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Assesment of Power Generation Resources in Nigeria

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Abstract: *Electricity is the major secondary energy needed in these modern time, hence natural resources on the earth surface and in the subsurface can be harnessed and converted to electrical power.*
Natural resources dispersed in different parts of the nation are assessed and appropriate generation and distribution methods examined and recommended.
Economic, environmental and technical challenges expected in the implementation are highlighted. Implementation of these will lead to increased power generation, reduced cost of distribution and encourage efficiency. The result will be intensive exploration and exploitation of these resources in the Nigeria's geo-political zones. The multiplier effects will be increase in economic activities, job creation and relief to old generating plants in the nation.
***Key words**: Generation, electrical power, natural resources.*

I. Introduction

Electrical power is the main energy used in the industries that drives the plants and the energy that powers appliances in our homes and offices, and so the means of generation and distribution of electricity is important. The available resources dispersed in our Nation can be harnessed to the maximum to generate enough electrical power for the teeming population and growing economy.
Energy is the ability or capacity to do work. Energy exists in various forms-heat energy, chemical energy, electrical energy, solar energy, etc. These forms of energy can be transformed from one form to the other. For example, coal in form of chemical energy can be burnt and the heat produced can be converted to mechanical energy to turn the turbine, the final result is the generation of electrical power in the generator. These leads to the fundamental law in energy technology, "Energy cannot be newly created, energy cannot be destroyed, in a closed system, the total mass and energy remains unchanged, in a closed system the energy is conserved'' (Rao and Parulekar, 2007). This law, at least holds in macroscopic scale.

Electrical energy, being the fundamental secondary energy is the energy of focus in this paper. The history of electricity dates back to about 600BC when the Greek philosopher Thales of Miletus observed that amber could make other objects move. It was in the eighteen century that experiments performed by Alessandro Volta, Hans Christian Oersted, Andre Marie Amperes, Georg Simon Ohm, Michael Faraday and others established laws of electricity. It led directly to the development of the rotary electric generator, which convert mechanical motion into electric energy.

Electricity is the flow of electric charges, which can be either positive or negative. In metals, electrons which are negatively charged are the carriers of electricity. So electric current is the flow of electrons, if the current flow is in one direction, it is called a direct current (DC), if the flow reverses direction periodically, it is known as alternating current (AC). Alternating current has many advantages and uses over direct current. The main advantage being, the ease of transformation from one level to another in the mains.
So all discussions in this paper is essentially alternating current. Electrical power plays a pivotal part in domestic and industrial life of the modern man, as lighting, heating, communication, cooling, operation of machines and appliances, etc. depend on electricity. Electrical power is the backbone of modern industrial society.
Each Geo-political zone has unique natural resources that can be used to generate electricity, instead of relying on natural gas from some zones and Hydro-electricity which are subject to constrains.

II. Discussion

2.1 ENERGY DEMAND

The demand for energy is rising rapidly with growing population and industrialization. The demand for power in Nigeria grew at an average annual rate estimated at 15 to 20 percent after the start of the 1973-74 oil boom. The then, National Electrical Power Authority, NEPA , having an installed capacity of 881 megawatts in the Financial Year, FY 1976--almost half of which was located at the Kainji hydroelectric plant. By Financial Year, FY 1978 an additional 250 megawatts had been installed, of which 200 megawatts were at Kainji, but a drought in 1977 and 1978 significantly lowered the level of Kainji Reservoir and thus reduced the plant's output. During the drought, blackouts were frequent, verging industrial establishments. Goods in the production process had to be destroyed, and interruptions in machine operations substantially reduced productivity. The situation improved in the 1980s, with two 120-megawatt (MW) units added to the Kainji hydroelectric station, ten units of 120 megawatts each installed in Sapele, new hydroelectric stations built at Shiroro on the Kaduna River and Jebba downstream from Kainji Reservoir, and another 200 megawatts added at various smaller plants [Library of Congress Country Studies; CIA World Factbook, 1991].

