International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 10, October- 2014

Prospects of Gas Turbine Power Plants Towards Electricity Stability in Nigeria

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***Abstract*--- The endemic power crisis in Nigeria which came as a result of the inability of the existing power plants to meet the ever increasing demands poses as a challenge to the development of the country. Residential homes, office buildings and industries generate their own electricity through alternative sources to make up for irregular power supply. To address the problem of power shortage in Nigeria, Gas turbine power plants serve as the best option to overcome the electricity crisis because of the presence of large natural gas reserve in the country.**

Keywords*---*Electricity, Gas turbine, Natural gas, Power crisis, Power plants

I. INTRODUCTION

The gas turbine prime mover was first used in United Kingdom in 1940 for the generation of electricity for a large central station [1]. Since then, several stations have been built with gas turbine to drive electric generators. Natural gas is a natural occurring gaseous mixture of hydrocarbon with 0-20% higher hydrocarbons having methane as its primary constituent. Other hydrocarbon fuel such as methane cathrates found in coal beds is also an important fuel source used as feedstock. Natural gas must undergo several processing to remove almost all materials which include: buthane, ethane, pentane, sulphur, carbon dioxide, water vapour, nitrogen and helium leaving only methane which is used as fuel. After processing, natural gas is transported through pipelines to the power plants. The gas mixes with compressed air in the compressor and burns in the combustion chamber, the product of the combustion is the energy which propels the gas turbine shaft on which the electric generator is coupled. The energy produced by the combustion of natural gas (fuel) in the combustion chamber is directly proportional to the generated electrical power. This implies that natural gas plays an important role in the generation of electricity. Nigeria has an estimate of 187 trillion standard cubic feet of gas (tscf) of proven natural gas reserves, giving the country one of the top ten natural gas endowments in the world and the largest in Africa [2]. It is ironic and unfortunate to note that even with the large natural gas reserves, the country still suffers from availability of power (electricity) which is crucial for growth, industrialization, economic development and national security. The country's current power generation stands at 3,800MW and the per capita basis was among the lowest in the world when compared with the average per capita electricity usage in United States, 13,265kwh; China, 3,298kwh; Libya, 3,926kwh; South Africa, 4,604kwh; Singapore, 8,404kwh and India, 684kwh.Nigeria is ranked a distant 178th with 149kwh per capita, well behind Gabon (907kwh), Ghana (344kwh), Cameroon (256kwh), and Kenya (155kwh) [3]. To ensure stable supply of electricity in Nigeria, gas turbine power plants project should be constructed and operated across the country to boost power generation.

II. DYNAMICS BEHIND GAS TURBINE POWER GENERATION

A gas turbine power plant consists of a compressor in which the working medium is raised to a high pressure. From the compressor, the working medium which is a mixture of natural gas and air is taken to a combustor where the temperature is raised at approximately constant pressure [4]. This high pressure and high temperature working medium is then expanded in a turbine to which the generator is coupled.

III. RESOURCES FOR GAS TURBINE POWER PLANTS IN NIGERIA

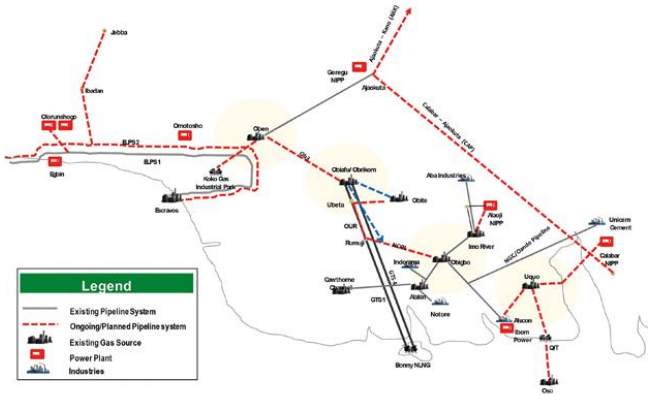

Fig I: Natural gas reserves and pipelines in Nigeria

Nigeria's huge gas reserves are located in the Niger-Delta region of the country from where it is explored, processed and transported via pipelines to industries and gas turbine power plants as shown in Fig I. For the past fifty years, oil has been the big story in Nigeria. However, Nigeria's gas reserves are far greater than its oil reserves. Gas has the potential to power Nigeria and her neighbors

