricity is being stolen by illegally connecting directly to the distribution feeder of the power grid.

Fig. 1: Electricity Theft by Direct Connection to the Distribution Feeder [21].

Fig. 2 shows a case of meter tampering by bypassing the meter. This incident took place in a residential building in Ikorodu, a suburb of:

Fig. 2: Electricity Theft by Bypassing the Meter.

Lagos State, Nigeria. The supply phase going into the first energy meter (from left) has been bypassed. Shorting the input and outputs terminals of the energy meter, or swapping the input terminals for the output terminals and vice versa to prevent the meter from reading is also a way of tampering with the meter [22]. Furthermore, some advanced ways of stealing electricity by meter tampering is using a supply phase, and a ground as a return path, instead of using the neutral supply from the utility company as a return path. In this case, the energy meter would assume no energy flow, and no reading would be recorded [7]. Damaging the insulation on the secondary side of the current transformer of the energy meter and tapping electricity directly from it to reduce the meter reading is also another way [19]. Electricity theft by piggybacking is another way of stealing electricity [23]. It is a situation whereby power is being illegally tapped, this time, not directly from the distribution feeder but from other legal consumers who are oblivious of such action.

Other forms of electricity theft are resetting the meter readings, deliberate non-payment of electricity bills, vandalising the utility infrastructure, stealing electricity cables, and the unfaithful act of utility employees who collect bribes from electricity consumers to connect them illegally to the power grid; or collect bribes from electricity theft offenders, instead of fining them and reporting them appropriately. These unscrupulous utility employees could also help the consumers in picking lower meter readings instead of the correct and accurate readings and thereby cause billing irregularities [19].

3. Causes and effects of electricity theft

Electricity theft is more prominent in the developing countries [24] than it is in the developed countries [25]. Most of the electricity theft occurrences in the developing countries are as a result of poverty [3], while others are due to greed and moral laxity [26]. The moral laxity displayed by corrupt utility employees or representatives who compromise their call to duty and connive with electricity consumers to negotiate personal terms of financial settlement, instead of being honest and objective. In this case, consumers and the utility employees have chosen to tow the corruption path instead of being modest and law abiding. Other moral laxity issues that cause electricity theft especially in Nigeria is the scandalous notion that, it is only criminal to steal from neighbours, families or friends but not a crime to steal from the State or public utilities [7]. The fact that some citizens believe that electricity supply should be a social service, which should be given for free, is also a contributing factor [27]. Other causes of electricity theft in Nigeria are the inability of the DisCos to provide electricity meters for all their consumers who wish to only pay for what they consume. Since those kind of consumers only get estimated billings, and at most times outrageous ones, they tend to waste the power and cause unnecessary NTLs for the DisCos. At most times, the metered consumers too also get erratic estimated billings for a good part of the year. These estimated billings shoot up their electricity bills swiftly, and eventually turn them unjustifiably into stark debtors to the DisCos. A debt which remains permanent on their electricity bills, and which the DisCos always insist they must pay. This ugly event discourages the genuine customers from wanting to pay their electricity bills. High unemployment rate in the country [28], [29] which culminates into harsh economic conditions for the electricity consumers is also a factor that contributes to electricity theft in Nigeria. Since electricity is an essential commodity, but there is little or no money for the consumers to pay their bills, they tend to tow the desperate path by stealing the precious commodity. Despite the existing laws against electricity theft as contained in Section 94 (3) of EPSRA 2005 [30], Section 9 and Section 10 of the Miscellaneous Offences Act (MOA) [31], and the draft of NERC Electricity Theft and Other Related Offences Regulations, 2014 [32], their weak enforcements have encouraged the electricity thieves to carry on. Illiteracy of some sort on the part of some consumers, who are oblivious of the fact that there are established laws against electricity theft is also a factor. Lastly, the epileptic nature of the electricity supply in Nigeria discourages Nigerians from wanting to pay their electricity bills. Most of them ask the question: “why do we have to pay for what we are not getting?”

