Nuclear Power and Ghana's Future Electricity Generation

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Abstract. One of the major challenges facing Ghana in her developmental efforts is the generation of adequate and affordable electricity to meet increasing demand. Problems with the dependency on hydro power has brought insecurity in electricity supply due to periodic droughts. Thermal power systems have been introduced into the electricity generation mix to complement the hydro power supply but there are problems associated with their use. The high price of crude oil on the international market has made them expensive to run and the supply of less expensive gas from Steps are being taken to run the thermal plants on less expensive gas from Nigeria has delayed due to conflicts in the Niger Delta region and other factors. The existing situation has therefore called for the diversification of the electricty generetion mix so as to ensure energy security and affordable power supply.

This paper presents the nuclear option as a suitable alternative energy source which can be used to address the energy supply problems facing the nation as well the steps being taken towards its introduction in the national energy mix. In addition, electricity demand projections using the MAED model as well as other studies are presented. The expected electricity demand of 350000 GWh (4000MWyr) in 2030, exceeds the total electricity supply capability of the existing hydropower system, untapped hydro resources and the maximum amount of gas that can be imported from Nigeria through the West Africa pipeline. Also presented is a technological assessment on the type of nuclear reactor to be used. The technological assessment which was done based on economics, grid size, technological maturity, passive safety and standardization of reactor design, indicate that a medium sized pressurized water reactor (i.e. a PWR with capacity 300MW to 700MW) is the most favourable type of reactor. In addition the challenges facing the implementation of the nuclear power programme in Ghana are presented.

1. INTRODUCTION

The supply of adequate and affordable electricity is essential for the socio-economic development of every modern society. Therefore as the world's population grows and individuals everywhere strive to improve their standard of living, demand for electricity is sure to rise in most parts of the world. Studies have shown that the high growth in demand for electricity is expected to take place mainly in the developing countries [1] [2]. This is because developing countries are now putting in place the necessary infrastructure for development.

Ghana's situation is not different from the global trend and has therefore experienced significant increase in electricity demand over the years. Despite the high increase in electricity demand, the security of power supply is under big threat. The electricity generation system is hydro power dominated with hydro power accounting for 65% of total installed capacity. This creates shortfall in power supply whenever there is drought. In order to deal with this problem, thermal power generators which account for the remaining share of installed capacity were introduced to compliment the hydro power supply. The thermal generators run on imported crude oil but there are plans to fuel the thermal plants with gas imported from Nigeria. The high price of crude oil on the international market has made the thermal plants very expensive to run. In addition, the security of supply of gas from Nigeria is threatened due conflicts in Niger Delta region, the source of gas as well as the interest expressed in the gas by some European countries. The existing situation therefore calls for the diversification of

the energy supply base through the utilisation alternative sources of energy. Among the alternatives options which have received serious attention is nuclear energy.

This paper presents the current situation in the electricity generation in Ghana and the steps being taken towards the implementation of a nuclear power programme in Ghana. In addition, electricity demand projections using the MAED model as well as other studies are presented. Also presented is a technological assessment on the type of nuclear reactor to be used and the challenges facing the implementation of a nuclear power programme in Ghana.

2. GHANA'S ELECTRICITY GENERATION SYSTEM

2.1. Electricity Generation and Transmission Network

The total installed capacity of Ghana's electricity generation system is currently 1810 MW. This made up of a hydropower system with installed capacity of 1 180 MW and thermal power generators which have total installed capacity of 630 MW. Hydro power therefore takes 65% of total installed capacity with thermal systems taking the rest. Hydro power was introduced in 1965 by constructing a dam on the river Volta. The hydroelectric plant was built as part of the government's industrialisation programme. The construction of the dam flooded a land area of about 8500km^2 making it the largest artificial lake in the world in terms of land area. The vulnerability of the hydro system to vagaries of the weather was experienced for the first time in 1983 when drought in the Volta basin led to the power shortage. Two additional major energy crises occurred due to drought and increasing energy demand. One occurred in 1998 and the other in 2007/2008. Before the second energy crisis, it had become clear that the hydroelectric power system cannot cope with the increasing demand for electricity. This is due to the extension of electricity to most parts of the country in connection with government's policy to electrify the entire country by 2020. To deal with the high growth of electricity demand as well as the unreliability of hydro power the utilisation of thermal plants was considered and the first thermal plant was constructed in 1997 with a capacity of 220 MW.