In recent years, there had been upgrade of facilities at Egbin thermal plant, near Lagos, Sapele steam and gas plants and gas plant in Ughelli both in Delta State. New Gas plant at Afam , Oyigbo in Rivers State , Omotosho, etc.

These plants generate less than 5000MW which is far less than what the present population of Nigeria that stands at about 160 Million need for domestic, services, industrial and other uses.

2.2 NIGERIA'S POWER GENERATING PLANTS

The power plants are Non-Renewable (Gas) and Hydroelectric Power stations.

Table 1: Hydroelectric Power Stations

S/N0	HYDROELECTRIC STATION	LOCATION	TYPE	CAPACITY	YEAR COMPLETED	RESERVOIR	RIVER
1	Kainji	Niger State	Reservoir	800MW	1968	Kainji Lake	Niger
2	Jebba	Niger state	Reservoir	540MW	1985	Lake Jebba	Niger
3	Shiroro	Kaduna state	Reservoir	600MW	1990	Lake Shiroro	Kaduna
4	Kano	Kano state	Reservoir	100MW	2015		Hadejia
5	Zamfara	Zamfara state	Reservoir	100MW	2012	Gotowa Lake	Bunsuru
6	Kiri		Reservoir	35 MW	2016		Benue
7	Mambilla	Taraba	Reservoir	3050 MW	2018	Gembu, Sum and Nghu lake	Donga

Table 2: Non-Renewable Power Stations

S/NO	POWER STATION	LOCATION	TYPE	CAPACITY	STATUS	YEAR
1	Afam 1V – V	Afam, Rivers state	Gas Turbine	726 MW	Partially Operational	1982(Afam 1V), 2002 (Afam V).
2	Afam V1	Afam, Rivers state	Combined cycle gas Turbine	624 MW	Operational	2009, 2010
3	Egbin	Egbin, near Lagos	Gas-fired steam Turbine	1,320 MW	Operational	1985-1986
4	AES Barge	Egbin, near Lagos	Gas Turbine	270 MW	Operational	2001
5	Delta (II), (III) and (IV)	Ughelli, Delta state	Gas Turbine	360 MW	Operational	1964, 1978 , 1991.
6	Sapele	Sapele, Delta state	Gas/Steam Turbine	450MW	Partially Operational	1980s
7	Omotosho 1	Ondo state	Gas Turbine	336MW	Operational	2005
8	Omotosho 11	Ondo state	Gas Turbine	450 MW	Partially Operational	2012-2013
9	Omoku	Rivers state	Gas Turbine	150 MW	Operational	2005
10	Alaoji	Aba, Abia state	Combined cycle gas Turbine	1074 MW	Under Construction	2013-2015
11	Egbema	Imo State	Gas Turbine	338 MW	Under Construction	2012-2013
12	Calabar	Cross River state	Gas Turbine	561 MW	Under Construction	2014
13	Ibom	Akwa Ibom state	Gas Turbine	190 MW	Partially Operational	2009
14	Ihovbor	Edo State	Gas Turbine	450 MW	Under Construction	2012-2013
15	Okpai	Delta state	Combined cycle gas Turbine	480 MW	Operational	2005
16	Olorunsogo 1	Ogun state	Gas Turbine	336 MW	Partially Operational	2007
17	Olorunsogo II	Ogun state	Combined cycle Turbine	750 MW	Partially Operational	2012

Sources: Afam-Gas Turbine Power Station in Afam, Nigeria, Mbendi Information Services, 2010.
Egbin - Thermal Power Station in Egbin, Nigeria, Mbendi Information Services, 2010

Surprisingly, what is being generated presently nationwide is about 4000MW.

