

EVALUATION OF THE RESERVED ENERGY RESOURCES FOR NIGERIA POWER GENERATION AND TRANSMISSION CAPACITIES IMPROVEMENT

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Abstract

The problem of inadequate electric power generation has contributed to slow pace of industrialization of Nigeria. The present poor energy mix as well as lack of development of the abundant energy resources has made electric power a scarce commodity in our country, affecting virtually every aspect of our economy. An introduction of reserved energy resources of coal, natural gas and new hydro potentials to the existing generation mix will definitely pave way for industrialization of the country. The erratic and epileptic state of power supply in Nigeria resulting to insufficient generation to meet the load demand would be solved by harnessing the abundant reserved energy potentials of our nation. This paper thus presents the reserved energy resources to electric power potential conversion algorithm, and incorporated the converted power into the existing installed power generation capacity for a new improved generation capacity. New transmission lines were equally introduced to the present grid system for efficient power wheeling capability. The reserved estimated energy resources of coal, natural gas and new hydro potentials were evaluated to contribute a total of 63,876.96MW to the grid system; and when added to the existing installed capacity of 12,066MW will give a total of 75,942.96MW.

Keywords: Reserved Energy Resources, Electric Power Potential, Estimated Reserve, Proven Reserve, Coal, Natural Gas, Hydro Potential

1. INTRODUCTION

The electric power system of a country must meet the electricity demand of the citizens. Every household and business office should have access to adequate power supply.

Energy is a means of satisfying important needs of a society. The industrial growth rate of Nigeria is a function of the amount of reserved energy resource available and the extent to which this reserved energy resource is utilized for the design and the construction of additional power plants in sufficient numbers. Nigeria has sufficient reserved energy resources of coal, natural gas and new discovered hydro potentials that can serve as an input to all economic activities. Reserved energy resources of coal, natural gas and new discovered hydro potentials are the energy producing installations basket that contains power plants fired by fossil fuels (coal and natural gas) and hydro potentials. The proven reserved coal in Nigeria is about 445 million tones, consisting approximately of 81.05% sub-bituminous, 4.81% bituminous and 14.14% lignite coals. The estimated reserved coal in Nigeria is about 2,559 million tones, consisting approximately of 42.32% sub-bituminous, 45.17% bituminous and 12.51% lignite coals. The reserved proven coal and estimated coal can contribute 1,964MW and 12,082MW respectively to the grid system at 60% capacity utilization for over 100 years. The total reserved proven natural gas in Nigeria are 4 trillion cubic meters (or 142 trillion standard cubic feet) and 5.4 trillion cubic meters (or 189 trillion standard feet) respectively. The reserved proven natural gas and estimated natural gas can contribute 29,505MW and 39,270MW respectively to the grid system at a capacity of 60% for 100 years. The new discovered

hydro potentials and the existing electricity generation capacity in Nigeria are about 12,525MW and 12,066MW respectively. The reserved estimated energy resources of coal, natural gas and new hydro potentials can contribute a total of 63,876.96MW to the grid system, and when added to the existing installed capacity of 12,066MW will give a total of 75,942.96MW. Only 56.6% (42,943.6MW) of 75,942.96MW is utilized in the current generation and transmission capacities expansion that gives expanded 86-bus network with the reserved energy resources.

The key factor in the Nigeria energy crises is the very wide gap between the demand of electricity and the available supply in the country [1, 2, 3].

The Nigeria power system is currently suffering from inadequate generation and transmission capacity. The demand is much higher than the generation and this has led to constant load shedding and erratic power supply. The installed generation capacity of the Nigeria power system is currently 12,066MW with on-going included of which 18% is hydro, 10% is coal-fired thermal plants and 70% is gas-fired thermal plants.

At present, only about 4,200MW is generated on the average compared to the installed capacity. Rural electrification schemes and connection of more consumers to the grid are expected, and the estimated power demand in Nigeria is 15,730MW [1, 4]. To meet this growing demand, energy resources models are formulated and deployed in the conversion of reserved energy resources of coal, natural gas and new hydro potentials into its equivalent electric power resource. The reserved-based electric power resource is incorporated into the existing installed power generation

capacity for upgrading to higher generating capacity standard.

The existing transmission system is not sufficient to transfer the additional power injected to the grid by the new power plants from the reserved generation mix. New transmission lines are created and incorporated into the present grid system for efficient evacuation of the new expanded generated power capacity.

2. STATUS OF THE RESERVED ENERGY RESOURCES

Generation capability can be achieved with large reserved of coal deposits, unlimited reserved quantity of gas and crude oil and abundant hydro reserve.

2.1 Coal Fuel Resources

Coal is a fossil fuel which is a natural substance, and is one of the world's most important sources of energy that is used to generate around 37% of electricity worldwide [5].

