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THE EFFECTS OF ENERGY THEFT ON CLIMATE CHANGE AND ITS POSSIBLE PREVENTION USING SMART METERS: CASE STUDY NIGERIA

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Abstract— It has been indirectly re-echoed that electricity consumption is positively related to the growth of a nation and is therefore a key factor in everyday life that has formed the backbone of Industrialisation. With the ever increasing need for electricity, power theft increases like a plague. 70% of the Green House Gas (GHG) emissions come from fossil fuel combustion from electricity generation. Despite efforts to curtail GHG emissions, energy theft dwarfs these efforts in the developing economies. The ability to effectively generate electricity by power generation bodies gets stalled when in the process of distribution, energy theft occurs. Invariably this accounts for unnecessary blackouts thereby encouraging users to opt for alternative sources of electricity in the form of diesel and petrol generators increasing GHG emissions. Nigeria continues to wallow in the doldrums of inadequate generation, supply and distribution of power. A major contributing factor to the ineffectiveness of Nigeria's power network is electricity theft. Many consumers have resorted to electricity theft and tampering of electricity devices leading to unreliability, overloading of power lines and increased billing on the part of legal consumers. Here, the generation, transmission and distribution sub-sectors face their own share of challenges. The issues of non-metering, estimated billing, overbilling and electricity theft have virtually driven the distribution subsector of the Nigerian power sector to a halt. Furthermore, sharp practices such as meter tampering and by-passing of meters have reduced revenue to distribution companies thereby stalling the development of the power sector. Most climate discussions have been on how to reduce GHG emissions, however, seldom has one looked at the effects of energy theft. Using Smart Meters (SM) a solution is proposed to reduce energy theft by constantly monitoring the electricity grid and remotely isolating points of theft. The SMs are expected to be resident on each transformer, distribution pole as well as the consumer's premises. The readings are then sent to the distribution company's database for analysis through a communication network and remotely cut-off problem areas if detected. This system would increase overall returns to the distribution company, improve transparency in the metering process thereby improving performance which would directly amount to the reduction of GHG emissions.

Index Terms— Carbon, Climate Change, Energy theft, Green House Gas, Smart Meter, Wireless

1.0 INTRODUCTION

The global climate must be viewed as operating within a complex atmosphere, earth, ice, ocean, or land system. Any change to this system, resulting in climate change, is produced by forcing agents – the causes of climate change. Such forcing agents may be either internal or external [1]. As a developing nation, Nigeria is sensitive to the effects of climate change because of its dependence on climate sensitive resources [2]. Nigerians already suffer from nutritional imbalances, climate change would only have negative effect on the food supply.

Electricity theft is a significant economic issue that is by no means limited to the Developing nations. In Nigeria electricity theft has emerged as a very serious problem in power sector. This has contributed to a great amount of loss in revenue, so severe that the government incurs heavy losses instead of generating revenue. The government is forced to provide subsidies to the power sector to maintain a reasonable price of electricity. Since the loss in income must be recovered, this results in the deterioration of the quality of the energy systems, a slower electrification rate and higher tariffs for those who do pay. The financial loss also results in shortage of funds for investments to expand the existing power capacity and as a result the government fails to satisfy the ever increasing demand of electricity. This latter effect often harms the poorest segment of the population the most, as they tend to be the first ones not connected when there is a low degree of electrification [3].

Electricity losses abound in the transmission and distribution system of Nigeria's power network. Nigeria's power grid has a total transmission and distribution loss of 40% [4]. The losses are due to either commercial or technical losses. Technical losses occur due to energy dissipated in conductors and equipment used in the transmission and distribution of power. Commercial losses, on the other hand are due to defective meters, in the estimation of unmetered energy supply and electricity theft. While Losses due to defective meters are defined as the difference between the amount of energy actually delivered through the meters and the amounted registered by the meters; unmetered losses refer to situations where the energy usage is estimated instead of measured with an energy meter [5].