for the next fifty years [5], and it offers a relatively cheaper, more secure and cleaner way of generating energy. Nigeria's gas reserves were estimated at 187 trillion standard cubic feet of gas (tscf), comprising of 98tscf of associated gas (AG) and 89tscf of non-associated gas. The daily production estimate of year 2012 was about 8.26 billion standard cubic feet of gas. The liquefied natural gas project is the largest natural gas initiative in Nigeria and is operated by the Nigerian National Petroleum Corporation (NNPC) and by several oil firms. The domestic gas supplied by Nigerian Petroleum Development Company (NPDC) a dominant gas supplier to industries and power plants almost doubled from 185 million scfd to 357 million scfd in 2012. The plan for construction of a 120km East-West gas pipeline crossing the Niger River is ongoing [6]. With this pipeline, the huge gas reserves in the eastern Niger- Delta are linked to other parts of Nigeria. Another gas pipeline infrastructure is the Calabar-Ajaokuta- Abuja- Kaduna- Kano gas pipeline, which will open up gas access to the northern part of the country thereby making the construction of gas turbine power plants possible in every geopolitical region of the country.

IV. GAS POWER PLANTS IN NIGERIA

Nigeria's gas power plants are categorized as follow:

- Privatized Power Holding Company of Nigeria (PHCN) gas (thermal) power plants
- Privatized National Integrated Power Projects (NIPP) gas power plants
- Independent Power Producers (IPP) gas power plants
- International Oil Companies (IOC) gas power plants

TABLE I
OPERATIONAL GRID CONNECTED GAS TURBINE POWER PLANTS IN NIGERIA

CATEGORY	NAME OF POWER PLANTS	CAPACITY(MW)
PRIVATIZED PHCN GAS (THERMAL) POWER PLANTS	EGBIN	
	AFAM IV & V	
	SAPELE STEAM + GAS	
	DELTA (UGHELLI)	
	GEREGU	
	OMOTOSHO	
	OLORUNSHOGO	
	KADUNA	
	TOTAL PHCN THERMAL	22O7
	CAPACITY DELIVERABLE	1545
PRIVATIZED NIPP GAS POWER PLANTS	ALAOJI	
	OLORUNSHOGO	
	SAPELE	
	IHOVBOR	
	CALABAR	
	GBARAIN	
	GEREGU PHASE II	
	OMOTOSHO PHASE II	
	EGBEMA	
	OMOKU	
	TOTAL NIPP	2234
	CAPACITY DELIVERABLE	1564
IPP-A	IBOM POWER	
	OMOKU	
	TRANS-AMADI	
	AES	
	TOTAL IPP-A	352.5
	CAPACITY DELIVERABLE	247
IPP-B	GEOMETRIC POWER ABA	
	PARAS ENERGY	
	NOTORE POWER	
	RIVERS STATE GOVT. AFAM I & II	
	DANGOTE POWER (OBAJANA)	
	TOTAL IPP-B	160
	CAPACITY DELIVERABLE	112
IOC	AGIP PHASE I	
	SHELL	
	TOTAL IOC	1130
	CAPACITY DELIVERABLE (IOC)	791
TOTAL GAS PLANTS INSTALLED CAPACITY CONNECTED TO GRID (JULY 2014)		6083.5
TOTAL CAPACITY DELIVERABLE BY GAS POWER PLANTS TO GRID (JULY 2014)		4259

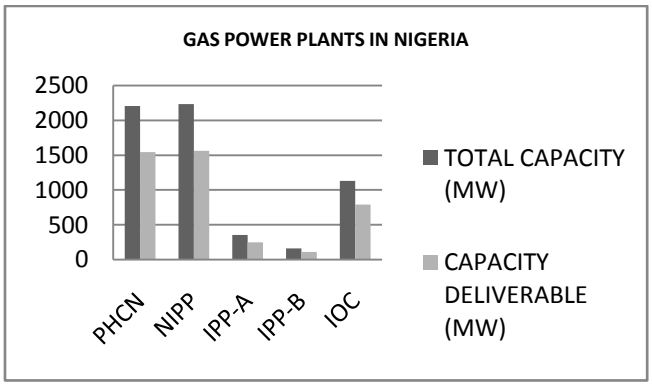

Fig II: Gas Power Plants in Nigeria plotted from table I

In utilizing the gas power potentials of Nigeria, more gas power plants are to be built. Some parameters are to be considered for the effective utilization of the gas power potential locations and they are as follows:

- Type of gas power plants
- Site selection of gas turbine power plants
- Components of gas turbine power plants
- Prospects of gas turbine power plants
- Merits and demerits of gas power plants

A. Type of gas turbine power plants

A gas turbine can work either on an open cycle, a closed cycle or a combined cycle.