2.2 Hydropower Reserved Resources

Nigeria has abundant and undeveloped hydropower resources. Hydropower resources are classified as large,

medium, intermediate, small, mini and micro scales. Large scale hydropower is defined internationally as any hydro installation rated at greater than 100MW. Medium scale hydropower is any hydro installation rated at the range 50 to 100MW, whereas intermediate scale hydropower is any hydro installation rated at the range 10 – 50 MW; while small hydropower is defined internationally as any hydro installation rated at less than 10MW. Hydropower accounts for over 22% of the total power generation in Nigeria. The existing large scale hydropower generating plants in Nigeria are the 760MW capacity Kainji Dam, 578MW capacity Jebba Dam and 600MW capacity Shiroro Dam, all located in Niger State. Nigeria has large undeveloped hydropower potentials, some of which have been shown to be technically and economically viable.

3. PRESENT POWER GENERATION CAPACITY

Presently, the total installed power generating capacity in Nigeria is 12,066MW, whilst the available capacity fluctuates between 3000MW and a little above 4000MW. Table 1 shows the installed capacity of the power plants and the current actual generation in Nigeria; while Table 2 shows the power plants under construction expected to be connected to the grid between 2012 and 2020.

Table 1: Power Generation capacity of the current Nigerian grid.

S/N	Station	State	Turbine	Installed Capacity (MW)	Available Capacity (MW)
1	Kanji	Niger	Hydro	760	253
2	Jebba	Niger	Hydro	578	351
3	Shiroro	Niger	Hydro	600	402
4	Egbin	Lagos	Steam	1320	900
5	Trans-Amadi	Rivers	Gas	100	57.30
6	A. E. S.	Lagos	Gas	302	211.80
7	Sapele	Delta	Steam	1020	170
8	Ibom	Akwa-Ibom	Gas	155	25.30
9	Okpai (Agip)	Delta	Gas	480	221
10	Afam I – V	Rivers	Gas	726	60
11	Afam VI (shell)	Rivers	Gas	650	510
12	Delta	Delta	Gas	900	281
13	Geregu	Kogi	Gas	414	120
14	Omoku	Rivers	Gas	150	53
15	Omotosho	Ondo	Gas	335	88.30
16	Olorunshogbo Phase I	Ogun	Gas	135	54.30
17	Olorunshogbo Phase II	Ogun	Gas	200	105.50
	Total Power (P₁)			8825MW	3863.50MW

Table 2: Generation capacity of ongoing New plants.

Station	State	Turbine	Installed capacity, MW
Calabar	Cross River	Gas	563
Egbema	Imo	Gas	338
Ihorbor	Edo	Gas	451
Gbarian	Bayelsa	Gas	225
Alaoji	Abia	Hydro	714
Eket	Cross River	Gas	500
Obite		Gas	450
Total (P₂)			3,241 MW
Grand Total (P₁+P₂)			12,066MW

The installed capacities of existing and ongoing Nigeria power plants are estimated at 12,066MW. This means that even with new plants and transmission lines being added, there may still be inefficient generation and transmission capacities due to demand increase.

4. MATERIALS AND METHODS

In this paper, the procedures taken for the conversion of reserved energy resources into its equivalent electric power resource include: development and formulation of energy reserved models; simulation of the energy reserved models to convert the reserved energy resources into its equivalent electric power; evaluation of the reserved – based electric power resource and incorporation of the reserved – based electric power resource into the existing installed power generating capacity.

4.1 Conversion of Raw Coal Resources into Electrical Energy

Coal is burnt in power stations to generate electricity. Generally, the raw coal is first grounded into a powder which allows it to burn more quickly. The powdered coal is burnt at a high temperature of around 1,100 degrees Celsius. The heat energy is converted into steam energy [5, 6].

The high-pressure steam is passed into the turbine connected to a generator, which in turn is connected to the electricity grid.

When the steam is passed into the turbine, it causes the turbine shaft to rotate at high speeds (the speed is usually fixed at 3,000 rotations per minutes). This energy is converted into electricity by the generator and passed into the electricity grid [7, 8, 9, 10,].

Available data from Nigeria energy commission on the proven and estimated coal reserves in the various parts of the country are as shown in table 3. Table 4 shows the heat content of various coal types.

Table 3: Composite of reserved proven and estimated coals.

S/N	Coal type	Proven reserves (tons)	Estimated reserves (tons)	% proven reserves	% estimated reserves
1	Sub-bituminous	361E +06	1083E +06	81.05	42.32
2	Bituminous	21.42E +06	1156E +06	4.81	45.17
3	Lignite	63E +06	320E +06	14.14	12.51
	Total	445.42E +06	2559E +06	100	100

Table 4: Heat content of the coal reserves.

s/n	Coal type	Heat content (GJ/ton)
1	Bituminous	27 – 30
2	Sub – bituminous	20 – 26
3	Lignite	10 – 19

Table 3 presents the composite of reserved proven and estimated coals in Nigeria. The proven coal reserve is about 445 million tones, consisting approximately of 81.05% sub-bituminous, 4.81% bituminous and 14.14% lignite coals, as shown in table 3.