2.1 ELECTRICITY DISTRIBUTION COST/LOSS IN NIGERIA

Inadequate supply of electric power is a major problem confronting Nigeria. Power loss has led to less than 40% of the Nigerian population supplied with electricity leaving the rest without.
The country's paltry power generation, which is shamefully low, is expectedly inadequate for those connected to the grid. As such, these Nigerians rely on generators with its attendant operational and maintenance costs for running their homes, factories, schools, universities, government offices and the entire economy. Private portable electrical power generators are common household items in Nigeria owing to inadequate electrical power provision for the public. On average, the monthly cost for the fuel to run these generators adds an additional $48 to a household's bill.

That is three times the cost of direct supply [6]. It is estimated that Nigerians spend about five billion dollars yearly to fuel their generators [7].

The generators being put to constant use generate a lot of pollutants and in the last 50 years, contributed to an increase in carbon emissions and the concentration of greenhouse gases in the amosphere leading to the enhanced greenhouse effect, which in turn is expected to result in climate change, arguably the most important and dangerous, and certainly the most complex global environmental issue today.

While in developed nations Smart Grid initiatives are being developed that contribute to energy efficiency and electricity conservation, as controlling demand is often the cheapest and most effective way to reduce emissions and costs.

2.2 POWER THEFT

The emergence of power theft as a serious problem has evolved due to several recent trends. Most countries developed electric power systems that were highly centralized state owned monopolies, where efficiency and profits were not high priority. The prvatization of the infrastructure and new modes of power policy requires the new business-like enterprises to operate efficiently and try to optimize profits in an environment of rapid change. In many countries power theft is an issue of open discussion, even in the most efficient (such as in the USA) and moderately effcient (Malaysia) systems. In South Asian countries, electric power is rarely discussed without reference to power theft, since it is such a prevalent practice. However, in some countries like Thailand and China the topic is rarely part the analysis of power sytem [8].

2.2.1 TYPES OF ELECTRICITY THEFT ELECTRICITY THEFTS OCCUR IN DIFFERENT FORMS.

There are different types of theft done all over the world. Huge amount of power theft are done by tapping from line or bypassing the meter, According to a study 80% of the total theft detected all over the world is from residential buildings and 20% from commercial and industrial premises [9]. Theft and pilferage account for a substantial part of the high transmission and distribution losses in Nigeria theft/ pilferage of energy is mainly committed by two categories of consumers, that is, non-consumers and legal consumers.

Some of the modes for illegal abstraction or consumption of electricity are given below:

i. Meter tampering
ii. Meter bypass
iii. Illegal terminal taps of overhead lines on the low tension side of the transformer
iv. Illegal tapping to bare wires or underground cables
v. Unpaid bills
vi. Billing irregularities:

2.2.2 IMPLICATIONS OF ELECTRICITY THEFT

Electricity theft has the following implications both to the distribution company as well as the consumer:

i. Increased billing on the part of legal consumers
ii. Economic losses to the Utility
iii. Overloading of power lines
iv. Unreliability of Electricity service
v. Unsafe environment for troubleshooting

Many consumers all across the country have resorted to electricty theft and tampering of electricity devices leading to overloading of power lines, unreliability and increased billing of legal consumers. It is on the basis of these challenges that a remote monitoring system using a "power meter" on power lines is suggested [10]. This power meter would transmit data wirelessly to the base station located at the distribution company. The power meter would be located on each transformer, distribution pole as well as the consumer's premises. The readings are then sent to the distribution company office for analyses through the wireless network. This system while increasing overall returns to the distribution company and improve transparency in the metering process.

2.3 CLIMATE CHANGE

In Nigeria, extreme weather and climate events such as drought, flood, ocean surges, etc. have become more regular. The impacts of these extreme events may be gradual but their destruction to lives and property has a negative impact on the economy [11]. Greenhouse gases trap heat and make the planet warmer. Human activities are responsible for almost all of the increase in greenhouse gases in the atmosphere over the last 150 years [12].

Climate change is a fundamental threat to human life as it flourishes due to environmental pollution and pollutants originating in human activity that has an impact on the environment. These greenhouse gases play a vital role that increase the atmospheric temperature. Carbon dioxide (CO_2) makes up the vast majority of greenhouse gas emissions from the sector, but smaller amounts of methane (CH_4) and nitrous oxide (N_2O) are also emitted. These gases are released during the combustion of fossil fuels, such as coal, oil, and natural gas, to produce electricity [13].

