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The Daunting Challenges of the Nigerian Electricity Supply Industry

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Abstract
The future state of the Nigerian Electricity Supply Industry (NESI) is seemingly beginning to look promising amid the recent change in the country's leadership and the increase in tariffs. Nevertheless, more still needs to be done to ensure the quality, availability and reliability of electricity supply to the citizenry; thus restoring the much-needed faith in the ongoing sector reforms as the Nigerian Electricity Regulatory Commission (NERC) set about implementing the Electric Power Sector Reform Act of 2005. With the wide array of energy sources available in the country such as biomass, large and small hydro, daily solar radiation of up to 7.5kWh/m^2, coal, lignite, wind, municipal solid waste (MSW), niobium, natural gas and crude oil, sufficient electricity generation using all these available sources of energy should be a given but this is not the case. Hence this paper carefully analyses each segment of the NESI and successfully identifies the root-causes of constant power outages in the country which has led to a high unreliability of supply, with a view to proffering workable solutions.
Keywords: Nigeria electricity supply industry, energy, power reliability

1. Introduction

Electricity as a secondary source of energy is essential and vital to meet man's immediate needs, improve living standard and way of life, as well as boost society's socio-economic development. Its economic relevance to the development of any country cannot be over-emphasized. This can easily be observed in the per capita consumption, which can also serve as a further indicator of the citizenry's standard of living. This is shown in a quick comparison of developed countries such as the United States of America, Australia, Germany and Japan with electricity consumption per capita of 12,947kwh/capita, 10,218kwh/capita, 7,138kwh/capita and 7,753kwh/capita respectively; and less-developed countries like Bangladesh, Cambodia, Nigeria and Myanmar with per capita electricity consumption of 280kwh/capita, 206kwh/capita, 155kwh/capita and 152kwh/capita respectively [1]. As an economic good, it is a product of intricate technical processes but unlike other market goods, it cannot simply be stored away on production. It is often strategically produced to match its generation/supply with demand; and being one of the basic necessities of life and society as a whole, demand for it is always high. It is thus imperative that its production and subsequent supply be made readily available, always reliable and relatively affordable for the common good.

In the sub-Saharan West African state of Nigeria- with a population of approximately 178.5million people [2] and tropical weather conditions, availability and reliability of electricity supply is a major concern. The country is blessed with vast natural resources requisite for electricity generation such as the conventional fossil fuels of crude oil, tar sands, natural gas, coal and lignite; renewables like wind, large hydropower, strong solar radiation, biomass (fuel-wood, plant and animal waste), municipal solid waste (MSW) as well as other sources of energy such as niobium and nuclear [3, 4]. Yet the sector is dogged by frequent and prolonged power outages with neither apology nor explanation to the customers. This unreliability in availability of electricity supply has greatly hindered the development of economic activities in the country, especially small businesses [5]. Most businesses now resort to on-site diesel-powered generators as their means of reliable electricity generation. A pattern which is majorly responsible for the high operating cost of the much bigger firms/industries.

In a recent survey of the nation's power system reliability by the Manufacturers Association of Nigeria (MAN), it was observed that the country's System Average Interruption Duration Index (SAIDI[1]) was less than 60,000minutes [6]. Not only is this figure extremely high and totally impracticable when compared with the internationally-accepted standards of 90 – 180mins [7], its rate of occurrence (SAIFI[2]) was stated as not being less than 600 interruptions per year. This is also totally unacceptable when compared with internationally-acceptable standards of 1 or 2 sustained interruptions per year[3] [7]. All these issues occurring together greatly hamper the reliability of the Nigerian electricity power system. It bears a huge negative impact on commercial and industrial activities and consequently stunts the country's economic growth. Aptly put "the performance of

[1] An indication of the total duration of interruptions an average customer experiences during a predefined period of time, usually one year and often measured in customer-minutes or customer-hours of interruption [7]
[2] SAIFI – System Average Interruption Frequency Index
[3] This also depends on the power system configuration. It can be higher for a radial system configuration (as in the case of Nigeria), smaller for underground residential system configurations and smallest for grid network configurations [8]

the sector is much below international best practice" [4] and the state of the nation's electricity industry, quite saddening.