From the tables, the analysis of generation stations give;
Gas Turbine = 5127 MW = 37%
Hydroelectric Plants = 5225 MW = 38%
Combined (gas and steam) = 3378 MW = 25%

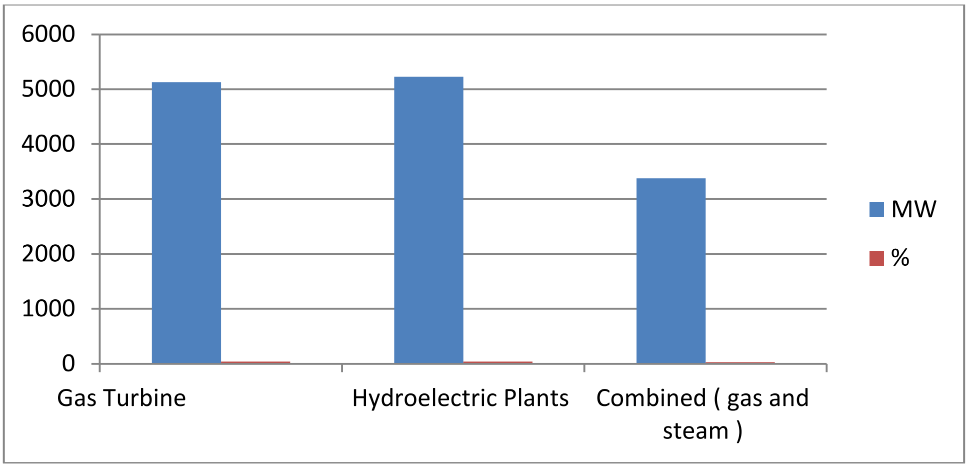

Fig.1: comparisons of Gas, Hydro, and Combined (gas and steam) plants.

There are no coal or nuclear power generating station (fig.1). Gas turbine is expensive to maintain, and has short lifespan. Until we exploit other resources like coal and nuclear power, we may not meet the challenges of the increasing need of electrical power in this 21st century.

2.3 NIGERIA'S SIX GEO-POLITICAL ZONES AND THEIR NATURAL RESOURCES

Nigeria is divided into six geopolitical zones namely South-South, South-East, South-West, North-East, North-Central and North-West. The six zones made up the 36 states and the Federal capital territory, Abuja (fig.2). Natural resources like natural gas, coal, water, uranium, etc. are dispersed in the zones which can be used to generate electricity. Electrical power is generated in many parts of the country, the power plants are either gas turbine plant, steam turbine plant or hydroelectric plant. Most of the gas turbine generating plants are located in the South-South zone of the country due to the availability of natural gas.

There is the need to exploit other natural resources like coal, uranium, etc. in addition to the use of natural gas and hydroelectric plants in the generation of electricity in the country.

Table 3: States and Natural Resources Available.

S/N0	GEO-POLITICAL ZONE	STATES	NATURAL RESOURCES AVAILABLE	RECOMMENDED POWER PLANT
1	South-South	Akwa-Ibom, Bayelsa, Cross River, Delta, Edo, Rivers.	Petroleum, Natural gas, Salt, Silica sand, Limestone, Coal, Kaolin, Clay, Feldspar, Glass sand, Talc, Granite, Barite,etc	Gas and Steam Powered Plant
2	South-East	Abia, Anambra, Ebonyi, Enugu, Imo.	Petroleum, Natural gas, Coal, Glass sand, Salt, Sandstone, Clay, Mable, etc.	Gas and Coal Powered Plant.
3	South-West	Ekiti, Lagos, Ogun, Oyo, Oshun , Ondo.	Petroleum, Bitumen, Silica sand, Kaolin, Clay, Laterite, Gravel, etc.	Gas and Steam Powered Plant
4	North-Central	Benue, kogi, kwara, Nasarawa Niger, Plateau, Federal Capital Territory, Abuja.	Coal, Clay, Limestone, Gemstone, beryl, Feldspar, Dolomite, Granite, Galena, Zircon, Cassiterte, Kaolin, etc.	Coal and Hydro Powered Plant.
5	North-East	Adamawa, Bauchi, Bornu, Gombe, Taraba, Yobe .	Uranium, Granite, Limestone, Clay, Kaolin, Barite, Salt, Silica sand, Quartz, Topaz, Feldspar, Iron ore, Tin, Mica, etc.	Nuclear and Hydro Powered Plant.
6	North-West	Jigawa, Kaduna, Kano, Katsina, kebbi, Sokoto Zamfara.	Uranium, Kaolin, Manganese, Feldspar, Clay, Laterite, Silica, Salt, Limestone, Mica, Iron ore, Gold, etc.	Nuclear and Hydro Powered Plant.