The effect of Global warming is growing at an alarming rate year by year and one of the major contributors to this is CO_2 emissions. In that, electric generator exhaust emissions have a significant contribution.

If we take a break down it is found that CO_2 around constitutes 12-15 % of total exhaust emissions. Every gallon of diesel fuel contains 2,778 grams of pure carbon. Every gram of atomic carbon, when oxidized with oxygen, forms 3.666 grams of carbon dioxide. (This is another way of saying that each molecule of CO_2 weighs 3.66 times more than an atom of carbon alone.)

In an average liquid hydrocarbon-burning engine, it can be assumed that about 99 percent of the fuel will oxidize [14]. (It is assumed that somewhat less than 1 percent will fail to fully oxidize, and will be emitted as particulates or unburned hydrocarbons instead of CO_2).

Therefore, we can multiply the amount of carbon per gallon of diesel by the ratio of carbon weight to CO_2 weight by 99 percent.

2,778 g x 3.66 x 0.99 = 10,084 g.
Each gallon of diesel fuel produces, on average, 10,084 g of CO_2, or about 22.2 lb.
So if your diesel generator uses, for example, 15 gallons of diesel fuel per hour, it'll be producing:
15 gallons/hour x 22.2 lb/gallon = 333 lb.
Just insert the fuel burn rate for your diesel generator, and you'll get the amount of CO_2 that it produces
1 gallon of diesel will give 10,084 g of CO_2; so if a generator consumes 1 gallon per day, it will produce 10084 x 365 = 3,680,660 g of CO_2 annually

Greenhouse gases emission including CO_2 concentration in the atmosphere are the most adverse situation that are prevalent on the planet. Unexpected events may occur more frequently that will be detrimental for sustainable life. The emission of greenhouse gases especially elevated CO_2 should be ceased to combat the harsh outcomes of climatic variations which will affect billions of people if its bases are not stopped i.e. elimination of greenhouse gases particularly CO_2.

Generator proliferation is an exceptionally high level of CO_2 emissions [15]. While a coal power plant, usually considered the worst energy option for the environment, might produce ~1,000 gCO_2/kWh, an individually-owned 5kW diesel generator emits twice as much. Larger generators, which are even more expensive and far less common, only fare a little better than coal.

Table 1: Levels of CO_2 emmissions

CO2 emissions	g/KWh
Diesel generators	1580
Small (<60KW)	883
Small (<60KW)	699
Large (>300KW)	
Power plants	
Coal	969
Oil	792
Natural	553

The aggregate effect of all these generators is huge. If we just take Nigeria, which is Africa's largest importer of diesel generators with an estimated 9 million units in use; estimate is based on average gCO_2/kWh emissions for generators of varying sizes, which are differenced from the average g/kWh for natural gas, then multiplied by the estimated number of generators and weighted by each size group's share of imports, as reported by United Nations Commodity Trade Statistics Database, (COMTRADE) [16], a proxy for the distribution of sizes in use. The numbers are enormous: we estimate generators produce about 29 million metric tons of CO_2 each year. That is greater than expected emissions from the controversial Medupi coal plant in South Africa—but because it is spread out among individuals, it goes unnoticed and unprotested. Electricity production generates the largest share of greenhouse gas emissions. Approximately 67 percent of our electricity comes from burning fossil fuels, mostly coal and natural gas [17].

3.1 Power Meter Design

A smart meter is an advanced energy meter that measures the energy consumption of a consumer and securely communicates this and additional information to the utility [10]. The ability of smart meters for bi-directional communication of data enables the utilities to collect information regarding the electricity fed back to the power grid from customer premises. In addition to secure communication, smart meters can execute control commands remotely as well as locally. Therefore, smart meters can be used to monitor and control all home appliances and devices at the customer's premises. They are capable of collecting diagnostic information about the distribution grid, home appliances, and can communicate this information with other meters in their reach. They measure electricity consumption, support decentralized generation sources and integrate energy storage devices. Distributed power generation sources would be an essential and integral part of future households. All of these additional services and demand management techniques require utilities to collect large quantities of real-time data.