1.1 Aims and Objectives

This paper investigates the root-cause(s) of constant power outages in Nigeria leading to high unreliability of supply. It prominently differs from previous researches carried out in the same subject area, in the extensive nature of its scope. It goes beyond a singular aspect of the nation's electricity supply industry - usually the generation and/or distribution segment- to delve into every segment of the industry; intrinsically analyzing the operations of each segment in detail and clearly illustrating its findings in the various graphs shown.

1.2 Overview of Previous Works done

Over the years, many studies have been done and papers written by scholars who have decried the poor state of the Nigerian electricity sector. Research has shown that many households are not able to access electricity despite its existence in the country for over a century [3], thus highlighting the need for effective reforms in the sector. The technical state of the nation's electricity distribution infrastructure has also been studied [8] but most of the previous works done analyzed the country's energy problem as that of inadequate generation [9, 10 and 11]. Further stating that for the country to transform from a low-income economy to (at least) a middle-income industrializing one over the next 15 years, the electric power generation will have to rise from the present capacity of less than 10GW to over 160GW. This would give the country an electricity consumption of 5000kWh per capita [4] as compared to its present 155kWh/capita consumption.

2. Nigerian Electricity Supply Industry (NESI): Some background information

The advent of electricity in Nigeria can be traced back to 1896 with the installation of the first generating power plant in Lagos. However the Nigerian electricity industry can be said to have formally started when the first utility service company began operations in 1929 with the construction of a hydroelectric power station at Kurra, Plateau State [12]. From that period until 1950, electricity generation in the country was in the form of individual/unit facilities with a few undertakings being carried out by the then government Department of Public Works, others by the different regional municipal authorities and local native authorities.

By 1950 the Electricity Corporation of Nigeria (ECN) was formed in a bid to integrate the rapidly expanding electricity power industry and make it more effective. This brought the electricity department and all power undertakings in the country under the reins of one state-controlled body. This also started a flurry of developments in the sector such as the commissioning of a four-unit coal powered station in Oji in 1956; the construction of the first 132KV transmission line linking Ijora Power Station in Lagos to Ibadan Power Station in Oyo State- a distance of over 60km- in 1962; and the establishment of the Niger Dam Authority (NDA) in 1962 to develop the hydropower potentials of the country [12]. Thereafter, the Kainji Hydropower station was commissioned in 1968.

The Federal Government later merged the ECN and NDA in 1972 to form the National Electric Power Authority (NEPA) with the statutory function of developing and maintaining an efficient, well-coordinated and economical system of electricity supply throughout the Country. NEPA had full monopoly of all commercial electricity supply in the Country but it did not inhibit individuals who wished to buy and run thermal plants for domestic/private use from doing so [13]. Failing to satisfactorily perform its statutory function of electricity provision to the citizenry, the privatization process began for NEPA in 1999 with reforms in the sector still ongoing.

Presently there are fifty-eight (58) on-grid generating licensees expected to supply the grid 26,423.2MW of electricity – this being their total installed capacity when fully completed and all tied-in. Another three (3) licensed for embedded generation within the distribution network with a total embedded generation capacity of 133MW and nineteen (21) off-grid licensees with a total installed capacity of 312.5MW [14]. The nation's transmission grid network made up of seventy-two (72) 330kV circuits and one hundred and eighty-five (185) 132kV circuits is a government-owned monopoly. It has a total combined capacity of 19,427.5MVA, twenty-seven (27) 330kV substations and one hundred and fourteen (114) 132kV substations [15]. It is controlled and operated by a single government-owned system operator: the National Control Centre, Oshogbo. While the nation's distribution network is being handled by fourteen (14) distributing companies directly responsible for the supply and metering of electricity to the consumers.