One of the adverse effects of electricity theft in Nigeria is that it worsens the current fickle power situation in the country. It leads to economic losses and hinders economic development, as foreign investors look elsewhere to do their businesses. Electricity problem is the biggest obstacle to doing business in Nigeria [33], and one of the key reasons for this is high energy losses. In fact, some multinational companies that used to ply their trades in Nigeria have shut down their various companies and have moved to other nations with steady power supplies [34]. The direct consequence of this is job losses. Also, as a result of electricity theft, the power supply equipment is overloaded. This leads to damages to the grid infrastructure and consequently leads to reduction in power quality. The liquidity crunch brought about by electricity theft to the DisCos affects everyone. The innocent legal consumers too pay the price for electricity theft, and the scourge also robs them of the available electricity. The DisCos tend to impose excessive tariffs on them, since they cannot bear the burden alone [35]. Everyone pays indirectly from the illicit acts of stealing electricity, and this is a major reason the issue should concern everybody. It should be the duty of everyone to report anyone found culpable of stealing electricity. Stealing electricity also leads to serious injuries and fatalities [7].

4. Panacea to the electricity theft problem

There is no problem that is insurmountable if the right solution is applied. The electricity theft solution could be technical or non-technical. The technical solution is the main solution while the non-technical solution is a supporting solution. The non-technical solution is more of a preventive measure proffered to give a benefit of the doubt, that peradventure, the consumers would yield to the call and stop the illicit acts of stealing electricity. The technical solution becomes the only viable solution, and the last resort to the human eventual notorious activities and drive towards stealing electricity. The technical solution could serve the purpose of prevention, detection, and control. However, the non-technical solution is meant to augment the technical solution but not for the technical solution to expunge it. It should be noted that in reality, electricity theft or NTLs cannot be totally eradicated, but could be reduced to a tolerable minimum [36], [37].

4.1. Non-technical solution

For the non-technical solution, the Nigerian electricity consumers need to be sensitised that electricity is not a social service that is given freely but a manufactured commodity that needs to be paid for to continue enjoying it. There is need for the implementation and enforcement of the existing laws and regulations against electricity thieves as mentioned in Section III. Effective collaborative efforts and engagements between the DisCos and the Police is very vital. If offenders know they would get arrested and charged to courts, they would desist. Also, the need for special courts to handle electricity theft related cases is important in the war against the scourge. If there is speedy judgement and electricity theft offenders are jailed and/or told to pay huge fines, it will serve as a deterrent to others who aid and abet or engage directly in such illegal activities. Electricity consumers should be enlightened and encouraged to report electricity theft offenders. If they are aware that the theft of electricity takes out money from their pockets too, they will be willing to give tip-offs about suspected electricity thieves. Toll-free telephone numbers should be made available to the public to report anonymously electricity theft related

matters. Reliable tip-offs could be compensated with financial rewards to encourage the consumers to report more offenders. Periodic impromptu inspection of the homes of electricity consumers will also help a great deal in curbing the electricity theft menace.

4.2. Technical solution

SG deployment is the technical solution that would help mitigate the lingering electricity theft problem, and improve the quantity and quality of power supply in Nigeria. SG would assist countries in sub-Saharan Africa to have universal access to electricity. It provides the opportunity to surpass the conventional or traditional grid systems to improve electrification [38]. SG is the modernisation of the conventional electrical power grid system [39]. It utilises digital information and communications technology (ICT) to improve the conventional power grid, enhance distributed generation, and instills the economics of electricity generation and utilisation. SG enables the seamless integration of renewable energies into the power grid, and enables it to be used more efficiently [39]. Some of the landmark features of SG is self-healing, self-monitoring, fault and tamper detection, two-way communication between consumers and the utility companies, automated billing, wireless sensors throughout, demand response, and electricity theft detection [40], [41]. These features make the power grid intelligent and reduce human level of participation in its operation. Subsequently, there would be no more manual meter readings, as consumption readings are sent directly in real time to the utility companies via the two-way communications facilities between the consumers and the utility companies. This thereby knocks off the probable corruption deal between the utility employees and the consumers. The networked automated system brought about by the SG technology improves reliability, energy conservation, reduction in carbon emission, resilience, energy efficiency, security, transparency, sustainability and flexibility [42]. This explains the reason most solutions to electricity theft in the literatures have been identified as technical. SG takes care of the shortcomings of the traditional power grid, and addresses the issue of electricity theft by the deployment of AMI [43], a technology found on the consumption side of the power grid. SG system ensures that electricity is delivered and consumed in an efficient way. The concept of SG has provided a huge opportunity for the developing countries to revamp and modernise their power sectors to stimulate growth.

