Power Generation Cost and Quality of Household Electricity Generator as a Back-up for Grid Supply in Nigeria

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***Abstract*—In this paper operation data were collected to evaluate petrol (PMS) fuel when used as primary source of energy to generate electricity. The analysis highlight cost effectiveness and power quality of this means of generating electricity. For the exercise, a 2 KVA electric power generator was loaded from 800W to 1200W at 100W increment and one-hour duration respectively for each load. The Data collected during generator operation include the load current, supplied voltage, power frequency, power factor and power consumed at five minutes' interval for each load value. The generated Data were analyzed using mathematical and graphical approach to determine the generated power quality and unit cost of generation. The results, compared with the grid, show that the grid is far more economical and have better power quality.**

***Index Terms*—2 KVA Electric Generator; Grid; Power Quality; Unit Generated Cost.**

I. Introduction

The Nigeria Electricity sector face challenges ranging from poor distribution system (caused by aged equipment), inadequate transmission infrastructure, inconsistency of the available power generation capacity (characterized by gas pipelines and transmission lines vandals), and gross inadequacy the generating capacity (supply) to meet the consumers demand among other factors.

On global perspective, the increasing reliability on technology, which has gradually increase electricity consumption, requires continuous increase in electricity generating capacity. The short fall of this trend in Nigeria due to generating capacity constraints and irregularity in the available supply, has result in higher electricity demand than supply and difficult usage planning by consumers. Consequently, virtually every household, commercial and industrial sectors in Nigeria have alternative means of generating their electricity needs. Also, the larger population not connected to the grid wholly depend on alternative means.

Considering the inevitability of using electricity generating set and the Nigeria household economic challenges (relatively small per capita GDP), coupled with the major two (2) goals in generating electricity (which are economic of generation and power quality), carrying out this exercise to determine unit cost of generation and the power quality of the alternative means used by Nigeria household is in right direction.

II. Previous Studies

Mainly all the previous studies report similar values of generating capacity over time. Some of the studies suffices for this paper are summarized here under.

Aliyu, A. et al [2] says Nigeria is one of the most populated countries in Africa, but only 40% of the people are connected to the energy grid. The 40% connected to power experience difficulties around 60% of the time.

Awosope [3] in his paper declares that Electricity supply is a very crucial issue characterized by several political and economic complexities in many countries that often times defines the industry's effectiveness.

Okeke R. [4] findings show that the Nigeria Electricity peak demand estimated at 19,100MW while the total installed generating capacity is 11,165.4 MW. From the installed capacity, only 7,139.6 MW is the available generation due to gas and transmission lines inadequacy, the problems which have not been resolved over the years. According to the current Minister of Power, Works and Housing (Fashola R.), the increase in generation to 7001 MW, transmission on to over 7000 MW and distribution to an average of 4900 MW respectively is a sign of progress which should continue.

III. Electricity in Nigeria: Pre and Post Deregulation Era

Prelude to the deregulation of the Power Sector in Nigeria, huge investments was committed to the Sector with the objectives of compensating for years of investment neglect and to overhaul the sector and make it economically viable to attract investors. To enhance these objectives, the sector was unbundled into three (3) major sub-sectors (generation, transmission and distribution). The goal is to have an efficient, reliable and quality power supply. Thirteen years after deregulation, the aspiration of having a reliable and efficient power supply is still to no avail. Areas of the country with electricity supply pre-deregulation era are now cut off completely (Okitipupa, Irele, Ilaje, Ese-Odo, e.t.c., local government areas in Ondo state are typical examples – these areas are the locality I visited regularly

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and, just some few weeks back, the youth of the Ilaje area stage protest that was captured by TVC Television (Nigeria) on this issue).

Presidential Retreat for Power Sector Investors (Oct.2010), clearly show that the post deregulation era intended to address the following pre-deregulation menace in Power Holding Company of Nigeria:

i. Pronounced managerial inefficiencies and poor infrastructure maintenance.
ii. Government-owned monopoly market of the sector that is vertically integrated and non-viable commercially.
iii. Investment deficiency in the three arms of the sector.
iv. A continuous increase in demand that is barricaded with a stagnant supply caused by static generation capacity.
v. Poor and unreliable service delivery.
vi. Ineffective metering system which make consumers debt recovery almost impossible.