3. Methodology

This study involved field visits to some of the thermal stations in the country and the National Control Centre Osogbo where interviews were conducted. A desk study was also carried out to assess existing data on the country's electricity supply industry. Majorly using statistical measures of central tendency to analyze data gotten from both the technical visits and the desk study, the findings from the analysis of the NESI are outlined below.

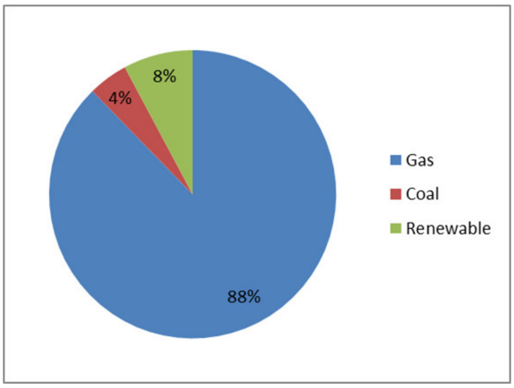


Figure 1a: Installed capacity by fuel-type

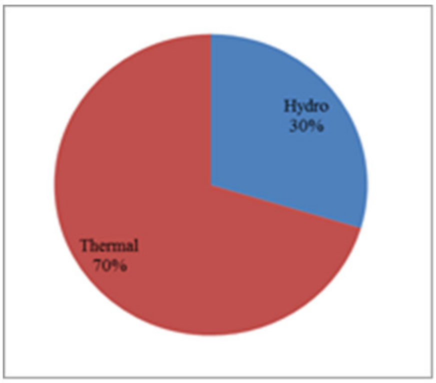


Figure 1b: Net generation by fuel type

3.1 Untapped Energy Sources

One of the striking features of the NESI is the heavy dependence on gas-fired generation. This is primarily due to the large availability[1] of natural gas resource in the country though yet to be fully utilized as much of it is still being flared. Another reason for the heavy dependence on gas-fired generation is the reduced construction time of gas-turbine generators due to less on-site installations, as compared with other types of conventional generating plants like coal plants. This heavy-dependency on gas is thus evident when a face-value analysis of the country's generating licenses shows that 88% of the total generating licenses are for gas-fired power stations, another 4% for a coal-fired generation and only 8% for generation from renewable energy sources comprising mainly of hydropower (Figure 1a). A further analysis of the actual electricity generated showed a generation imbalance with 30% of the electricity generated coming from the hydropower installations while the gas-fired stations contributed the remaining 70% (Figure 1b). With the variety of available energy sources in the country especially renewable energy sources, more needs to be done to actualize sufficient electricity generation using these alternative energy sources.

3.2 Aging Infrastructure

One of the causes of the generation imbalance mentioned in subsection *3.1* above is generation inefficiency due to aging plant infrastructure. A scattered plot of installed plant-units against their year of commissioning revealed (as shown in Figure 2) that the bulk (67%) of the country's current electricity infrastructure were commissioned between 1963 and 1990 (that is 52 – 25 years ago).

This makes their repair & maintenance extremely difficult as most of these plants' parts have become obsolete even at the manufacturer's end. Consequently, many of these old power stations continually have low available generating capacities with plants like Ajaokuta, Afam I-V and Sapele having average availability factors of 0%, 1.5% and 9.1% respectively.