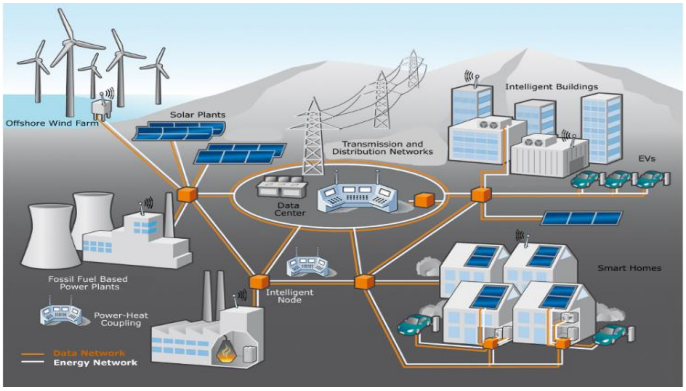

Fig. 3: The Smart Grid Architecture [45].

AMI is the modernisation of the electricity metering system by replacing the old electromechanical meters with smart meters [42]. The AMI consists of the SMs and data collectors which aggregates home and neighbourhood electricity usage data, which are sent via cables or wirelessly to the utility control centre [44]. The architecture of the SG which depicts the system structure is shown in Fig. 3. As could be seen above, the Figure consists of smart homes and buildings with SMs, the conventional fossil fuel generation plants, and other distributed renewable sources like the wind farm and the solar plants integrated into the system.

The conventional energy meters are still being used mainly in Nigeria. Prepaid meters were introduced, though not evenly distributed, but has failed to reduce the NTLs effectively. The introduction of SMs would improve power quality, load sharing and detect NTLs [46]. The SM is a unit of the AMI which communicates the utility companies in a two-way fashion. Fig. 4 is a typical sample of a SM. The use of intelligent electronic meter or SM is the most effective

Fig. 4: Smart Meter [45].

way to make electricity related frauds easier to detect, and more difficult to perpetrate [36]. SM has the ability to record zero reading [22], detect a mismatch between phase and neutral current [9], and send alert to the utility companies to take necessary actions against probable electricity theft, unlike with the electromechanical meters [7]. Users of SMs see the amount of consumed electricity in real time and get notification from the utility companies as to when it is cheaper or more expensive to use electricity, so as to make informed economic decisions. At times, the utility companies could advise the consumers to lower their electricity usage by sending commands through their SMs, and a failure to do so could attract remote disconnection. This phenomenon is called demand response. It is to ensure that load is

being managed within demands, or that power is being generated and consumed at the limits of the grid [47]. In India, a developing country with similar power situation and sector privatisation like Nigeria, the North Delhi Power Limited (NDPL) reduced energy losses from 53% to 15% within five years, by deploying SMs at the premises of the largest electricity users [48]. It worked for NDPL in India and it would work in Nigeria too. If the losses due to electricity theft is not addressed, it could completely bring down the power industry.

5. Conclusion

It is of no use to bemoan the past and the present situation in the Nigerian power sector, in terms of electricity theft, and other intricacies. Rather it is time to swing into action and apply the right solution for the future. The deployment of SG with its inherent SMs has been identified as a formidable solution to ending the electricity theft and by extension other power issues plaguing the country. With SMs, electricity theft would be reduced to the barest minimum. This would reduce the huge losses in revenue, ensure financial profits, and enhance the DisCos, the TCN, and the GenCos to meet their targets as contained in their Performance Agreement [49]. Majority of Nigerians only want to pay for what they consume, just like in the use of their mobile phones, where they are charged in accordance with their exact consumption. Some Nigerians took into electricity thievery because they are not metered properly and appropriately. Also, there is always a limited instinct of nefarious activities if proper and reliable technology is put in place to instill the right checks and balances. Deployment of SG will achieve all these and eventually put smiles on the faces of Nigerians.

References

[1] B. Budget, "Daily Yellowstone journal," *Newspaper article*, 27-Mar-1886. [Online]. Available: https://chroniclingamerica.loc.gov/lccn/sn86075021/1886-03-27/ed-1/seq-2/. [Accessed: 12-Mar-2019].

[2] J. L. Viegas, P. R. Esteves, R. Melício, V. M. F. Mendes, and S. M. Vieira, "Solutions for detection of non-technical losses in the electricity grid: a review," *Renew. Sustain. Energy Rev.*, vol. 80, pp. 1256–1268, 2017. https://doi.org/10.1016/j.rser.2017.05.193.