1. In an open cycle gas turbine as shown in Fig III, atmospheric air enters the air compressor which compresses it to a pressure of three to four atmospheres, at the same time increasing its temperature. Part of the pressurized air enters the combustion chamber to mix and burn with the fuel while the remaining pressurized air is used to regulate the temperature of the heated gas so that the temperature stresses in the turbine blades do not become excessive [4]. The products of combustion are expanded in the turbine, developing power and then exhausted into the atmosphere.

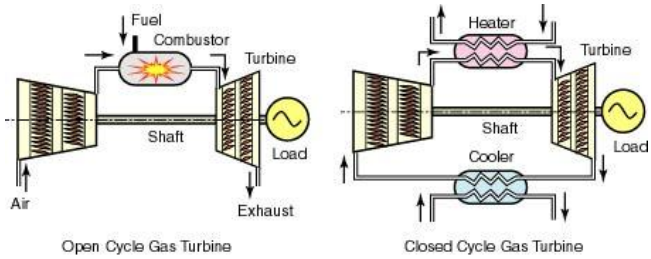

Fig III: Open and closed cycle gas turbine power plants

2. Closed cycle gas turbine power plants: The draw backs of an open cycle turbine power plants in which the fuel is mixed with air in the combustor thereby producing hot gases that causes erosion and corrosion of turbine blades as they expand in the turbine. In a closed cycle turbine power plants as shown in Fig III, the fuel does not mix with the working medium air or gas. The combustion of fuel takes place in the air heater and is external to the working medium of the system (air or gas) which it heats through heat exchanger and cooled down by cooling water in the precooler and is recirculated to the compressor.

3. Combined cycle gas turbine power plants utilize the heated exhaust gases to produce low pressure steam in a waste heat boiler for a steam power plant. The steam can be used also for other industrial operations [1].

B. Site selection of gas turbine power plants.

Knowledge and implementation of the following criteria must be given due consideration while selecting a gas turbine power plant site:

- Cheap and adequate quantity of fuel should be available
- Near to the load center to avoid transmission cost and losses
- The site should be far away from business centers due to their noisy operations
- Land should be available at cheap price since cost of land will add up to the capital cost of the plant

C. Components of gas turbine power plants

This section focuses on the components required for gas turbine power generation;

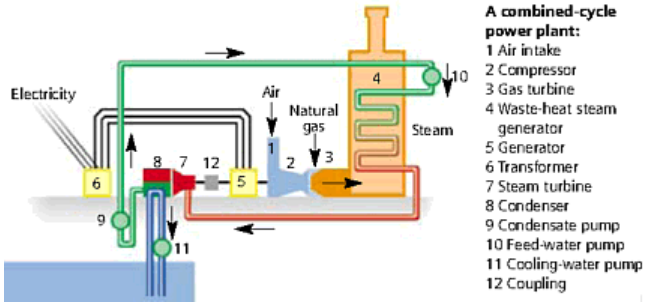

Fig IV: Components of a gas turbine power plant.

i. Compressor: Air which acts as a working fluid is compressed in the compressor which is either axial or centrifugal compressor that handles large volume of air and delivers it at 4 to 6 atmospheric pressure.

ii. Combustion chamber: The air fuel ratio in open cycle gas turbine varies from 50:1 to 250:1. The combustion chamber should provide thorough mixing of fuel and air as well as combustion products and air so that complete combustion and uniform temperature distribution in the combustion gases may be achieved.

iii. Gas turbine: The arrangement of the rotor and stator blades in the gas turbine is similar to that of steam turbine. If the entire pressure drop of the turbine occurs across the fixed blades, the design is impulse type, while if this drop take place in the moving blades, the fixed blades serving only as deflectors, the design is called reaction type [7]. The blades are generally made of Nimic 80 alloy (heat resisting).

iv. Heat exchanger: Regenerator and the intercooler are the heat exchangers used in gas turbine power plants.

v. Generator: The generator converts the mechanical energy produced by the gas turbine into electrical energy.