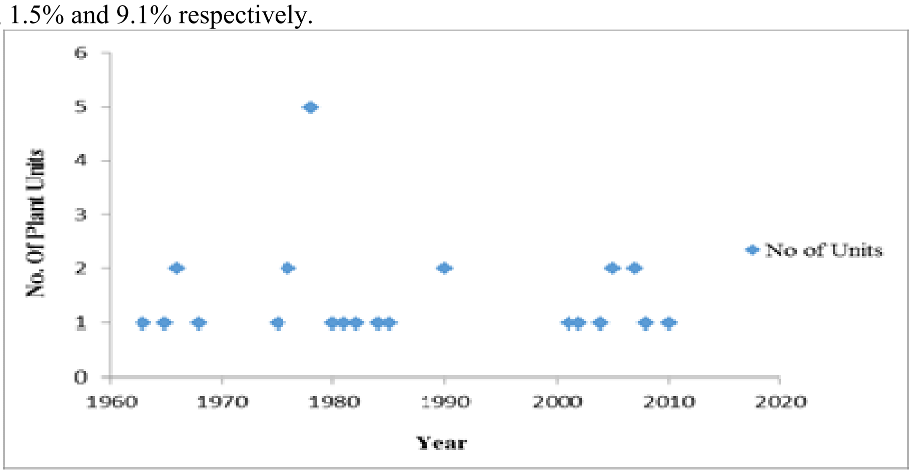


Figure 2: Generating Units and year commissioned

[1] The country has proven natural gas reserves estimated at 185trillion cubic feet, despite her large volume production of billions cubic feet yearly [9].

3.3 Under-utilization/Insufficient Generation

With the nation's electric infrastructure being so old and their available generating capacity very low, it is obvious that most of these power plants generate well below their installed capacity. For example in 2013, gas-fired stations like Afam I-V, Sapele and Olorunsogo had their utilization factor as low as 1.1%, 5.82% and 9.19% respectively - *where plant utilization factor is the ratio of the actual capacity utilized to the installed capacity of the same plant*. Figure 3a clearly shows the wide difference between the installed capacity, available capacity and utilized capacity of the grid-connected power stations in 2013; while Figure 3b illustrates the nation's total installed capacity, average monthly available capacity and the utilized capacity, for the same period. More so, the total installed name-plate capacity of all grid-generating plants in the country from 1970 till date (9386.2MW) have not been sufficient to meet the nation's suppressed demand of 10,000MW nor the forecasted 2010 demand of 15,730MW [9].These variances as depicted in the graphs, clearly show that the country does not only have insufficient generation; she has also not been able to fully utilize that which has been installed.