The estimated coal reserve of Nigeria is about 2,559 million tones, consisting approximately of 42.32% sub – bituminous, 45.17% bituminous and 12.51% lignite coals, as presented in table 3.

The conversion procedures of raw coal deposits in tones into their equivalent electrical energy in megawatt hour (MWH) for the proven and estimated coal reserves are detailed as follows:

I. The various raw coal reserves in different mines location of each state are aggregated by summing the various reserve quantities. The coal reserves from the various mines

scattered in a particular state are pulled together to serve as fuel for a generation plant in the state. Column 1 of conversion results present only the states where the coal mines are located.

II. The type of raw coal deposited in each state is considered. This is important as it determines the heat or energy content of the raw coal reserves. Three raw coal types exist in Nigeria, namely bituminous, sub-bituminous and lignite. The heat content of the bituminous coal types ranges from 27 to 30GJ/ton. Sub-bituminous coal type has the heat content ranging from 20 to 26 GJ/ton and that of lignite coal type ranging from 10 to 19 GJ/ton. The heat content for variant coal types will serve as the conversion factors from tones to British Thermal Unit (BTU) as shown in table 4.

The three raw coal types are presented in column 2 of the conversion results.

III. The British Thermal Unit (BTU) is adopted as the unit of thermal energy. Column 3 of the conversion results has the raw coal reserves for the different states in tons. These raw coal reserves in tons are converted into their equivalent heat values in BTU as follows:

$$T_e = 26.5 \times 10^6 M \text{ for bituminous coal type} \quad (1a)$$

$$T_e = 23 \times 10^6 M \text{ for sub-bituminous coal type} \quad (1b)$$

$$T_e = 14.5 \times 10^6 M \text{ for lignite coal type} \quad (1c)$$

Where:
 T_e = Thermal energy in BTU
 M = Mass of raw coal reserves in tones

The computed thermal energy values in BTU are given in column 4 of the conversion results.

IV. The thermal energy content (T_e) of the coal in BTU is converted into the equivalent electrical energy in watt-hour as follows:

$$1KWh = 3412 \text{ BTU}$$

$$\text{Conversion ratio} = E_{WH} = \frac{1KWh}{3412 \text{ BTU}}$$

$$\frac{1Wh \times 10^3}{3412 \text{ BTU}}$$

$$0.2931 \frac{WH}{BTU} \quad (2)$$

Where:

$$E_{WH} = \text{Electrical energy in } WH$$

The computed electrical energy values in WH are given in column 4 of the conversion results.

V. The electrical energy content in WH is further converted into the equivalent 60% conversion efficiency in MWH . The steam turbine is expected to work at 60% capacity utilization for 100 years. The electrical power in MW is obtained as follows:

$$P = \frac{E}{t} = \frac{E}{100 \text{ years} \times 365 \times 24} = \frac{MWH}{87600 \text{ Hours}} \quad (3)$$

Where:

$$P = \text{Electrical power in MW}$$

$$E = \text{Electrical energy in MWH}$$

$$t = \text{time in hours}$$

The computed electrical power values in MW are presented in the last column of the conversion results. A MATLAB program was used to perform all the computations involving the conversion of raw coal reserves into electrical energy.

Figure 1 shows the algorithm (flow charts) of the conversion of raw coal reserves into electrical energy.