Source of natural resources: Nigeria Geological survey.

NIGERIA AND ITS STATES

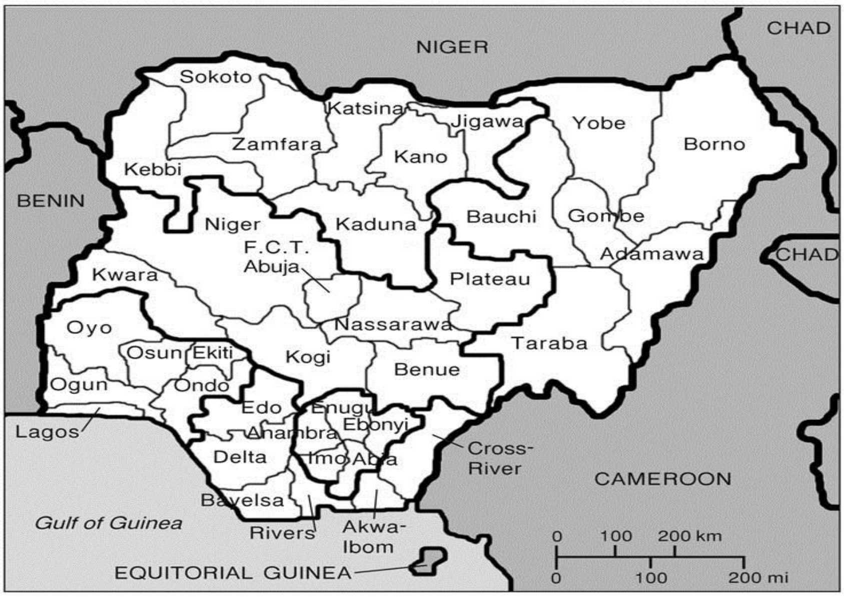

Fig.2 : Map of Nigeria showing the six geo-political zones.

THE SIX GEOPOLITICAL ZONES IN NIGERIA

- SOUTH EAST ------------------Anambra, Enugu, Ebonyi, Imo and Abia states.
- SOUTH SOUTH ----------------Edo, Delta, Rivers, Bayelsa, Cross-River and Akwa-Ibom states
- SOUTH WEST -------------------Lagos, Ogun, Oyo, Osun, Ondo and Ekiti states
- NORTH CENTRAL ---------------Kwara, Kogi, Plateau, Nassarawa, Benue, Niger and F.C.T
- NORTH EAST -------------------Taraba, Adamawa, Borno, Yobe, Bauchi and Gombe states
- NORTH WEST -----------------Sokoto, Zamfara, Kebbi, Kaduna, Katsina, Kano and Jigawa states

III. Implications Of The New Power Plants

3.1 ECONOMIC IMPLICATIONS OF THE NEW POWER PLANTS

No doubt, citing of more gas and steam powered turbines, coal and nuclear powered generating stations in the six zones of the nation will boost the economy of the states in the zones. More economic activities will result, small and medium Enterprises will spring up since less money will be spent on power by entrepreneurs. Small and Medium Enterprise (SME) is known worldwide to be the driver of the economy and the highest employer of labour, both skilled and unskilled labour.