[3] Ç. Yurtseven, "The causes of electricity theft: An econometric analysis of the case of Turkey," *Util. Policy*, vol. 37, pp. 70–78, 2015. https://doi.org/10.1016/j.jup.2015.06.008.

[4] C. C. O. Ramos, A. N. Souza, J. P. Papa, and A. X. Falcao, "Fast non-technical losses identification through optimum-path forest," in *2009 15th International Conference on Intelligent System Applications to Power Systems*, 2009, pp. 1–5. https://doi.org/10.1109/ISAP.2009.5352910.

[5] J. B. Leite and J. R. S. Mantovani, "Detecting and locating non-technical losses in modern distribution networks," *IEEE Trans. Smart Grid*, vol. 9, no. 2, pp. 1023–1032, 2018. https://doi.org/10.1109/TSG.2016.2574714.

[6] A. V. Christopher, G. Swaminathan, M. Subramanian, and P. Thangaraj, "Distribution line monitoring system for the detection of power theft using power line communication," in *2014 IEEE Conference on Energy Conversion (CENCON)*, 2014, pp. 55–60. https://doi.org/10.1109/CENCON.2014.6967476.

[7] S. S. S. R. Depuru, L. Wang, and V. Devabhaktuni, "Electricity theft: Overview, issues, prevention and a smart meter based approach to control theft," *Energy Policy*, vol. 39, no. 2, pp. 1007–1015, 2011. https://doi.org/10.1016/j.enpol.2010.11.037.

[8] D. R. Boccardo, L. C. G. dos Santos, L. F. R. da Costa Carmo, M. H. Dezan, R. C. S. Machado, and S. de Aguiar Portugal, "Software evaluation of smart meters within a Legal Metrology perspective: A Brazilian case," in *2010 IEEE PES Innovative Smart Grid Technologies Conference Europe (ISGT Europe)*, 2010, pp. 1–7. https://doi.org/10.1109/ISGTEUROPE.2010.5638881.

[9] S. Sardar and S. Ahmad, "Detecting And Minimizing Electricity Theft: A Review." JETAE, 2016.

[10] A. A. Adedeji, "Spatial exploration and analysis of electricity poverty: a case study of Ibadan, Southwestern, Nigeria." Department of Geography, 2016.

[11] N. David, *THE EFFECTS OF ENERGY THEFT ON CLIMATE CHANGE AND ITS POSSIBLE PREVENTION USING SMART METERS: CASE STUDY NIGERIA*, vol. 9. 2018.

[12] "Nigerian Electricity Regulatory Commission - Power Generation in Nigeria." [Online]. Available: https://www.nercng.org/index.php/home/nesi/403-generation#. [Accessed: 24-Apr-2019].

[13] Z. G. Usman, S. Abbasoglu, N. T. Ersoy, and M. Fahrioglu, "Transforming the Nigerian power sector for sustainable development," *Energy Policy*, vol. 87, pp. 429–437, 2015. https://doi.org/10.1016/j.enpol.2015.09.004.

[14] U. P. Onochie, H. O. Egware, and T. O. Eyakwanor, "The Nigeria Electric Power sector (opportunities and challenges)," *J. Multidiscip. Eng. Sci. Technol.*, vol. 2, no. 4, pp. 494–502, 2015.

[15] "Discos owe NERC, NBET, TCN N205.51bn – Market Operator -," 2018. [Online]. Available: https://majorwavesenergyreport.com/discos-owe-nerc-nbet-tcn-n205-51bn-market-operator/. [Accessed: 29-Apr-2019].

[16] I. A. Yusuf, "GenCos, DisCos at war over mounting debts," 2017. [Online]. Available: https://thenationonlineng.net/gencos-discos-war-mounting-debts/. [Accessed: 24-Apr-2019].

[17] "DisCos Lose N30 Billion Monthly to Energy Theft, Others | Nigeria Electricity Hub," 2018. [Online]. Available: https://www.nigeriaelectricityhub.com/2018/06/08/discos-lose-n30-billion-monthly-to-energy-theft-others/. [Accessed: 22-Apr-2019].