Today, more confusion has set in and the Distribution arm of the sector is willing to opt out if a willing buyer or the government is willing to reimburse them of their committed capital. The post deregulation era is characterized with challenges like inadequate metering, outrageous bill estimation (refer to as crazy bill), inability to evacuate available electricity generated due to transmission line constraint, and inability to evacuate available power on the transmission line by the distribution sector due to equipment age problem.

Nnaji [1] in his assessment of the sector mentioned the following:

i. Only 40% of Nigerian population has access to electricity grid.
ii. The grid capacity is further depleted by high energy losses (technical and non-technical losses).
iii. High operating cost.
iv. Average per annum growth rate of less than 1% due to limited investment and huge capital required to overhaul and replace network equipment that is obsolete.

Nnaji [1] concludes: "Nigeria has a large and energy hungry population".

The power sector suffers pronounced fund starvation in the past years, which has significant contribution to the current challenges witnessed in the sector. Between 1989 and 1996, the sector received no fund and from 1997 to 2000, the sector received very few millions of United States Dollars. This decade of investment neglect has its toll in today's challenges.

PWC [5] reported annual per capita electricity consumption of Nigeria as 151kwh, which is among the lowest globally. The sector currently faces value chain losses, transmission coverage limitation, disruptions in supply, theft and corruption at the distribution arm.

United Capital [6] claims the 2013 Comprehensive reform of the power sector that commenced in Nigeria was considered to be one of the global boldest power reforms initiatives. The two-fold objectives of the reform were to address chronic inefficiency embedded in the old government utilities, and attract private investors required to propel the sector to meet Nigeria's fast growing demand of electricity. The question that needs answer is, why has the sector seen little process on these two fronts?

IV. Power Quality and Economy of Generation

Power quality and optimal generation are two major priority of electricity utility company. While quality of power is one of the critical measures of electric power reliability, the optimal generation determines how cheaper the generation unit cost is.

A. *Power Quality*

To a large extent, power quality affects the efficient operation and durability of electrical equipment, and also, the economy of operation.

According to Watson et. al. [7] power quality disturbance (or poor power quality) occur whenever there is deviation in voltage or current from the ideal sinusoidal waveform. Such disturbance result in economic loss influenced by malfunction or destruction of equipment arising from poor power quality.

Considering power quality from the generation point of view, not only should the supplied voltage be sinusoidal, but its Root Mean Square (RMS) value and the power frequency value should be constant and within specified variation standard.

These two components are mathematically expressed as follows;

$$E = 4.44\, f\phi T \quad (1)$$

$$f = \frac{PN}{120} \quad (2)$$

Where,

E is the generator induced RMS voltage
ϕ is the generator field flux
T is the generator winding number of turns
P is the generator field number of poles
N is the rotor mechanical speed
f is the generator power frequency

As shown in equations (1) and (2), Frequency is a function or depends on mechanical speed and the induced voltage depends on frequency and hence, depends on the mechanical speed.

The generator mechanical speed performance is based on the generator set fuel used, so also is the mechanical speed response to load variation. This is accounted for in generator design as it influences the power quality and unit cost of generated power.

B. *Economy of Generation*

Optimal generation financial efficiency is key in electricity production to facilitate efficiency of operation, energy affordability and good returns on investment.

In a mix-generation grid system, the hydro generators are used to supply base load just to achieve cost efficiency through the primary (or input) energy for generation system.

Aside from energy unit cost consideration based on the cost of primary energy (or fuel) for generation, environmental pollution impact is another area of crucial consideration but not captured in this discussion.

V. Household Electricity Generator and Grid Supply Assessment

For the quality and economic assessment of generator set compared with the grid, based on the primary input energy (or fuel), a 2KVA generator, with PMS fuel carburetor is powered in turn at different loads for fixed time interval, the data recorded within this period and that of the grid are shown in Table I and Table II below.