There will be more jobs for the unemployed, presently, only a handful of youths get job in the oil and gas companies. They will be under less pressure to employ the youths, hence, less tension and youth restiveness in the zones.

Mining of coal and uranium will be revitalized and this will give more jobs to the unemployed and will give rise to other complimentary companies. Mining

Companies will explore for more resources / minerals used in the generation of electricity as coal and uranium reserves in the zones will be exploited to the maximum, since there will be ready market for the resources.

However, before any power station can be set up, the following economic factors should be considered.

i. Capital cost of the plant
ii. Capital cost of erecting and maintaining the transmission lines and the annual energy loss in transformation and transmission of electric power.
iii. Energy generation cost compared among the different generation methods (Gupta, 2005).

3.2 ENVIRONMENTAL IMPLICATION OF THE POWER STATIONS

Natural gas, being a fossil fuel has some impact on the environment. For example, carbon-dioxide CO_2 is produced when oil, coal, and gas combust in power stations, heating systems, and car engines. Carbon-dioxide in the atmosphere acts as a transparent blanket, that contributes to the global warming of the earth or ‘’greenhouse effect’’ this warming significantly alter our weather (Ackerman and Knox, 2003). Possible impacts include threat to human health, environmental impacts such as rising sea levels that can damage coastal areas, and major changes in vegetation growth patterns that could cause some plants and animal species to become extinct. (Montgomery, 2003). Sulphur dioxide SO_2 is also emitted into the air when coal is burned.

The sulphur dioxide reacts with water and oxygen in the clouds to form precipitate known as ‘’acid rain’’. Acid rain can kill fish , trees, and damage vegetation, limestone buildings and materials.(Tiwari, 2007).
However, carbon-dioxide and sulphur can be converted to other substances in the power stations.
Nuclear power plant, no doubt posses potential threat to humans, animals and plants in the event of accident and it can be fatal, as the effect of radioactive particles can last for several years. Recall the April 26, 1986 nuclear accident at Chernobyl in the Ukrainian republic of the former Union of Soviet Socialist Republic (USSR). The principal environmental effect of the Chernobyl accident has been the accumulation of radioactive fallout in the upper layers of soil, where it has destroyed important farmland. The second most important impact has been the threat to surface water and groundwater.
Nevertheless, with careful and controlled management, nuclear plants can add significantly to the generation of electricity in Nigeria as some states in the North-East and North-West of the country have deposits of uranium (table 3).
Flooding along the river banks is the possible environmental problem posed in the event of release of water in the reservoir of a hydroelectric plant. But with appropriate dredging of the river channels, the problem can be checked.

3.3 TECHNICAL IMPLICATIONS OF NEW POWER STATIONS

Building of coal and nuclear powered stations in the country will lead to the acquisition of technology, exchange of ideas, and collaborations between Nigeria and the advanced economies of the world that have nuclear and coal powered stations.

Technologically, the nation will be better off. Prospecting power station will employ, train and re-train their technical staff. Not only the engineering sector will receive a boost, other complimentary companies and services will also receive a boost in the development of the technical know-how.
There will be more interest among the younger generation to study science and science-based courses in our tertiary institutions, as many will aspire to be Nuclear Engineers / Scientists, Electrical / Mechanical Engineers, Metallurgy Engineers, etc.

IV. Methods Of Power Generation

Existing and conventional methods of power generation are reviewed in this section. The methods are being improved to make them environmentally friendly.
The existing technologies can be deployed and new technologies incorporated to make the generation more efficient.

4.1 METHOD OF PRODUCTION OF ELECTRICITY THROUGH THE GAS TURBINE

(a) The Turbine

A turbine is a rotary engine that converts the energy of a stream of water, steam, or gas into mechanical energy. The basic element in a turbine is a wheel or rotor with paddles, propellers, blades, or buckets arranged on its circumference in such a fashion that the moving fluid exerts a tangential force that turns the wheel and imparts energy to it. This mechanical energy is then transferred through a drive shaft to operate a machine, compressor, electric generator, or propeller. Turbines are classified as hydraulic, or water turbines, steam turbines, or gas turbines. Turbine-powered generators produce most of the world’s electrical energy.