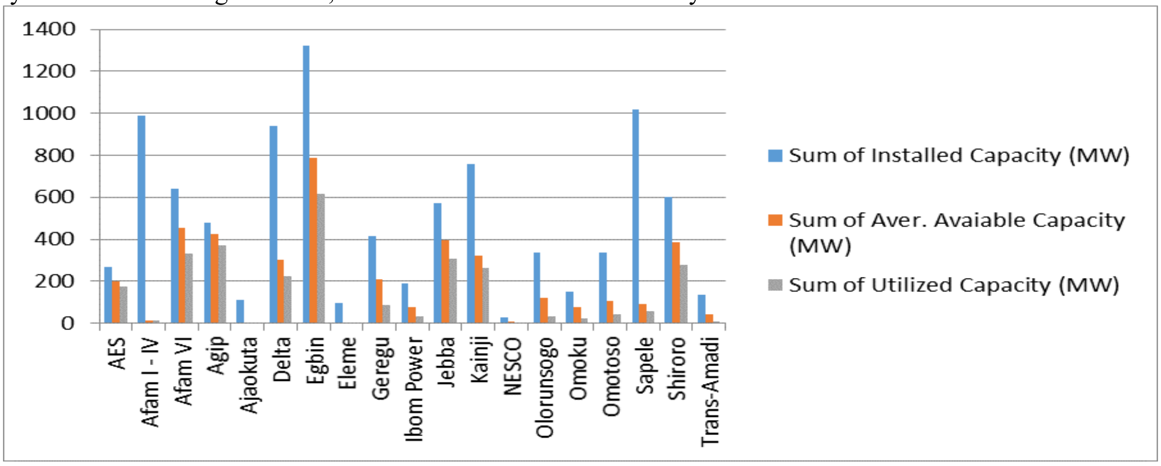


Figure 3a: Power Plants Capacity

3.4 Irregular gas supply

A major setback in the Nigerian Electricity Supply industry is the high irregularity in gas supply to the thermal power stations. This irregularity – a major cause of the plants' poor utilization factor – is the key contributing factor to the generation imbalance mentioned in subsection *3.1*. Reasons for this irregularity ranged from unguaranteed Gas Supply Agreements (GSA) between the thermal stations and the government-owned Gas transmission company- the Nigerian Gas Company (NGC), to lack of gas network infrastructure to adequately transport the gas to the plants. These lapses in the gas supply logistics subsequently results in issues of incessant low gas pressure, gas shortages and even condensate accumulation in the pipelines. All these issues acting together, adversely hinders the efficient utilization of the plants' available capacity, consequently having a dire impact on the nation's generating output.

3.5 Transmission grid outages & failures

The transmission network itself is another major challenge facing the NESI. In 2010 alone, a total of 748 power outages were observed on the 330kv transmission circuit, while 4101 outages were recorded on the 132kv circuit [16]. Comparing the ratios of the different types of outages experienced on both lines show that the forced and emergency outages were much more than the planned outages for both lines (shown in Figures 4a & 4b). This was not much different from the previous year where a total of 655 outages were recorded on the 330kv circuit and 4149 power outages recorded on the 132kV lines [16]. This clearly shows that the outages were a frequent yearly occurrence, revealing an underlying problem in the transmission network.

Further analyzing causes of grid failures- both partial and total from 1987 to 2010 showed that: Out of a total 298 partial grid-failures experienced in this period, **78%** were caused by transmission faults (that is 233) while the remaining **22%** partial grid-failures (65) were caused by faults from the generating units [16]. Similarly **66%** of the faults responsible for total-grid failures during the same period were also caused by transmission network faults as compared to the **34%** caused from generating units (Figures 4c & 4d). Most of the transmission circuits are also single-circuits, thus causing single-line emergencies which lead to frequent power cuts and constant tripping, throwing parts or the whole country into darkness.

