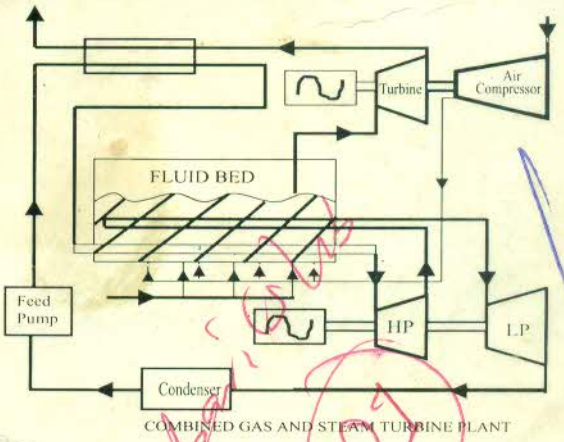
Federal University of Technology, Minna

SUSTAINABLE ENERGY TECHNOLOGY FOR THE 21ST CENTURY

INAUGURAL LECTURE Series No.2



COMBINED GAS AND STEAM TURBINE PLANT

By

PROFESSOR FOLORUNSHO OLAYIWOLA AKINBODE
Professor of Mechanical Engineering and Dean
School of Engineering & Engineering Technology.

Thursday, 26th February, 2004

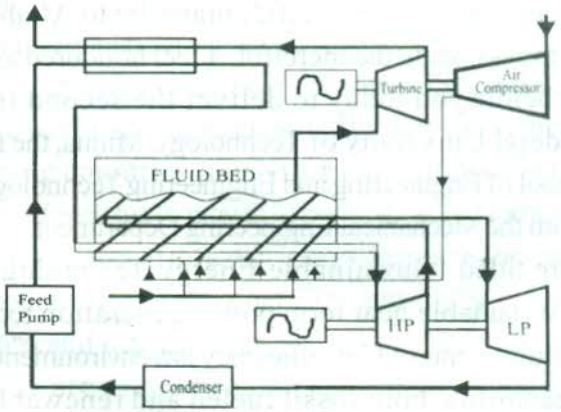
PROFESSOR FOLORUNSHO OLAYIWOLA AKINBODE

Professor of Mechanical Engineering and Dean
School of Engineering & Engineering Technology.

Federal University of Technology, Minna

SUSTAINABLE ENERGY TECHNOLOGY FOR THE 21ST CENTURY

INAUGURAL LECTURE Series No.2



COMBINED GAS AND STEAM TURBINE PLANT

By

PROFESSOR FOLORUNSHO OLAYIWOLA AKINBODE
Professor of Mechanical Engineering and Dean
School of Engineering & Engineering Technology.

Thursday, 26th February, 2004

SUSTAINABLE ENERGY TECHNOLOGY FOR THE 21ST CENTURY

The Vice – Chancellor
Deputy Vice-Chancellor
Principal Officers of the University
Deans of Schools and Directors of Units
Members of the Academic
Friends of the University
Gentlemen of the Press
Distinguished Ladies and Gentlemen

PREAMBLE

Hausbillahi Minasetani Rajim. Bisimillahi Rahamani Raheem. In the name of Allah, the compassionate, the merciful, praise be to Allah, Lord of the world, the compassionate the merciful. I feel honoured and highly delighted to stand before you today to deliver the second Inaugural Lecture of the Federal University of Technology, Minna, the first in the series from the School of Engineering and Engineering Technology and the first in the series from the Mechanical Engineering Department.

This lecture titled "Sustainable Energy Technology for 21st Century discusses sustainable near term power generation technology which meet the requirements of high efficiency low environmental impact and economical feasibility, both fossil fueled and renewable energy technology have been evaluated. Among the fossil fueled energy technologies, advanced combined cycle power generation with fuel to energy conversion efficiencies up to 60% and cogeneration plants with fuel energy utilisation factor up to 85 – 90% are the near – term technologies. Pressurized fluidized bed combustion, integrated gasification combined cycle power plants and advanced gas turbines and fuel cell based combined cycle power plants are categorized as environmentally sound and highly efficient

power generation technologies. Renewable energy sources and then integration into total energy supply system are also discussed.