(b) Raw materials for production

Natural gas is a gaseous fossil fuel usually found in association with petroleum. Natural gas contains 60 to 80% of methane, 5 to 9% of ethane, 3 to 18% of propane and 2 to 18% of heavier hydrocarbon. Pipeline natural gas is principally methane. Natural gas are supplied by producing companies like Shell Petroleum Development Company of Nigeria (SPDC) and Nigeria Gas Company (NGC) at a gas pressure of about 19 to 21bars. The other raw material is the atmospheric air that is filtered and compressed. Part of the air is used for cooling and atomization of diesel fuel (where need be) for combustion during operation.
Most part of the compressed air is used for combustion in the combustion chambers, with the natural gas.
Hydrogen is used in cooling the heavy generators e.g. Delta 1V plant in Ughelli power plant. This is because of the enormous heat that the generator windings emit. Hydrogen cools ten times better than air, hence its preference for air despite its high inflammability.

Lube oil or lubricant oil is used in the gas turbine station for lubrication of the bearings, for hydraulic pressure and heat extraction.

The gas turbine consists of the following components:

1. The starting device, a 3.3kV starting motor or prime mover in a black start system.
2. The air-filter arrangement
3. The compressor

4. The combustion chambers
5. The turbines
6. The expansion bellows or exhaust
7. The generator
8. The exciter

The gas turbine use natural gas and compressed air as fuel to burn and rotate the shaft that turns the generator thereby generating electricity. Excitation is necessary to produce the required magnetic flux.

When a straight conductor of length l is moving across a magnetic flux density B with velocity v, the emf (electromotive force) induced in the conductor is given by

Induced emf = e =Blv ------------------------------- 1

When B, v, and the conductor are all perpendicular to one another.

According to Faraday's law of electromagnetic induction, the emf induced in the coil when the magnetic flux through it changes by $\Delta\phi$ in the time Δt is given by

Induced emf = e = - N $\Delta\phi/\Delta t$ ---------------------------- 2

Where N is the number of turns, and

Φ (magnetic flux) = B A (magnetic field density)(cross-sectional area)

Most of the electrical energy generated is transported through transformers and network of conductors to various locations around the country in the form of grid.

4.2 HYDROELECTRICITY

This is a process of generation of electricity through a running water. Water in a reservoir, flowing from higher level to lower level has kinetic energy which can be converted to mechanical energy and then electrical energy. Usually dams or barriers are built across a reservoir of water. Hydroelectricity contributes about 8% of world's electrical energy needs and about 38% of the total power generated in Nigeria. Hydroelectricity has limitations as reduction in the level of water in the reservoir leads to reduction in the output of power generated.

The principle of generation is the same with the gas plant except that the kinetic energy that turns the turbine come from the running water. The reservoir of water at a certain height h, possess potential energy according to the equation,

P.E. (potential energy) = mgh --------------------------- 3

Where m = mass of the water
g = acceleration due to gravity
h = height of the dam (reservoir)

As the water descends, it is converted to kinetic energy according to the equation,

K. E. (kinetic energy) = $\frac{1}{2} mv^2$ ------------------------------ 4

Where m = mass of the water
and v = velocity of the water.

This kinetic energy is converted into mechanical energy by allowing the water to flow through the hydraulic turbine runner. This mechanical energy is utilized to run an electric generator which is coupled to the turbine shaft. The electrical power, P developed in this way is given as

$P = w Q H \eta \times 9.81 \times 10^{-3}$ kW -------------------------- 5

where w is the specific weight of water in kg/m^3
Q is the rate of flow of water in m^3/s
H is the height of fall or head in meters and
η is the overall efficiency of operation.

The power developed is fed to the transformer for transmission and distribution.