V. PROSPECTS OF GAS TURBINE POWER PLANTS IN NIGERIA

The application of gas turbine power plants can be foreseen in the following fields in Nigeria:

- Base load gas power plants
- Peak load gas power plants
- Captive power plants
- Retrofitting of old and uneconomical power plants
- Co-generation gas turbine power plants

a) Base load gas power plants: Due to the under utilization of existing installed capacity and faster pace of demand

growth, power shortage can be mitigated by installing more gas turbine power plants due to their less gestation periods and low installation cost.

b) Peak load gas power plants: All large load centers such as industrial estates need this type of power plants to stabilize the grid when frequency is falling either due to overdrawing of power or less feeding to the grid due to failure of few operating power plants.

c) Captive power plants: Gas power plants are best suitable to generate electricity with units' capacities below 100MW due to their higher efficiency, low cost of installation/KW and high reliability. Industrial clusters in Ogun state have such power plants that supply a group of industries off-grid, similar projects can be replicated in other industrial estates across the country.

d) Retrofitting of old and uneconomical power plants: Some of the power plants which cannot generate electricity at economical cost due to their less design efficiency, also non-functional power plants such as Ijora thermal power station in Lagos state, Calabar power station in Cross river state and Oji river power station in Enugu state can be converted into combined cycle power plants.

e) Co-generation gas turbine power plants: These systems are ideally suited for process industries such as sugar, paper, petrochemical, fertilizer, cement and several industries which require both process heat and electricity [4]. Efficiencies of the order of 80-85% can be achieved in these power plants because exhaust gases are used directly for heating requirements and also for producing steam required for industrial processes.

A. Merits of gas turbine power plants

- The installation cost/MW capacity of gas turbine power plants is low compared to other conventional fossil fuel power plant of the same unit size.
- Combined cycle plants efficiency is of the order of 42-47% which are nearly 10-20% more efficient than fossil fuel conventional power plants.
- Gas turbine power plants are highly reliable.
- Gas turbine power plants have fast starting characteristics.
- Flexibility in locating gas power plants.

B. De-Merits of gas turbine power plants

- Gas turbine power plants have operating life of around 15-20 years but depend mainly on the type of fuel used and the actual combustion temperature [8].
- Gas turbine power plants efficiency is considerably low when they are operated at partial loads.

VI. CONCLUSION

To effectively utilize gas power potentials in Nigeria, local and foreign investors must be encouraged to take an advantage of the huge opportunities and enabling environment in the nation's power sector to invest in the construction of gas turbine power plants across the country ,especially in locations close to the gas pipeline routes, in addition, floating barge gas power plants can be docked along the vast ocean bank of the country as it offers the advantage of being close to most gas processing plants. The government would also have to intensify the implementation of policies which serve as an incentive for investors such as regulation of gas pricing, import waiver on power plant equipments, power facilities security etc. These prospects when realized will stabilize the generation and supply of electricity in Nigeria.

REFERENCES

1. Rai G.D,"An Introduction to Power Plant Technology",Khanna Publishers, Delhi,2003, p 588.
2. Sambo A.S,"Matching Electricity Supply with Demand in Nigeria", International Association of Energy Economics,4th Quarter,2008, Pp 32-36.
3. The Worldbank data on Electric Power Consumption retrieved from http://data.worldbank.org/indicator/EG.USE.ELEC.KH.PC
4. Sharma P.C,"Power Plant Engineering",S.K. Kataria,Delhi,2007, p 407.
5. Nigeria Infrastructure Advisory Facility retrieved from http://niaf.org/powering-nigerias-future-from-gas/
6. Nigeria Gas Company Projects retrieved from http://ngc-nnpcgroup.com/projects/future-projects.
7. Deshpande M.V,"Elements of Electrical Power Station Design",Wheeler,Allahabad,1979.
8. El-Wakil,"Power Plant Technology",McGraw Hill, New York, 1984.