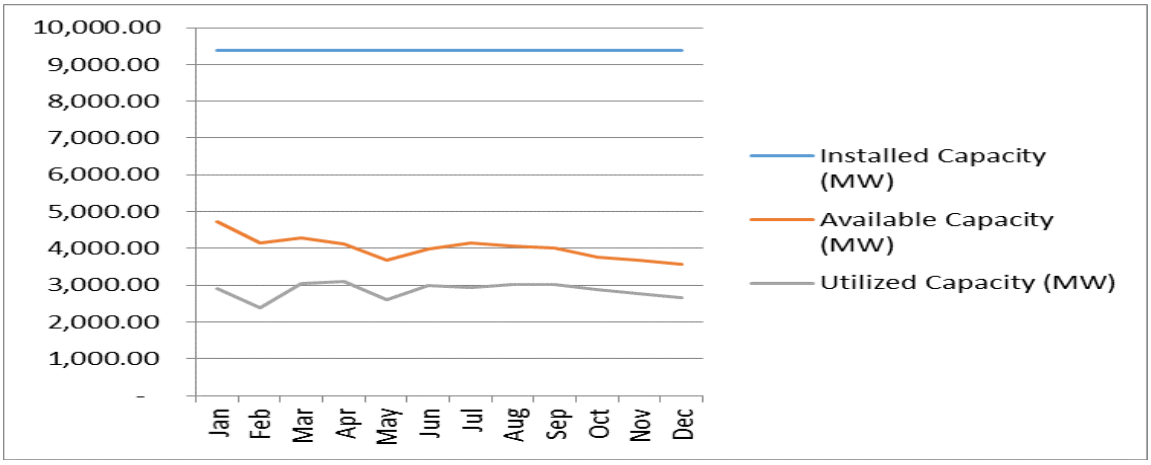


Figure 3b: Plants Monthly Capacity in MW

3.6 High Transmission losses

Further confirming the inefficiency of the transmission network are the high transmission losses recorded in the NESI. Plotting in Figure 5 the graphs of electricity generated by the power stations in 2010; that sent out or injected into the grid by the power stations, and that finally received by the distribution networks in the same year; the large amount of transmission losses obtainable in the NESI is clearly seen [17]. These transmission losses - calculated to be approximately 10.05% of the energy fed into the grid - can be seen/observed as the gap between the graphs of *Energy Sent out (GWh)* and *Energy for Sale (GWh).* These transmission losses which are 22.41% higher than that of the previous year are quite high when compared to countries like the USA who have succeeded in reducing their total transmission & distribution losses to an average of about 7% of the electricity transmitted [18].

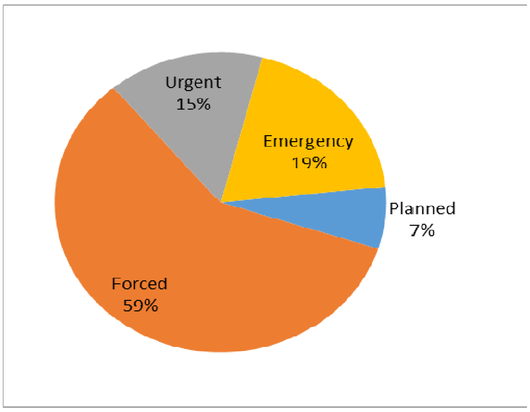


Figure 4a: 330kV Circuit Power Outages

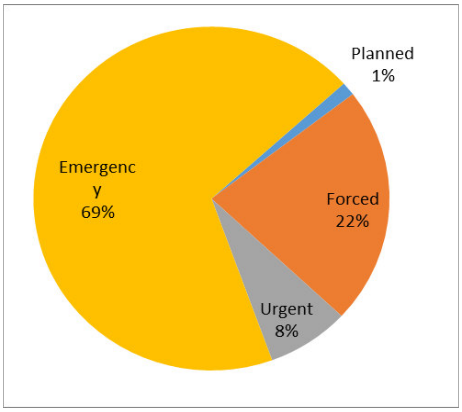


Figure 4b: 132kV Circuit power outages

3.7 Inefficient metering system/high loss of revenue

The distribution system like all other parts of the sector also plays its role in the incessant power interruptions experienced by customers. This is evidenced by the under-equipped state of most of the distribution substations in dire need of urgent upgrades and expansion. This also adversely limits the number of customers connected to the distribution networks. For a country with a population of over 178million people, only an approximate 65million people (that is, 36.5%) have access to electricity [3] of which, less than 5% are legally-connected to the distribution companies [19].

Further compounding this issue is the fact that only about 65% of these customers are metered while the remaining 35% are still billed on a monthly-estimated sum, creating a tremendous scope for electricity theft. These all combine to make the collection of electricity revenue inefficient & ineffective. This further shows that the proportion of illegally-connected electricity consumers (approximately 96.5%) far-outstrips the legally-connected customers and the need for distribution companies to expand their networks into rural areas in other to accommodate customers in the hinterlands.