The introduction of thermal power systems has increased the country's energy import bill due to the high cost of crude oil on the world market. The original plan is to run the thermal plants on natural gas imported from Nigeria through the West African gas pipeline project. Though the natural gas option makes it cheaper to run the thermal plants, the supply of gas has delayed thus forcing the nation to run the thermal plants on crude oil. The delay in gas supply is mainly due to the conflicts in the Niger Delta region in Nigeria, the source of gas supply. In addition, there is also a proposal to construct a 2500 mile trans-Saharan gas pipeline across the Saharan desert to transport natural gas from Nigeria's Delta region to Algeria's Beni Saf export terminal on the Mediterranean to Europe [3]. These issues, coupled with the fact that Nigeria has to meet its own growing demand have raised doubts on whether the gas from Nigeria, which has a maximum capacity of 474 million standard cubic feet/day can be obtained.

The country's electricity transmission system currently consists of a 4000 km transmission line linking 36 161/33kV and 161/11kV substations in a circuitous loop covering the entire country (fig.1). About 600 kilometres of the transmission network is currently energized at 34.5 kV and another 133 circuit kilometres energized at 69 kV. The network is also connected to the neighbouring states. A 130 km, 225 kV single circuit line is connected to the network of La Cote d'Ivoire and 129 km, 161 kV double circuit line to the network of Togo/Benin. The network also connects the network of Burkina Faso through a 33 kV line. The transmission network is expected to be part of the West African Power Pool project. This project was launched in 2000 to foster economic and regional cooperation in the West African sub-region. It involves the interconnection between 15 West African states.