TABLE I: Data Recorded when Generator Runs

Time (Mins)	Load (W) Actual	Load (W) Recorded	Voltage (V)	Current (A)	Frequency (HZ)	Power factor (PF)
01		832.50	225	3.70	48	1.00
10		810	225	3.76	47	1.00
20		840	224	3.75	49	0.99
30	800	825	220	3.75	47	1.00
40		840	224	3.75	49	1.00
50		810	225	3.76	48	0.99
60		820.20	220	3.76	47	0.97
Sub-Total Fuel (PMS) used – 0.92 Ltrs						
61		1037.10	224	4.63	48	0.99
70		1041.60	224	4.65	48	1.00
80		1041.60	224	4.65	48	0.99
90	1000	1013.98	219	4.63	46	1.00
100		1032.49	223	4.63	48	1.00
110		1037.12	224	4.63	48	0.99
120		1066.24	224	4.76	46	0.96
Sub-Total Fuel (PMS) used – 1.02 Ltrs						
121		1254.40	224	5.60	45	0.98
130		1254.40	224	5.60	45	0.97
140		1254.44	224	5.56	45	0.97
150	1200	1245.40	224	5.60	45	0.97
160		1240.96	224	5.54	45	0.97
170		1252.16	224	5.59	45	0.98
180		1252.16	224	5.59	45	0.98
Sub-Total Fuel (PMS) used – 1.20 Ltrs						

TABLE II: Data Recorded when Load is on Grid

Time (Mins)	Load (W) Actual	Load (W) Recorded	Voltage (V)	Current (A)	Frequency (HZ)	Power factor (PF)
01		806	232	3.47	50	1.00
10		805	232	3.47	50	1.00
20		805	234	3.45	50	0.99
30	800	804	233	3.45	49.99	1.00
40		804	234	3.44	50	1.00
50		804	235	3.42	49.99	1.00
60		803.5	234	3.43	49.98	0.99
61		1009.82	233	4.34	50	1.00
70		1010.30	234	4.32	50	1.00
80		1011.60	234	4.32	49.99	0.99
90	1000	1010.98	233	4.33	50	1.00
100		1012.49	233	4.35	50	1.00
110		1012.12	234	4.32	49.99	0.99
120		1012.24	234	4.33	50	1.00
121		1215.28	232.85	5.22	50	0.99
130		1215.40	233	5.21	50	1.00
140		1214.44	232.60	5.22	49.97	1.00
150	1200	1216.10	233	5.22	49.98	1.00
160		1215.96	233.40	5.21	49.99	1.00
170		1216.00	232	5.24	50	0.99
180		1216.10	232	5.24	50	0.99

The graphical illustration of the data recorded showing the voltage and frequency relationships of the two modes of electricity supply are shown in Fig. 1 to 6 for each respective operational load.