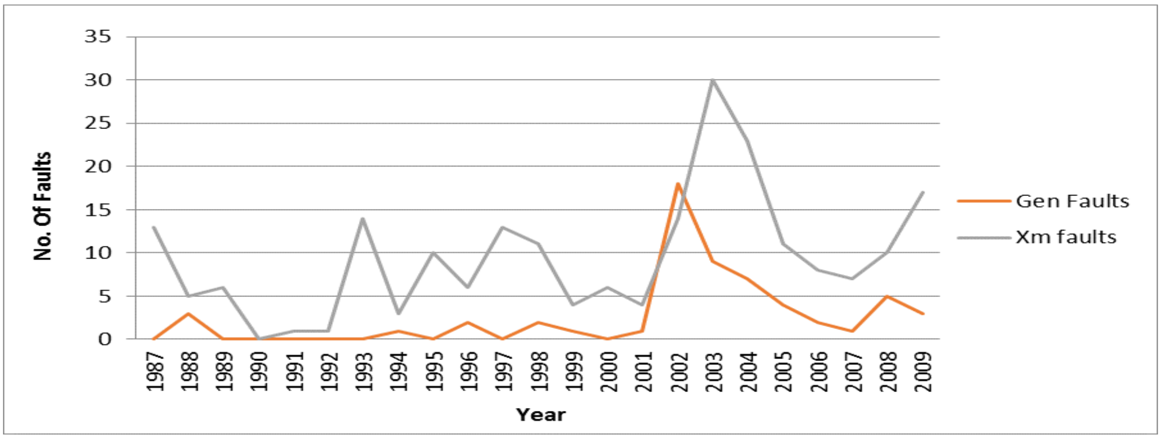


Figure 4c: Partial Grid failures

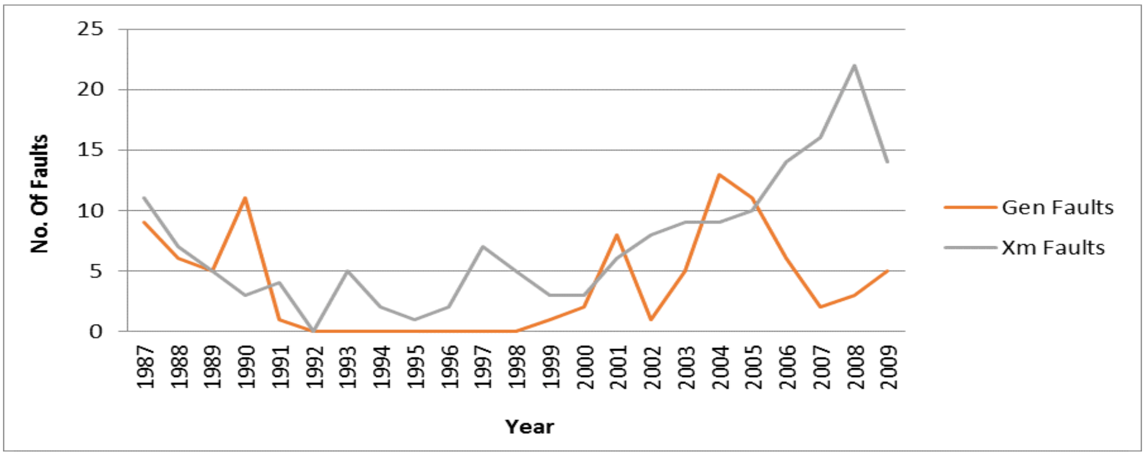


Figure 4d: Total Grid collapse

3.8 Cost Implication Analysis of Self Generation

Consider a typical low-income household that uses the smallest-sized generator in the Nigerian market rated 0.65kW with a 4-litre full-tank capacity of petrol-fuel.

Depreciation Cost

Initial Capital cost ~ $75 Useful life-span ~ 3 – 4yrs Salvage value ~ $5.00

Using straight-line depreciation:

$ (75.00 - 5.00) ÷ 4 = $17.50 per year = $1.46 per month

Minimum Operating Cost:

Daily continuous running @ 10hrs full-load and full-tank capacity

0.65kW x 10hr = 6.50kWh/day = 195kWh/month

Thus

6.50kWh ~ 4litres full-tank

Current pump price of petrol-fuel in Nigeria:

1litre (petrol) = $0.50

Thus

6.50kWh = 4 x $0.50 = $2.00 daily = $60.00 per month

Maintenance Cost:

Due to its daily usage, frequent routine maintenance is required.