[18] C. Fidelis, J. Chukwuemeka, and A. Helen Onyinye, *CONTROLLING ELECTRICITY THEFT, A SMART METER APPROACH: CASE STUDY NIGERIA*. 2017.

[19] S. S. S. R. Depuru, L. Wang, V. Devabhaktuni, and N. Gudi, "Measures and setbacks for controlling electricity theft," *North Am. Power Symp. 2010, NAPS 2010*, pp. 1–8, 2010. https://doi.org/10.1109/NAPS.2010.5619966.

[20] S. McLaughlin, D. Podkuiko, and P. McDaniel, "Energy theft in the advanced metering infrastructure," in *International Workshop on Critical Information Infrastructures Security*, 2009, pp. 176–187. https://doi.org/10.1007/978-3-642-14379-3_15.

[21] "IBEDC warns customers against illegal connections," 2018. [Online]. Available: http://www.theparadigmng.com/2018/06/15/eid-il-fitr-ibedc-warns-customers-illegal-connections/. [Accessed: 01-May-2019].

[22] M. Anas, N. Javaid, A. Mahmood, S. M. Raza, U. Qasim, and Z. A. Khan, "Minimizing electricity theft using smart meters in AMI," *Proc. - 2012 7th Int. Conf. P2P, Parallel, Grid, Cloud Internet Comput. 3PGCIC 2012*, pp. 176–182, 2012. https://doi.org/10.1109/3PGCIC.2012.42.

[23] J. Olanrewaju, "How to stop electricity 'piggybacking,'" 2017. [Online]. Available: https://techpoint.africa/2017/06/07/technology-place-electricity-distrbution/. [Accessed: 10-May-2019].

[24] N. Mohammad, A. Barua, and M. A. Arafat, "A smart prepaid energy metering system to control electricity theft," in *2013 International Conference on Power, Energy and Control (ICPEC)*, 2013, pp. 562–565. https://doi.org/10.1109/ICPEC.2013.6527721.

[25] V. Gaur and E. Gupta, "The determinants of electricity theft: An empirical analysis of Indian states," *Energy Policy*, vol. 93, pp. 127–136, 2016. https://doi.org/10.1016/j.enpol.2016.02.048.

[26] T. Sharma, K. K. Pandey, D. K. Punia, and J. Rao, "Of pilferers and poachers: Combating electricity theft in India," *Energy Res. Soc. Sci.*, vol. 11, pp. 40–52, 2016. https://doi.org/10.1016/j.erss.2015.08.006.

[27] "Nigerians see power supply as social service," 2019. [Online]. Available: https://punchng.com/nigerians-see-power-supply-as-social-service-nextier-boss/. [Accessed: 03-May-2019].

[28] "Nigeria's unemployment rate rises to 23.1% - NBS," 2018. [Online]. Available: https://www.premiumtimesng.com/news/headlines/301896-nigerias-unemployment-rate-rises-to-23-1-nbs.html. [Accessed: 04-May-2019].