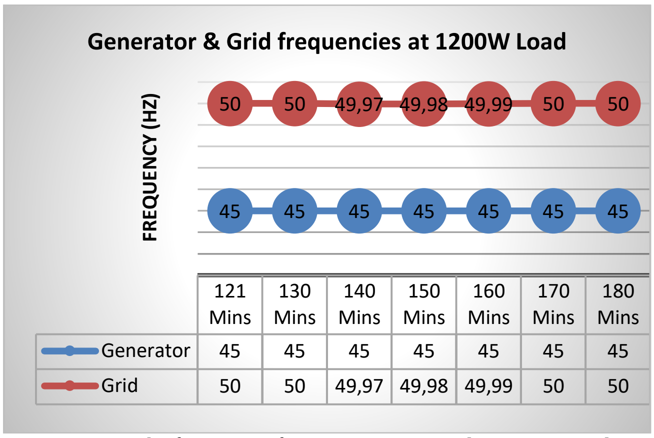

Fig. 1. Graph of Generator frequency against Grid at 1200W Load

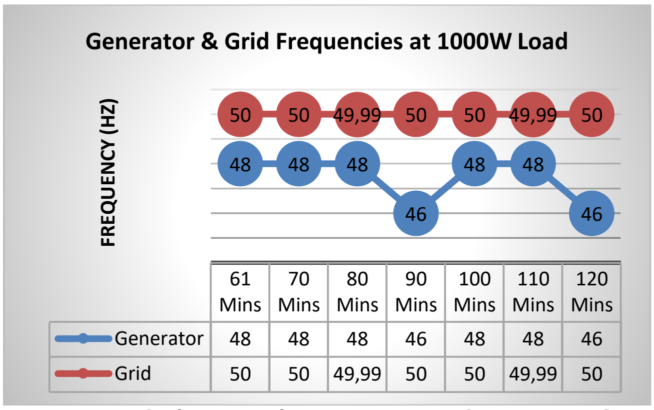

Fig. 2. Graph of Generator frequency against Grid at 1000W Load

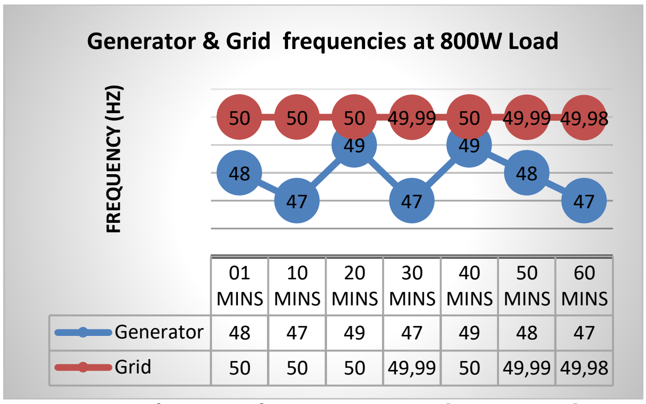

Fig. 3.G of Generator frequency against Grid at 800W Load

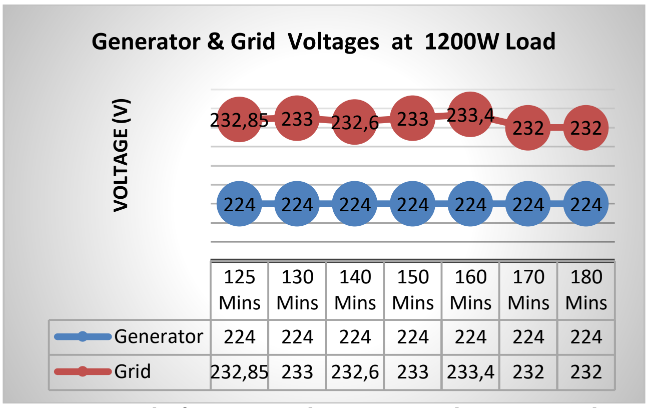

Fig. 4. Graph of Generator Voltage against Grid at 1200W Load

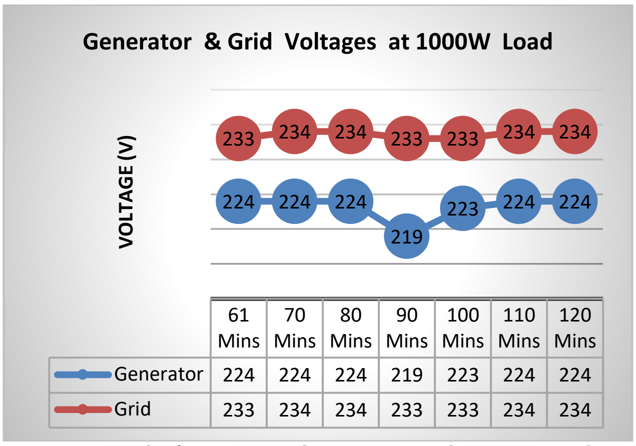

Fig. 5. Graph of Generator Voltage against Grid at 1000W Load

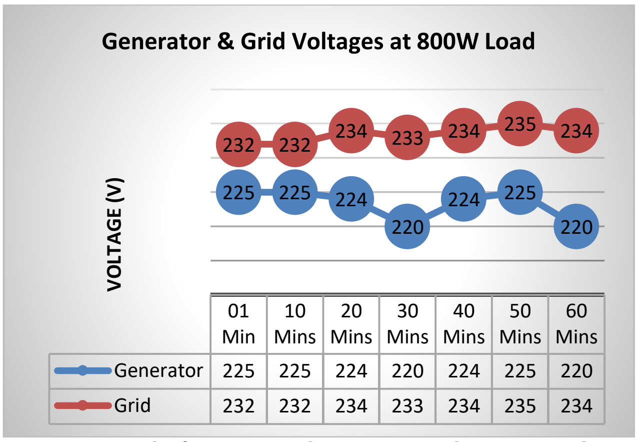

Fig. 6. Graph of Generator Voltage against Grid at 800W Load

A. *Power Quality Analysis*

For the power quality, the voltage and the frequency recorded will be examined. The standard acceptable RMS voltage for a single phase supply is 230V ± 2.5% while the frequency is 50Hz ± 0.5%.

B. *Voltage Quality*

At 800 Watts load, as shown in the table and Fig. 1, the voltage difference between the lowest (232V) and highest (235V) value for the grid is 3V while for the generator is (225V -220V) 5V. At 1000W load the difference is 1V for the grid and 5V for generator. Considering the 1200W load the variation is less than 1V for the grid and zero (0) for generator. We can draw conclusion that the voltage quality for grid is better at a higher load than at a lower load while for the PM, it is better at a higher load than at a lower load, when considering variation between the minimum and maximum values. Considering the allowable variation of ± 2.5% for voltage the acceptable range is 224V to 236V. It is clearly shown on the graph of Fig. 5 and Fig. 6 that the generator voltage falls outside this range at some point.

C. *Frequency Quality*

The frequency quality in comparison with the utility supply and that of a three phase generator set is very poor. It is not advisable to use frequency sensitive equipment on single-phase generator set. However, PMS on the overall show a better performance than LPG.

The generator frequency is at all-time outside the acceptable range of 50Hz ± 0.5%.

VI. Unit Cost Analysis of Electricity Generated