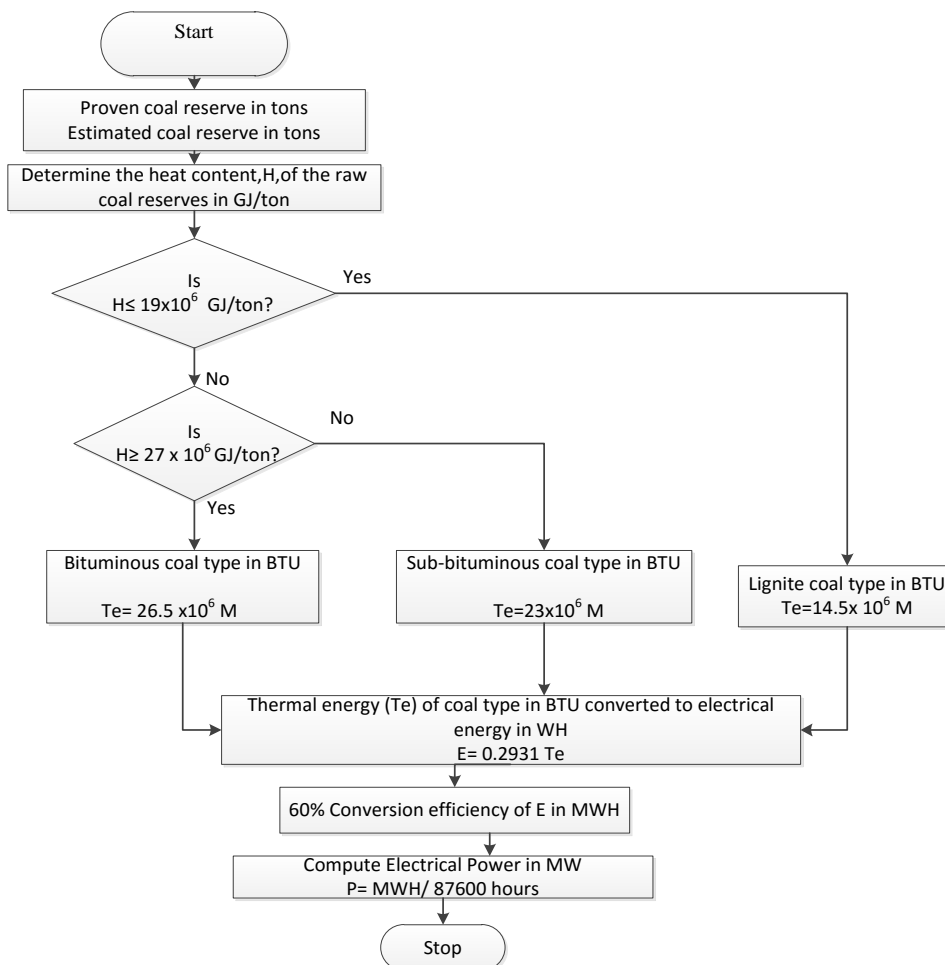


Fig. 1: Flow charts of the conversion of raw coal reserves into electrical energy.

Table 5 shows the proven coal reserve in Nigeria and its electrical power potential.

Table 5: Proven Coal Reserve in Nigeria and the Computed Values of Electrical Power Potential.

S / N	State	Coal Type	Proven Reserve (Tons)	Thermal Energy (BTU) (26.5E +6 for Bit) (23E +6 for S/Bit) (14.5E +6 for Lig)	Electrical Energy (WH) (0.2931)	MWH (/10 ⁶)	Eff = 60% (MWH 0.6)	Electrical Power (MW) (/876000)
1	Enugu	Sub-bituminous	140E +06	3.22E +15	9.44E +14	9.44E +08	5.66E +08	646.43
2	Delta	Lignite	63E +06	9.14E +14	2.68E +14		1.61E +08	183.39
3	Kogi	Sub-bituminous	164E +06	3.77E +15	1.11E +15	1.11E +09	6.63E +08	757.24
4	Nassarawa	Bituminous	21.42E +06	5.68E +14	1.66E +14	1.66E +08	9.98E +07	113.95
5	Benue	Sub-bituminous	57E +06	1.31E +15	3.84E +14	3.84E +08	2.31E +08	263.19
	Total		445.42E +06	9.782E +15	2.872E +15	2.872E +15	2.872E +09	1964.20

From the results computed electric power values in mega watts of the proven coal reserves, it is found that Kogi State of Nigeria produced the highest proven coal reserve of 757.24MW, while the lowest proven coal reserve of 113.95MW was recorded by Nassarawa State of Nigeria.

The estimated coal reserves in million tones, occurred in various States of Nigeria and their computed equivalent values of electrical power in mega watts are as shown in table 6. From the results obtained, it is clear that Enugu State bituminous coal of Nigeria has the highest estimated coal reserve of 5,319.97MW, whereas the lowest estimated coal reserve of 87.33MW came from Anambra State.

Table 6: Estimated Coal Reserve in Nigeria and the Computed Values of Electrical Power Potential.

S/N	State	Coal Type	Estimated Reserve (Tons)	Thermal Energy (BTU) (26.5E +6 for Bit) (23E +6 for S/Bit) (14.5E +6 for Lig)	Electrical Energy (WH) (0.2931)	MWH (/10 ⁶)	Eff = 60% (MWH 0.6)	Electrical Power (MW) (/876000)
1	Enugu	Bituminous	1000E +06	2.65E +06	7.77E +15	7.77E +09	4.66E +09	5319.97
2	Enugu	Sub-bituminous	456E +06	10488E +16	3.074E +15	3.074E +09	1.84E +09	2105.50
3	Imo	Lignite	40E + 06	5.80E +14	1.70E +14	1.70E +08	1.02E +08	116.44
4	Ebonyi	Sub-bituminous	50E +06	1.15E +15	3.37E +14	3.37E +08	2.02E +08	230.87
5	Anambra	Lignite	30E +06	4.35E +14	1.28E +14	1.28E +08	7.65E +07	87.33
6	Delta	Lignite	250E +06	3.63E +15	1.062E +15	1.062E +09	6.36E +08	727.73
7	Kogi	Sub-bituminous	502E +06	1.16E +16	3.38E +15	3.38E +09	2.03E +09	2317.90
8	Nassarawa	Bituminous	156E +06	4.13E +15	1.21E +15	1.21E +09	7.27E +08	829.92
9	Benue	Sub-bituminous	75E +06	1.73E +15	5.056E +14	5.056E +09	3.034E +08	346.30
	Total		2559E +06	1.049E +20	1.76E +16	1.76E +10	1.058E +10	12081.96

4.2 Conversion of Raw Natural Gas Reserves Into Electrical Power

A gas turbine plant consists of a compressor, combustion chamber, gas turbine and alternator. The compressor takes in atmospheric air, compresses it and supplies the pressurized

air to the combustion chamber and burnt in the presence of air supplied by the compressor. The combustion raises the temperature of air and increases its volume under constant pressure. The products of combustion, after expansion through the turbine, are finally exhausted to the atmosphere [14].