In a smart grid environment, smart meters play an important role in monitoring the performance of the grid and the customer energy usage characteristics. Collection of energy consumption data from all customers at regular intervals of time allows the utility to manage and optimize electricity demand more efficiently.

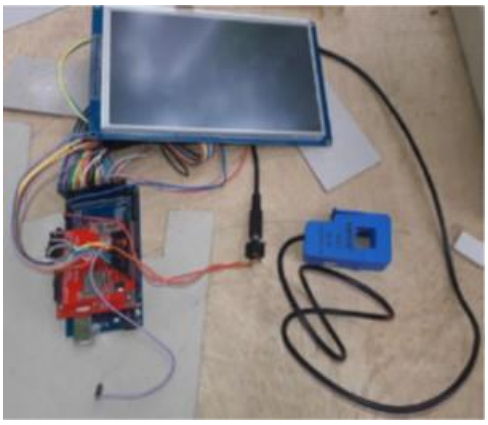

Figure 1: Snapshot of the power meter

The power meter consists of an Arduino mega 2560; Wi-Fi Shield; Non Invasive current sensor; 7inch LCD and Voltage sensor and is shown in figure 1. The current measurement circuit is used to eliminate the negative current readings while the Wi-Fi shield add on board is used to wirelessly connect the module to the internet. A current transducer (clamp on sensor), is used to sense the current by clamping the current sensor on the positive wire while a voltage sensor senses the voltage. The Arduino is programmed to compute energy consumed using the sensed current and voltage and then, wirelessly sends the data to the base station account using a web interface called Carriots. The Carriots serves as an online data base that keeps track of energy consumed for each consumer. Carriots is an application hosting and development platform (Platform as a Service) specially designed for projects related to the Internet of Things (IoT) and Machine to Machine (M2M) [18].

3.1.1 Wirelessly Monitoring Power Consumption

Utilization of the smart meter system involves a large quantity of data transfer between the utility, smart meter, and home appliances in the network.

The communication standards and guidelines are formulated to ensure that data transfer within the network is secure. It is equally important that this data must represent the complete information regarding the customer's energy consumption and status of the grids without any potential manipulations or miscalculations. So, this data must be authenticated and should reflect information about the target devices correctly. The communication standards and guidelines were formulated to ensure that data transfer within the network is secure. It is equally important that this data must represent the complete information regarding the customer's en-

ergy consumption and status of the grids without any potential manipulations or miscalculations. So, this data must be authenticated and should reflect information about the target devices correctly.

Communication technology to be chosen should be cost effective, provide good transmission range, better security features, bandwidth, and power quality with least possibility of repetitions [19].

3.2 PRINCIPLE OF OPERATION

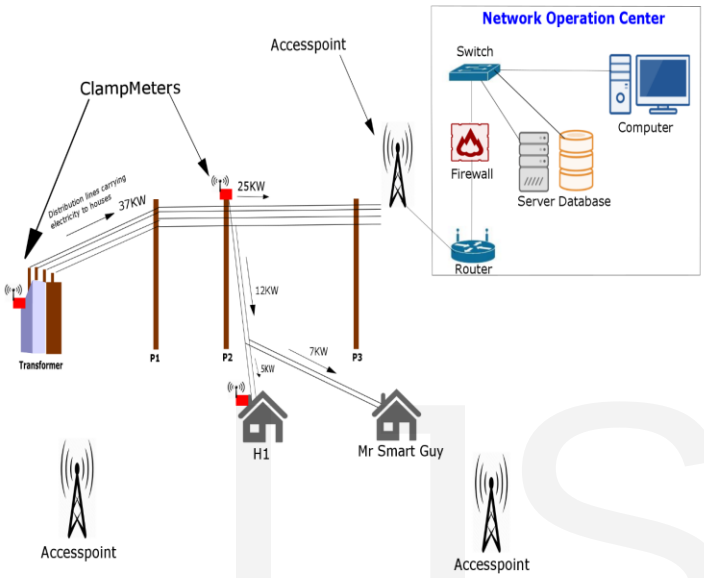

Figure 2: Power meters remotely monitoring consumption

The principle of operation is explained in the following steps and illustrated in figure 2:

i. Power meters are placed on the transformer supplying current to the location, each transmission tower attached to the corresponding transformer and the end users on each tower.
ii. The amount of power consumed at the various end users is measured via the power meter installed at each user's location. The total amount of power consumed is cross checked by the amount of power supplied from each transmission tower.
iii. The total amount of power consumed via all the transmission towers is then summed up and checked with the power supplied from the transformer.
iv. All these readings are wirelessly transmitted from each power meter to the base station where the analysis is carried out (allocation was made for leakage current).
v. Preventive measures are then carried out remotely by identifying power losses either from the end user or transmission tower and remotely switching it off.
vi. In the instance when it is not possible to isolate the erring user remotely, the transformer supplying power to that area is switched off.
vii. Power Meters Monitoring Consumption

The use of radio waves to achieve a wireless connectivity solution would definitely be cheaper to implement. The adopted topology is a star topology. This topology has the advantage of speedy setup and easy extension.

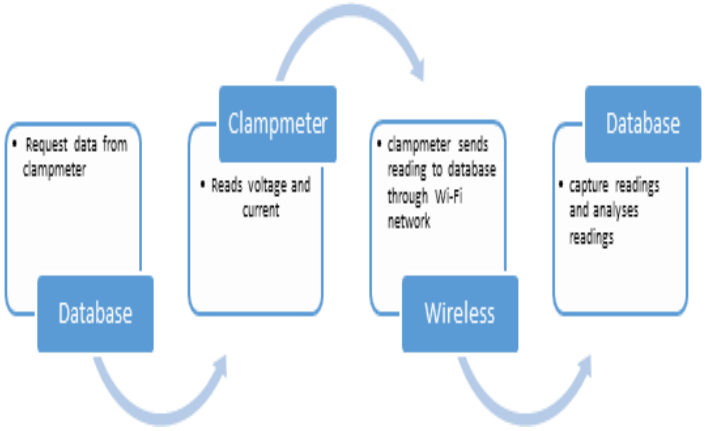

Figure 3: Data flow diagram

4.1 CONCLUSION

The effects of energy theft is devastating to the Power companies as it effects the income of distribution companies. If they are unable to recover their income they would invariably resort to fixed billing or reduce the amount of amount of power being distributed. This would result is more power cuts driving the populace to alternative source or power thereby increasing Carbon emissions. Due to the high initial costs of clean renewable energy the alternative is diesel or petrol generators.

In the last two centuries, society has dumped 220 billion tons of carbon dioxide into the atmosphere by burning fossil fuels. It added another 110 billion tons via deforestation and land-use changes.

Since no one would voluntarily choose a more costly generator over cheaper grid power, another way of thinking about this is to ask how much could Nigeria save in emissions by replacing generators with electricity from large-scale natural gas plants? Using reasonable assumptions, we estimate Nigeria could cut its CO_2-output by 18 million metric tons per year—a 63% decrease [17].

More than half of the nation's 176 million people are not connected to the national electricity grid. The country's paltry power generation, which is shamefully low, is expectedly inadequate for those connected to the grid. Added to this constraint is the continuous process of Energy theft that has a massive impact on the generation of electricity. This can take the form of damage to the grid where power surges and electrical system failure due to high loads cause power outages and damage to Hydro equipment and infrastructure, including the premature failure of distribution transformers. Climate goals cannot ultimately be achieved without radical changes in the ways electric power is produced and consumed