[29] "Nigeria Unemployment Rate | 2019 | Data | Chart | Calendar | Forecast | News." [Online]. Available: https://tradingeconomics.com/nigeria/unemployment-rate. [Accessed: 04-May-2019].
[30] "Federal Republic of Nigeria Official Gazette," 2005. [Online]. Available: http://www.nbet.com.ng/wp-content/uploads/2018/05/The-EPSRA-Act.pdf. [Accessed: 04-May-2019].
[31] "MISCELLANEOUS OFFENCES ACT." [Online]. Available: https://www.lawyard.ng/wp-content/uploads/2016/01/MISCELLANEOUS-OFFENCES-ACT.pdf. [Accessed: 04-May-2019].
[32] "Draft Regulation on Electricity Theft and Related Offences." [Online]. Available: https://www.nercng.org/index.php/component/remository/Draft-Documents/Draft-Regulation-on-Electricity-Theft-and-Related-Offences/?Itemid=591. [Accessed: 04-May-2019].
[33] "PROGRAM-FOR-RESULTS INFORMATION DOCUMENT (PID) CONCEPT STAGE." [Online]. Available: http://documents.worldbank.org/curated/en/266341497992825758/pdf/Nigeria-Power-Sector-Recovery-P4R-Concept-Stage-PID-8-3-2017.pdf. [Accessed: 14-May-2019].
[34] U. B. Akuru and O. I. Okoro, "Economic implications of constant power outages on SMEs in Nigeria," *J. Energy South. Africa*, vol. 25, no. 3, pp. 47–61, 2014. https://doi.org/10.17159/2413-3051/2014/v25i3a2658.
[35] S. S. S. R. Depuru, L. Wang, and V. Devabhaktuni, "Support vector machine based data classification for detection of electricity theft," in *2011 IEEE/PES Power Systems Conference and Exposition*, 2011, pp. 1–8. https://doi.org/10.1109/PSCE.2011.5772466.
[36] R. Jiang, H. Tagaris, A. Lachsz, and M. Jeffrey, "Wavelet based feature extraction and multiple classifiers for electricity fraud detection," in *Transmission and Distribution Conference and Exhibition*, 2002, vol. 3, pp. 2251–2256.
[37] T. B. Smith, "Electricity theft: a comparative analysis," *Energy Policy*, vol. 32, no. 18, pp. 2067–2076, 2004. https://doi.org/10.1016/S0301-4215(03)00182-4.
[38] M. Welsch *et al.*, "Smart and Just Grids for sub-Saharan Africa: Exploring options," *Renew. Sustain. Energy Rev.*, vol. 20, pp. 336–352, 2013. https://doi.org/10.1016/j.rser.2012.11.004.
[39] M. S. Hossain, N. A. Madlool, N. A. Rahim, J. Selvaraj, A. K. Pandey, and A. F. Khan, "Role of smart grid in renewable energy: An overview," *Renew. Sustain. Energy Rev.*, vol. 60, pp. 1168–1184, 2016. https://doi.org/10.1016/j.rser.2015.09.098.
[40] H. Farhangi, "The path of the smart grid," *IEEE Power Energy Mag.*, vol. 8, no. 1, pp. 18–28, 2010. https://doi.org/10.1109/MPE.2009.934876.
[41] A. Abdallah and X. Shen, "Security and Privacy in Smart Grid." Springer, 2016.
[42] S. Amin, G. A. Schwartz, A. A. Cardenas, and S. S. Sastry, "Game-Theoretic Models of Electricity Theft Detection in Smart Utility Networks: Providing New Capabilities with Advanced Metering Infrastructure," *IEEE Control Syst. Mag.*, vol. 35, no. 1, pp. 66–81, 2015. https://doi.org/10.1109/MCS.2014.2364711.
[43] S. C. Yip, K. S. Wong, W. P. Hew, M. T. Gan, R. C. W. Phan, and S. W. Tan, "Detection of energy theft and defective smart meters in smart grids using linear regression," *Int. J. Electr. Power Energy Syst.*, vol. 91, pp. 230–240, 2017. https://doi.org/10.1016/j.ijepes.2017.04.005.
[44] R. Jiang, R. Lu, Y. Wang, J. Luo, C. Shen, and X. S. Shen, "Energy-theft detection issues for advanced metering infrastructure in smart grid," *Tsinghua Sci. Technol.*, vol. 19, no. 2, pp. 105–120, 2014. https://doi.org/10.1109/TST.2014.6787363.
[45] Y. Kabalci, "A survey on smart metering and smart grid communication," *Renew. Sustain. Energy Rev.*, vol. 57, pp. 302–318, 2016. https://doi.org/10.1016/j.rser.2015.12.114.
[46] S. S. S. R. Depuru, L. Wang, and V. Devabhaktuni, "Smart meters for power grid: Challenges, issues, advantages and status," *Renew. Sustain. Energy Rev.*, vol. 15, no. 6, pp. 2736–2742, 2011. https://doi.org/10.1016/j.rser.2011.02.039.
[47] E. Al-Shaer and M. A. Rahman, "Security and Resiliency Analytics for Smart Grids - Static and Dynamic Approaches," vol. 67. pp. 3–134, 2016. https://doi.org/10.1007/978-3-319-32871-3_1.
[48] J. Smith, "Smart Meters Take Bite Out of Electricity Theft," 2011. [Online]. Available: https://news.nationalgeographic.com/news/energy/2011/09/110913-smart-meters-for-electricity-theft/. [Accessed: 16-May-2019].
[49] "Privatisation in the Power Sector - Navigating the Transition." [Online]. Available: https://www.pwc.com/ng/en/assets/pdf/pwc-round-table-post-privatisation.pdf. [Accessed: 10-May-2019].