Maintenance Fee = $16.36 per quarter = $4.09 per month

Total Monthly Cost:

Total Cost = Depreciation + Operating + Maintenance

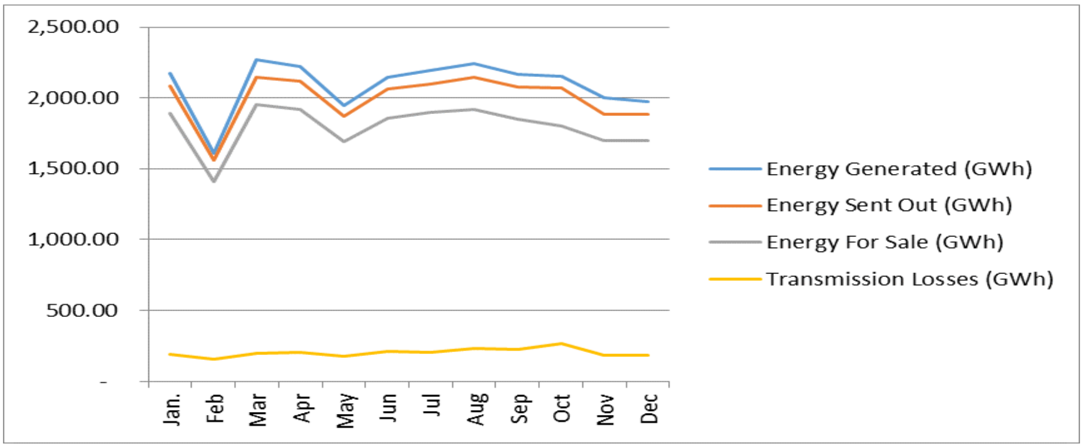
= $ (1.46 + 60.00 + 4.09) = **$65.55** per month

Generator Electricity Cost (per kWh):

195kWh = **$65.55** per month;

1kWh = **$0.34**

Figure 5: Transmission losses in GWh



Government Regulated Electricity Tariff:

This is made up of a fixed monthly charge and a variable energy charge

Fixed Monthly Charge = $3.65

Plus Energy Charge = $0.08 per kWh

Thus

195kWh = $3.65 + $(195 x £0.08)

= **$19.25** per month

= **$0.10** per kWh

Comparing the above monthly "*Generator Electricity Cost" (E)* and the "*Government Regulated Electricity Tariff" (F)*:

$0.34 - $0.10 = **$0.24 per kWh**

$65.55 - $19.25 = **$46.30 monthly**

This amount (**$46.30**) is the *minimum increased cost* to the consumer for generating his own electricity, barring the collateral cost of damage to goods, equipment, and/or production losses. **Minimum** increased cost here being that the consumer can choose to run the generator for longer hours than the stated 10hours full-load duration. The 10-hour period is used as a minimum because most households in Nigeria run their generators at night.

Conclusion

The challenges facing the NESI as outlined in this paper are indeed daunting, especially when juxtaposed with the country's enormous energy demand required to drive economic growth and development. Statistics clearly show that aside the challenge of insufficient generating capacity, the transmission network which is characterized by high levels of power losses and frequent conductor cuts, is mainly responsible for the incessant power outages experienced across the country. This is largely due to aging infrastructure, inadequate transmission backbone to wheel the available generated electricity and single line contingency constraints associated with most parts of the network. Also, the estimated $*0.24 per kWh* difference in cost of self-generated electricity and public utility electricity may seem negligible but when cumulatively calculated, bears a large impact on an already frail economy. Nevertheless, these challenges are surmountable. The situation can be salvaged and normalcy/efficiency restored to the industry but it will require resilience and determination on the part of government. It will also require that current efforts by government agencies and private investors in the sector be stepped-up and well-coordinated in a sustainable manner, in order to bridge the divide between demand for electricity and its supply.

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