REFERENCES

1. Igwebuike, M.N., Odoh, F.C., Ezeugwu, C.I., Oparaku, N.E. and Oparaku, O.U (2009).*Vulnerability and Adaptation to Climate Change*. In Anyadike RCN, Madu IA, Ajaero CK (Eds.) Conference Proceedings on Climate Change and the Nigerian Environment, 29th June – 3rd July, 2009, pp. 383-392.
2. Nnaji C. E. "Climate Change and Socio-Economic Development in Nigeria". Conference Proceedings on Climate Change and the Nigerian Environment, held at the University of Nigeria, pp. 205-215, 2010.
3. Karekezi, S. and Kimani, J. "Status of power sector reform in Africa: Impact on the poor. Energy Policy", 30, 923–945. doi:10.1016/S0301-4215(02)00048-4, 2002.
4. M. C. Anumaka, "Analysis of Technical Losses in Electrical Power System (Nigerian 330kV Network as a case study)", International Journal of Research and Review of Applied Sciences, pp. 320-327, 2012.
5. Mbunwe Muncho Josephine and David Nathan, "Curtailing Energy Theft by Remote Monitoring Case study: University of Nigeria, Nsukka", Proceedings of the World Congress on Engineering and Computer Science 2016 Vol I, WCECS 2016, San Francisco, USA, October 19-21, 2016 www.iaeng.org/publication/WCECS2016/WCECS2016_pp350-354.pdf
6. NOI Polls, "Nigerians Are Spending Almost Three Times The Cost Of Electricity On Alternative Sources Of Power", *4th August 2015, accessed June 27, 2017,* http://www.noi-polls.com/root/index.php?pid=343&parentid=13&ptid=1
7. Dogara, "$5bn spent on generators annually unacceptable – Dogara", Vanguard Newspaper,July 18, 2017, accessed July 20, 2017. http://www.vanguardngr.com/2017/07/5bn-spent-generators-annually-unacceptable-dogara
8. Thomas B.Smith, Electricity theft: a comparative analysis, Energy Policy, Elsevier, (2004) 2067–2076
9. D. O. Dike, U. A. Obiora, E. C. Nwokorie and B. C. Dike, "Minimizing Household Electricity Theft in Nigeria Using GSM Based Prepaid Meter", American Journal of Engineering Research (AJER), pp. 59-69, 2015
10 Nathan David, Franklyn N Anozie, Franklyn O Ebuka, Sylvia A Nzenweaku, " Design of an Arduino based Wireless Power Meter", International Journal of Scientific & Engineering Research, Volume 7, Issue 9, September-2016.
11 Abaje, I. B., Sawa, B. A. and Ati, O. F., Climate Variability and Change, Impacts and Adaptation Strategies in Dutsin-Ma Local Government Area of Katsina State, Nigeria, Journal of Geography and Geology; Vol. 6, No. 2, 2014
12 Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK, 2007
13. EPA 2015, SOURCES OF GREENHOUSE GAS EMISSIONS, 2015 HTTPS://WWW.EPA.GOV/GHGEMISSIONS/SOURCES-GREENHOUSE-GAS-EMISSIONS
14. Aaron Zvi, How to Calculate Carbon Dioxide Emissions from a Diesel Generator, https://www.hunker.com/12284423/how-to-calculate-carbon-dioxide-emissions-from-a-diesel-generator
15. Todd Moss and Madeleine Gleave, "How Can Nigeria Cut CO2 Emissions by 63%? Build More Power Plants", Center For Global Development, October 1, 2014, accessed 14 July 2017.https://www.cgdev.org/blog/how-can-nigeria-cut-co2-emissions-63-build-more-power-plants
16. COMTRADE https://comtrade.un.org/db/dqBasicQueryResults.aspx?px=H3&cc=850211,850212,850213&r=566&p=0&rg=1&y=2012,2011,2010,2009,2008&so=8
17. EIA, Last updated: May 10, 2017 https://www.eia.gov/energyexplained/index.cfm?page=electricity_in_the_united_states
18. CARRIOTS, "CARRIOTS IS A PLATFORM AS A SERVICE (PAAS) DESIGNED FOR INTERNET OF THINGS (IOT) AND MACHINE TO MACHINE (M2M) PROJECTS" HTTPS://WWW.CARRIOTS.COM/WHAT-IS-CARRIOTS
19. Soma Depuru, Lingfeng Wang, Vijay Devabhaktuni and Nikhil Gudi, Smart Meters for Power Grid – Challenges,Issues, Advantages and Status, EECS Department, University of Toledo, IEEE, 2011, https://tcipg.org/sites/default/files/rgroup/TCIPG-Reading-Group-Fall_2013_10-25_P1.pdf