4.3 PRODUCTION OF ELECTRICITY THROUGH COAL

Coal is a readily combustible black or brownish-black sedimentary rock normally occurring in rock strata in layers or veins called coal beds. Coal, a fossil fuel, is the largest source of energy for the generation of electricity worldwide. Coal is primarily used as a solid fuel to produce electricity and heat through combustion.

When coal is used for electricity generation, it is usually pulverized and then combusted (burned) in a furnace with a boiler. The furnace heat converts boiler water to steam, which is then used to spin turbines which turn generators and create electricity. The thermodynamic efficiency of this process has been improved over time. Simple cycle steam turbines have topped out with some of the most advanced reaching about 35% thermodynamic efficiency for the entire process.

ENERGY VALUE OF COAL

The energy density of coal, i.e. its heating value, is roughly 24 megajoules per kilogram.

The energy density of coal can also be expressed in kilowatt-hours for some unit of mass, the units that electricity is most commonly sold in, to estimate how much coal is required to power electrical appliances. One kilowatt-hour is 3.6 MJ, so the energy density of coal is 6.67 kW·h/kg. The typical thermodynamic efficiency of coal power plants is about 30%, so of the 6.67 kW·h of energy per kilogram of coal, 30% of that—2.0 kW·h/kg—can successfully be turned into electricity; the rest is waste heat. So coal power plants give approximately 2.0 kW·h per kilogram of burned coal as electricity.

As an example, running one 100-watt light bulb for one year requires 876 kW·h (100 W × 24 h/day × 365 day/year = 876000 W·h = 876 kW·h). Converting this power usage into physical coal consumption:

It takes 438 kg of coal to power a 100 W light bulb for one year. One should also take into account transmission and distribution losses caused by resistance and heating in the power lines, which is in the order of 5–10%, depending on distance from the power station and other factors.

4.4 NUCLEAR POWER PLANT

The basic principle of the nuclear power plant is the splitting of the heavy nucleus that releases enormous amount of heat energy which can be converted to electrical energy through some processes. Nuclear fuel has very high energy density. 1g of fissile fuel can give 1MW day of electrical energy. 100kg per day nuclear fuel produces electrical energy same as 2500 tonnes of coal. (Rao and Parulekar 2007). The raw materials are uranium-235, water, rods, etc.

The fission reaction proceed as follows,

$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{140}_{55}Cs + {}^{93}_{37}Rb + {}^{1}_{0}n + {}^{1}_{0}n + E\ (200MeV)$ --- 6

For the pressurized water reactor, in the core of the reactor, a self sustaining chain reaction takes place, controlled rods are raised or lowered to absorb neutrons and control the reaction and the amount of heat produced.

Double loop system is the commonest. In the primary loop, water is pumped and heated by the reactor coil in the heat exchanger. In the secondary loop, water, converted to steam in the heat exchanger is fed under pressure to turn turbine generators. The steam is cooled by water drawn from a river or ocean, it condenses to water which completes the loop.

Generators produces electricity which is delivered to the power grid by transmission lines.

V. Conclusion

Electrical power generated in power plants are not being stored, but are utilized as long as the generating plant is running, requires adequate and efficient plants to serve the teeming population of Nigeria.

As electrical power is a critical infrastructures and in fact, the fulcrum on which the wheel of socio-economic activities – manufacturing, services, small and medium enterprises, communication, entertainment, etc. revolve, need urgent attention. Non-renewable resources in our country can be exploited to the maximum and converted to electricity.

Each geopolitical zone can draw up a master plan for power generation with Federal Ministry of mineral resources in collaboration with the Nigerian Electricity Regulatory Commission (NERC) acting as the supervisory body. By so doing, the nation will attain at least 10000MW of power in a short time.

With adequate power supply, Nigeria's economy will shift from natural resource based to human resource based, then the vision 20: 2020 of Nigeria joining the most industrialized nations will be realized.

Acknowledgement

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