To account for losses in the system, average recorded power for each hour will be used instead of actual load power.

Hence, from Table I:

At 800W load, Average Power Consumption:

$$P_1 = \frac{\sum P}{7} = \frac{5777.7}{7} = 825.825W$$

At 1000W load, Average Power Consumption

$$P_2 = \frac{\sum P}{7} = \frac{7270.13}{7} = 1038.59W$$

At 1200W load, Average Power Consumption

$$P_3 = \frac{\sum P}{7} = \frac{8753.92}{7} = 1250.56W$$

Total Power Consumption:

$P_T = P_1 + P_2 + P_3 = 3114.54W$

Electrical Energy consumed in the 3hours runs,

$$E = P_T \times 3h = 3.11454kW \times 3h = 9.34362\ kWh$$

Total PMS Consumption = (0.92 + 1.2 + 1.2) ltrs = 3.14 ltrs

$$Fuel\ cost = cost\ per\ ltrs\ \times 3.14ltrs = ₦145 \times 3.14 = ₦455.3$$

For Generator maintenance at ₦3,500/100hrs runs, 3hrs run maintenance cost is ₦10.50.

Hence,

$$Cost\ for\ 3hrs\ run = ₦455.30 + ₦10.50 = ₦465.80$$

$$Unit\ cost(per\ kWh) = ₦465.80/9.34362 = ₦49.85$$

Considering unit cost comparison between generator and the grid it is cheaper still to be supplied from the grid whose unit cost is ₦21.30 per kWh.

VII. Conclusion and Recommendations

The Country generating capacity of averagely 10,000 MW which is grossly inadequate and the larger population not connected to the grid will continue to create larger market for portable generating sets.

Aside these, the initial cost of a generating set is relatively cheaper compared to other alternative sources of self-power generation, and is easier to operate. Definitely, the household generators will remain with us for a long while. On these bases, the following recommendations are expedient.

1. Further work to ascertain which fuel type generator is suitable for our environment is essential to regulate their importation.
2. Since greater percentage of the PMS we use in the country is imported, which in turn depletes our foreign reserve, attention should be drawn towards

making LPG relatively cheaper to use, since it is locally available.

3. Standards and specification that will reduce operational cost could be emphasized as a rule for Manufacturers of generators to follow, since the market for it is prominent.

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