The proven and estimated raw natural gas reserves in the various parts of the country are presented in tables 7 and 8 respectively. The computational procedures deployed in the conversion of raw coal reserves into electrical energy has been adopted in the conversion of raw natural gas reserves in trillion cubic meters (or trillion standard cubic feet) into electrical energy. The procedure includes:

(i) The conversion of raw natural gas reserves from cubic meters to cubic feet as follows:

$$1 \text{ cubic meter} = 35.5 \text{ cubic feet}$$

$$1Q_{CM} = 35.5Q_{CF}$$

$$\text{Conversion ratio} = 1Q_{CF} = \frac{35.5 \text{ CF}}{1Q_{CM}} \tag{4}$$

$$\begin{aligned} 4 \text{ trillion cubic meters} &= 4 \times 35.5 \text{ trillion cubic feet} \\ &= 142 \text{ trillion cubic feet} \\ &= 142 \times 10^{12} Q_{CF} \end{aligned}$$

(ii) Conversion of the natural gas reserves from cubic feet to thermal energy in BTU as follows:

$$1Q_{CF} = 1035 \text{ BTU}$$

$$\text{or, } 1Q_{BTU} = \frac{1035 \text{ BTU}}{1Q_{CF}} \tag{5}$$

$$1 \text{ KWh} = 3412 \text{ BTU}$$

$$E_{WH} = \frac{1 \text{ KWh}}{3412 \text{ BTU}} = \frac{1 \text{ Wh} \times 10^3}{3412 \text{ BTU}} = 0.2931 \frac{\text{WH}}{\text{BTU}}$$

Where

Q_{CM} = Quantity of natural gas in cubic meters

Q_{CF} = Quantity of natural gas in cubic feet

Q_{BTU} = Quantity of natural gas in BTU

Step 4 – 5 computational procedures for the conversion of raw coal reserves into electrical energy are adopted here.

The electrical energy content in WH is converted into the equivalent 60% conversion efficiency in MWH. The gas turbine is expected to work at 60% capacity utilization for 100 years. The electrical power in MW is computed as follows:

$$P = \frac{E}{t} = \frac{E}{100 \text{ years} \times 365 \times 24} = \frac{\text{MWH}}{87600 \text{ Hours}} \tag{7}$$

The computational software program used for converting the quantity of natural gas into megawatt is MATLAB.

Table 7 presents the proven natural gas reserves in trillion cubic meters (or trillion standard cubic feet), occurring in various states of federation and their computed equivalent values of electrical power in megga watts. From table 7, the total proven natural gas reserve in Nigeria is about 4 trillion cubic meters (or 142 trillion standard cubic feet). This proven natural gas reserves can support 29,505MW capacity power plants operating at a capacity factor of 60% for 100 years.

The computed equivalent electrical power values in megga watts from the proven natural gas reserves show that the maximum and minimum proven natural gas reserves could produce electrical power of 7,081MW (or 24%) and 885MW (or 3%) from the reserves located in Rivers State and Imo or Abia States respectively.

Table 7 shows the results of proven gas reserve and its electric power value

Table 7: Proven Gas Reserve in Nigeria and the Computed Values of Electrical Energy Potentials.

S/N	State	Proven Gas Reserve in trillion cubic meters ($\times 10^{12}$ cubic meters)	Proven Gas Reserve (%)	Gas in cubic feet ($\times 35.5$ CF)	Thermal Energy (BTU) ($\times 1035$)	Electrical Energy (WH) ($\times 0.2931$)	MWH ($/10^6$)	Eff = 60% (MWH X 0.6)	Electrical Power (MW)/(876000)
1	Rivers	0.96×10^{12}	24	3.408×10^{13}	3.527×10^{16}	1.034×10^{16}	1.034×10^{10}	6.203×10^9	7081
2	Bayelsa	0.60×10^{12}	15	2.130×10^{13}	2.205×10^{16}	6.462×10^{15}	6.462×10^9	3.877×10^9	4426
3	Akwa-Ibom	0.80×10^{12}	20	2.840×10^{13}	2.939×10^{16}	8.615×10^{15}	8.615×10^9	5.169×10^9	5901
4	Delta	0.80×10^{12}	20	2.840×10^{13}	2.939×10^{16}	8.615×10^{15}	8.615×10^9	5.169×10^9	5901
5	Edo	0.48×10^{12}	12	1.704×10^{13}	1.764×10^{16}	5.169×10^{15}	5.169×10^9	3.102×10^9	354
6	Ondo	0.16×10^{12}	4	5.680×10^{12}	5.879×10^{15}	1.723×10^{15}	1.723×10^9	1.034×10^9	1180
7	Imo	0.12×10^{12}	3	4.260×10^{12}	4.409×10^{15}	1.292×10^{15}	1.292×10^9	7.754×10^9	885
8	Abia	0.12×10^{12}	3	4.260×10^{12}	4.409×10^{15}	1.292×10^{15}	1.292×10^9	7.754×10^9	885
	Total	4×10^{12}	100	142×10^{12}	1.470×10^{17}	4.308×10^{16}	4.308×10^{10}	2.585×10^{10}	29505