1.0 INTRODUCTION

The prosperity of a country is dependent upon the efficient and rational use of energy, which is necessary for industry, transportation and also plays an important role in one's domestic life.

The world population is now 5.85 billion people with 72.3% living in Asia and Africa and it is expected to stabilize at the level of 8 billion people by 2100. The current world primary energy consumption (in 10^9 kWh) is 93.65, including Europe 33.6, North America 26.5 (U.S.A. 23.95), Asia 23.1 Latin America 4.65 middle East 3.1 and Africa 2.65 (Status 1993) B.P. statistical review of world energy, (1994) and Khartehentho (1998).

World's proven fuel reserves in 10^{21} J roughly are: coal 30, oil 6, natural gas 5, with the present rate of consumption, these reserves will be exhausted in 225, 45, and 65 years respectively. The world average energy consumption per capital was approximately 1.6 tonnes of oil equivalent (toe) per year with extremes of 7.5 toe in USA and 0.25 toe in Africa. By 2025, the world average is expected to stabilize at the above level but in developing countries like Nigeria it will double or triple compared to the present level due to growth of population and industrialization.

The shares of different energy forms in the current world energy consumption are oil 33%, coal 23%, gas 19% biomass 14%, hydro-energy 6% and nuclear energy 5.6%. These currently used energy resources are predominantly non-renewable and bound to exhaust. The patterns of the energy production and use are unsustainable and lead to severe deterioration of the environment. The sustainable energy sector is based on the efficient use of existing energy stocks and energy conservation to be able to satisfy the optimized energy needs of current and future generation without significant environmental impact.

To develop the sustainable energy sector the energy policy has to be considered in the light of energy policy and demand in the world and other constraints such as environmental pollution control requirements, the supply of trained scientist and engineers etc. It should also be directed toward:

a. Reduction in energy consumption especially in industrialized countries,
b. Energy conservation in all sectors of economy.
c. Full integration of renewable energy sources into global energy supplies system.

The electricity is currently generated power predominantly in large hydroelectricity power plants and oil and gas-fired steam power plants. Sustainable power generation systems show high energy conversion efficiency, low environmental impact and viable economics. High efficiency energy systems produce more electricity per unit of fuel burnt and thus produce less emissions of green house gases and pollutants such as SQ , NO_X, unburned hydrocarbons and CO. Advanced energy systems such as combined cycle power plants and clean energy technologies, offer enhanced efficiencies, improved economics and reduced environmental impact. Efficient emissions abatement techniques can remove up to 97% SO_2 and 90% NO_X (Khartchenko (1998)).

Mature fuel cell technology will provide combined cycle power generation and cogeneration plants featuring efficiency up to 65-70% (power generation) near zero emissions, quiet operation and load-following capabilities. Base-load and distributed power generation and cogeneration plants, industrial, commercial and residential natural gas, fuel cell power plants and cogeneration plants sized from 500kWe to 20MWe are expected to be economically feasible by 2010 (Khartehenko 1998).

Integration of renewable energy sources into energy supply systems will minimize problems associated with finite fossil fuel resources

and environmental deterioration due to emissions from fossil-fuel based energy system. Ultimately renewable energy systems will replace fossil-fuel based energy sector ((Boyle (1996) and Eurec Agency London (1996)). The purpose of this lecture is to provide information on the resources availability of the energy option and the technologies that will sustain them. It is also the purpose of the lecture to provide details of current research and development efforts in environmentally sound and highly efficient power generation technologies.

2.0 ENERGY RESOURCES

Table 1 gives a general view of the energy resources in Nigeria. The consumption rate and the lifetime at present rate of consumption are also given in this table.