Table 8 shows the values of the estimated natural gas reserves in trillion cubic meters (or trillion standard cubic feet), occurring in various States of Nigeria and their

computed equivalent values of electrical power in megga watts. From table 8, the total estimated natural gas reserve in Nigeria is about 5.4 trillion cubic meters (or 189 trillion

standard cubic feet). This estimated natural gas reserve can support 39,270MW capacity power plants operating at a capacity factor of 60% for 100 years.

The computed equivalent electrical power values in megawatts from the estimated natural gas reserves show that

Rivers state of Nigeria has the highest estimated natural gas reserve capable of producing 9,425MW, while Imo or Abia State has the lowest estimated natural gas reserve that could give 1,178MW.

Table 8: Estimated Gas Reserve in Nigeria and the Computed Values of Electrical Energy Potentials.

S/N	State	Estimated Gas Reserves in trillion cubic meters ($\times 10^{12}$ cubic meters)	Estimated Gas Reserves (%)	Gas in cubic feet ($\times 35.5$ CF)	Thermal Energy (BTU) ($\times 1035$)	Electrical Energy (WH) ($\times 0.2931$)	MWH ($/10^6$)	Eff = 60% (MWH $\times 0.6$)	Electrical Power (MW)(/876000)
1	Rivers	1.278×10^{12}	24	4.536×10^{13}	4.695×10^{16}	1.376×10^{16}	1.376×10^{10}	8.256×10^9	9425
2	Bayelsa	0.7986×10^{12}	15	2.835×10^{13}	2.934×10^{16}	8.600×10^{15}	8.600×10^9	5.160×10^9	5891
3	Akwa-Ibom	1.0648×10^{12}	20	3.780×10^{13}	3.912×10^{16}	1.147×10^{15}	1.147×10^{10}	6.880×10^9	7854
4	Delta	1.0648×10^{12}	20	3.780×10^{13}	3.912×10^{16}	1.147×10^{15}	1.147×10^{10}	6.880×10^9	7854
5	Edo	0.6389×10^{12}	12	2.268×10^{13}	2.347×10^{16}	6.880×10^{15}	6.880×10^9	4.128×10^9	4712
6	Ondo	0.2130×10^{12}	4	7.560×10^{12}	7.825×10^{15}	2.293×10^{15}	2.293×10^9	1.376×10^9	1571
7	Imo	0.1597×10^{12}	3	5.670×10^{12}	5.868×10^{15}	1.720×10^{15}	1.720×10^9	1.032×10^9	1178
8	Abia	0.1597×10^{12}	3	4.260×10^{12}	5.868×10^{15}	1.720×10^{15}	1.720×10^9	1.032×10^9	1178
	Total	5.3775×10^{12}	100	189×10^{12}	1.956×10^{17}	5.733×10^{16}	5.733×10^{10}	3.440×10^{10}	39270

Tables 9 and 10 show the comparison of electricity generation by proven and estimated fuel reserves respectively, in Nigeria. The proven fuel reserves of coal, natural gas and new discovered hydro potentials are compared with the highest value of 29,505MW coming from the natural gas. The proven and estimated fuel reserves can

provide a total of 43,994.20MW and 63,876.96MW respectively to the grid with the highest value of 39,270MW coming from the natural gas.

Table 9: Electricity Generation by proven Fuel Reserve in Nigeria.

Electricity Resource Mix	Proven Fuel Reserve	Percentage	Computed Generation Capacity (MW)
Coal	445.42×10^6 Tons	4.46	1964.20
Natural Gas	4 TCM or 142×10^{12} CF	67.07	29505
Large Hydro Potential		28.47	12525
Total		100.00	43,994.20

Table 10: Electricity Generation by estimated Fuel Reserve in Nigeria.

Electricity Resource Mix	Estimated Fuel Reserve	Percentage	Computed Generation Capacity (MW)
Coal	2559×10^6 Tons	18.91	12081.96
Natural Gas	5.32 TCM or 189×10^{12} CF	61.48	39270
Large Hydro Potential		19.61	12525
Total		100.00	63876.96

Table 11 shows the comparison of existing and on – going electricity generation by fuel, while Table 12 shows the comparison of electricity generation by proven fuel reserves, existing and on – going generation in Nigeria. The existing

and on-going can provide a total of 12,066MW to the grid. While the proven fuel reserve, existing and on-going can provide a total of 56,060MW to the grid.

Table 11: Capacity realizable by existing and ongoing projects in Nigeria.

Electricity Resource Mix	Percentage	Installed Generation Capacity (MW)
Coal: Existing	19.39	2340
Ongoing	Nil	Nil
Natural Gas: Existing	37.68	4547
Ongoing	18.90	2280
Hydro: Existing	16.06	1938
Ongoing	7.97	961
Total	100	12066

Table 12: Generation by Fuel Reserve, existing and Ongoing projects in Nigeria.

Electricity Resource Mix	Percentage	Computed Generation Capacity (MW)
Total Proven Reserve Capacity	78.48	43,994.20
Total Existing and Ongoing Electricity Generation Capacity	21.52	12,066
Grand Total	100.00	56,060.20

Table 13 shows the comparison of electricity generation by estimated fuel reserves and existing and on – going

generation by fuel in Nigeria. This can contribute a total of 75,942.96MW to the grid system.

Table 13: Comparison of Electricity Generation by Estimated Fuel Reserve and Existing and Ongoing Generation by Fuel in Nigeria.

Electricity Resource Mix	Percentage	Computed Generation Capacity (MW)
Total Estimated Reserve Capacity	84.11	63,876.96
Total Existing and Ongoing Electricity Generation Capacity	15.89	12,066
Grand Total	100.00	75,942.96

4.3 Evaluation and Integration of Reserved- Based Electric Power Resource and Existing Installed Capacity.

The reserved estimated energy resources of coal, natural gas and new hydro potentials would contribute a total 63,876.96MW to the grid; and when added to the existing installed capacity of 12,066MW will give a total of 75,942.96MW as seen in table 13. The new power stations of several megawatts from reserved energy resources of coal fired, gas fired and hydro power plants are created and added to the existing 28 – bus grid shown in fig. 2 resulting to an expanded network of 86-bus shown in fig.3, leading to an increase in the number generator buses from 10 to 51, load buses from 18 to 35; generation capacity expanded from 12,066MW to 42,943.6MW, while the transmission lines increased from 5,988Km to 11,711Km. The number of single lines and double lines improved from 16 to 34 and 16 to 58 respectively. More loops were equally created in the network from 4 to 7 as can be seen in table 16 and fig. 3 respectively.

Thirteen (13) new coal-fired power plants with bus-bars coloured blue contributed 13,000MW to improve the existing 28 – bus test system. These new coal fired power plants are designated as Kwara, Ondo, Delta1, Kogi, Anambra, Bauchi, Gombe, Bukuru, Plateau1, Adamawa, Benue, Enugu and Ebonyi as shown in table 14.

Eight (8) new natural gas fired power plants with bus- bars coloured yellow contributed 8,000MW to improve the existing 28 – bus test system. These new natural gas- fired power plants are designated as Bayelsa, Delta3, Edo, Imo, Abia, Rivers, Mabon and Ibom, as shown in table 15.

Thirteen (13) new hydro power plants with bus- bars coloured red contributed 12,153MW to improve the existing 28 – bus test system. These new hydro power plants are designated as Mambilla, Zungeru, Danko, Gurara, Sarkin, Lokoja, Obajana, Onitsha2, Plateau2, Kastina Ala1, Ikom, Kasimbila, Katsina Ala2.

Forty one (41) more generating units from the reserved energy resources added to existing power plants will result in increased power flow on transmission lines in the grid, as shown in expanded 86 – bus system with the reserved energy resources of fig.3.

Table 14: proposed coal – fired power plants with the reserved energy resources.

PROPOSED			EXISTING		
Bus No	With blue bus-bars	Capacity (MW)	Bus No	With black bus-bars	Capacity (MW)
8	Kwara	1000	13	Sapele PS	1020
11	Ondo	1000			
14	Delta 1	1000			
34	Kogi	1000			
36	Anambra	1000			
38	Bauchi	1000			
39	Gombe	1000			
40	Bukuru	1000			
41	Plateau 1	1000			
42	Adamawa	1000			
44	Benue	1000			
50	Enugu	1000			
51	Ebonyi	1000			
	Total	13,000MW			1020MW
	Overall Total	14,020MW			

Table 15: Proposed Natural gas – fired power plants with the reserved energy resources.