Table 1: Nigeria Energy Resources (1987)

Coal – Bituminous }   Sub- bituminous } 190 Mt   Consumption: 50,000 +   Lifetime at present rate of consumption = 380 years.
Oil   Proved recoverable reserves 2200 Mto   Consumption 62 Mto   Lifetime at present rate of consumption = 33 years.
GAS   Proved reserves $2.4 \times 10^{12} m^3$ (2210 mtoe)   Production: 3.7 mtoe   Lifetime: 600 years
RENEWABLE SOURCES   Hydropower   Biomass   Solar Energy   Wind Energy

Source: Williams (1990)

2.1 Fossil Fuels: Coal and Lignite

Coal started playing some part in the national economy soon after its discovery in Enugu State in 1909. As of now, seams of sub-bituminous coal deposits of economic significance are identified in five main location: Enugu and Ezimo (in Enugu State), Orukpa (Benue State) and also Okaba and Ogboyoga (Kogi State). Also in Agwatashi and Azara (Obi and Awe local government areas respectively of Nassarawa State), bituminous coal deposit of economic significance and inferred reserves are of the order 190mt and with the consumption rate put at 50,000 t, the coal will last about 400 years.

Lignite on the other hand has not effectively entered the energy market. Reserves are said to be about 206×10^9 kg distributed mainly in two zones:-

Ogwashi – Asaba (in Delta State): 64×10^9 kg.

Oba – Nnewi (in Anambra State): 142×10^9 kg.

It is thus reasonable to expect a national energy reserve in the neigbourhood of 0.0045Q from lignite (where $Q = 10^{18}$ kJ).

2.2 Fossil Fuels: Liquid Petroleum and Natural gas

"Reserves" of crude petroleum and natural gas are never easy to determine. Intensive and more expensive exploration had often tended to reveal new sources. The known reserves as at 1987 is shown in Table 1. Gas unassociated with petroleum liquid is not listed since usually all such gas wells are sealed. They are found mostly in the south-east and south-south states (Delta, Rivers, Cross Rivers, Akwa Ibom, Bayelsa, Abia and Imo).

2.3 Hydro Power

Hydropower systems rely on the potential energy difference between water reserves, dams or lakes and their discharge tail water levels down stream. The energy supply therefore is mechanical and conversion efficiencies

relatively high.

Nigeria is well endowed with hydro electric resources, three at the moment which are concentrated in the North central states. Feasibility studies are also reported that first priority would be given to the following sites; Lokoja, Makurdi, Ikom, Zungeru and Mambila (Esan (1981) and Ezeilo (1978).

2.4 Shale Oil And Bitumen Sands:

Currently, unquantified bituminous tar sand deposits of economic significance are identified in Ondo State (Agbabu and Gbelejuloda). The deposits have an estimated extrapolated reserve of about 42.7 million barrels of bitumen and heavy oil (Olabisi 2003). Experts say the bitumen runs through Ondo, parts of Ogun, Edo and Lagos States.

2.5 Biomass: Fuel wood – about 80% of Nigeria population live in rural areas and depend mostly on wood for heating and cooking. Since Nigeria is going through rapid urbanization, the consumption of wood for domestic purposes (mainly cooking) has to be minimized and replaced with LPG and electricity.

2.6 Solar And Wind Energy: A very small number of solar units are in Nigeria presently. They are for water heating and drying of grains. Wind energy is being used to pump water from wells.

3.0 ENERGY CONSUMPTION

The world energy scene is dominated by two factors, the increasing requirement for energy and the increasing population growth. It is clear that the growth rates are high but the increase in energy has been slightly greater than the population growth resulting in an increase in energy/capita between 1976 and 1987. This has generally resulted in a high quality life as indicated in a variety of statistical indicators e.g. life expectancy at birth has increased, as the number of cars on the road. The trend