PROPOSED			EXISTING		
Bus No	With yellow bus-bars	Capacity (MW)	Bus No	With black bus-bars	Capacity (MW)
18	Bayelsa	1000	2	Egbin	1,320
19	Delta 3	1000	7	Geregu	414
21	Edo	1000	9	Omosho	335
24	Imo	1000	10	Papalanto	335
26	Aba	1000	15	Delta 2 PS	912
28	Rivers	1000	16	Gbaran	225
30	Mabon	1000	17	Rain/Ube	225
47	Ibom	1000	20	Egema	338
			22	Omoku PS	252
			23	Agip Okpai PS	480
			25	Alaoji	504
			27	Afam (i – v)	931.6
			46	Calabar	561
	Total	8,000MW			6,832.6MW
	Overall total	14,832.6MW			

Comparison of the existing and the expanded transmission grids is giving in table 16.

Table 16: Comparison of the existing and expanded transmission grids.

	Existing 330KV transmission grid	Expanded 330KV transmission grid
Number of generators	10	51
Number of load buses	18	35
Number of buses	28	86
Grid capacity	12,066MW	42,943.6MW
Grid transmission lines	5,988km	11,711km
Number of single lines	16	34
Number of double lines	16	58
Number of loops	4	7

The necessary conditions for the selection and placement of additional generating plants into the test grid network are enumerated as follows:

- (a) A maximum return must be obtained with a minimum expenditure over the working life of the power plant.

- (b) The operation of such power plants should be carried out in such a way as to provide cheap, reliable and continuous service to ever increasing population.

Figs. 2 and 3 show the existing 28-bus Power network and 86-bus reserved- energy based expanded network.

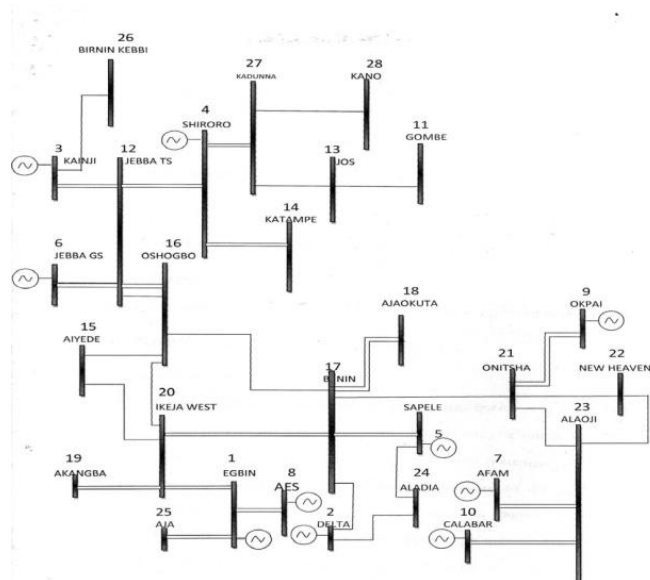


Fig. 2: The existing 28-bus 330KV Nigerian power grid

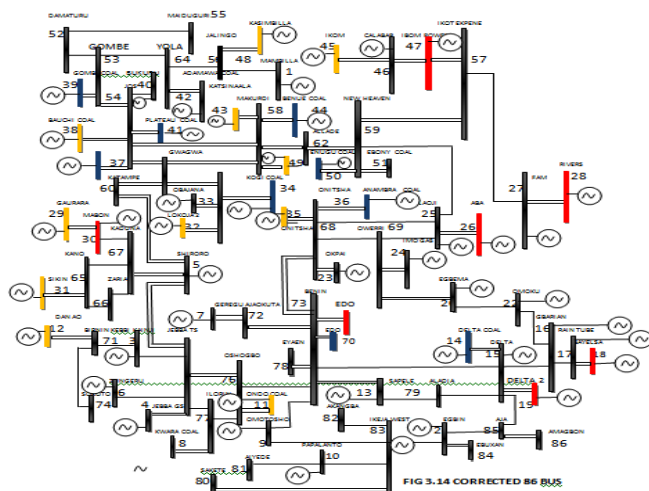


Fig 3: The expanded 86- bus power grid with reserved energy resources.

6. CONCLUSION

Effective sustainability, stability, efficiency and reliability of power supply based on increasing system loads would be achieved in Nigeria power system through the introduction of additional megawatts from abundant natural reserved energy resources. The reserved proven coal of 445 millions tons and estimated coal of 2,559 million tons would contribute 1,964MW and 12,082MW respectively to the grid system at 60% capacity utilization for over 100 years.

The reserved proven natural gas of 4 trillion cubic meters (or 142 trillion standard cubic feet) and estimated natural

gas of 5.4 trillion cubic meters (or 189 trillion standard cubic feet) would contribute 29,505MW and 39,270MW respectively to the grid system at capacity of 60% for 100 years.

The new discovered hydro potentials and the existing electricity generation capacity in Nigeria are 12,525MW and 12,066MW respectively. The reserved estimated energy resources of coal, natural gas and new hydro potentials would contribute a total of 63,876.96MW to the grid system, and when added to the existing installed capacity of 12,066MW will give a total of 75,942.96MW. Only 56.6% (42,943.6MW) of 75,942.96MW is utilized in the current generation transmission capacities expansion that gives expanded 86-bus network.

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