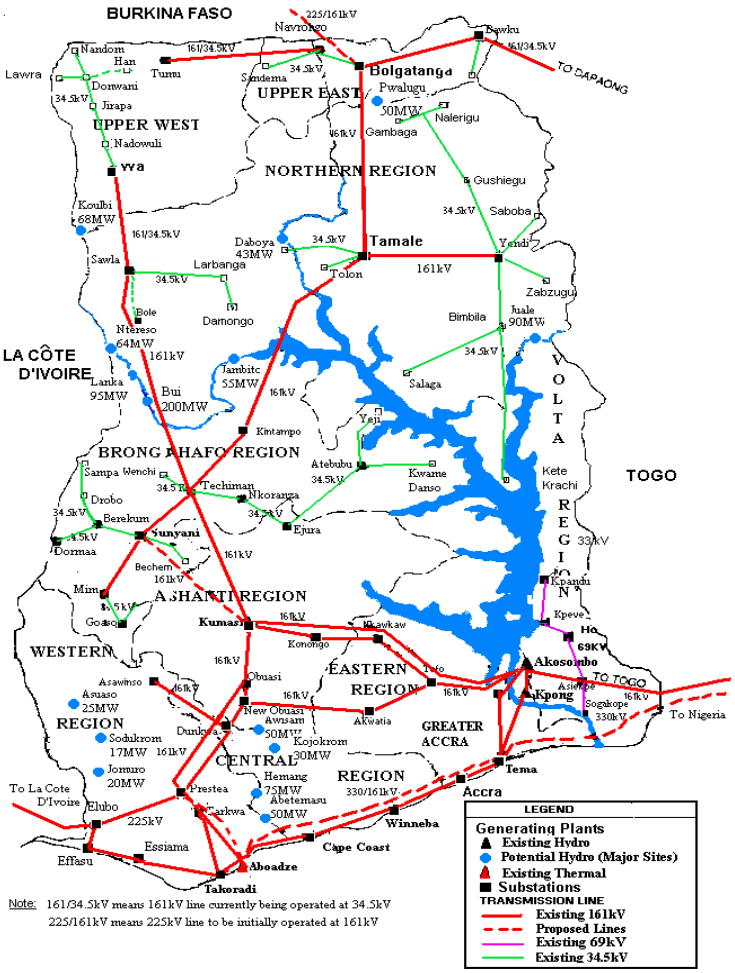

Fig.1. Map of Ghana showing electricity grid

2.2. Electricity Demand Projections

The problems associated with power generation as well as the need to undertake a comprehensive energy planning study for the nation led to an IAEA technical cooperation project GHA/0/008, "Planning for Sustainable Energy Development", commencing from 2006 to 2008. The use of the MAED model to perform energy projections has indicated that the nation will need about 350000GWh (4000MWy) of electricity by 2030 (fig. 2). The figure shows three scenarios. These are high, medium and low economic growth scenarios. The high economic growth scenario represents the most optimistic socio-economic plan of the government projected up to 2030 and it refers to a situation where the nation's GDP per capita increases to about $3000 by 2030. The medium scenario is considered as the reference scenario because the projected GDP growth rates fall within the government's expected long term GDP growth rate of 6 – 8%. Hence, it has been considered the most plausible socio-economic evolution up to 2030. In this scenario, the per capita income is expected to increase from the current $600 to $1400 by 2030. The low economic growth scenario represents the business-as-usual or a projection of the historical trend up to 2030. It is based on the premise that socio-economic parameters will improve gradually in line with the historical trend into the future. The GDP per capita is expected to increase to $830 in 2030.

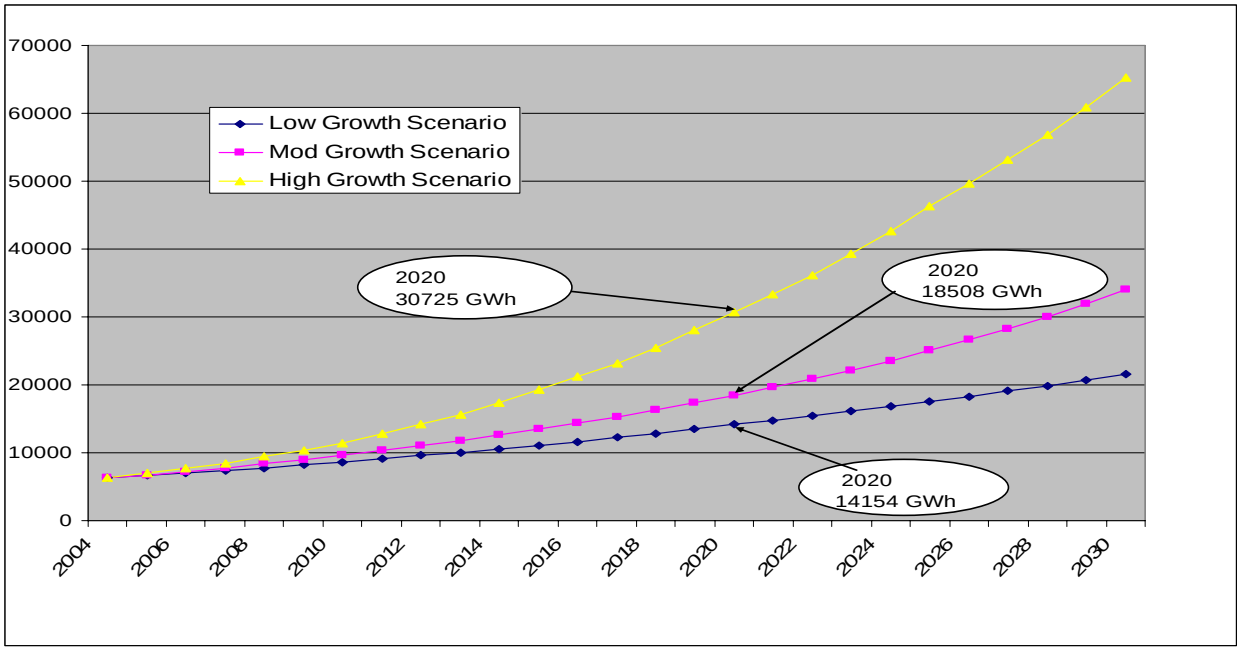

Fig. 2. Projected Electricity demand using the MAED model

The figure shows that in the reference scenario, electricity demand in 2020 is about 18500GWh (2111MWy) and increases to about 35000GWh (4000MWy) in 2030. The projected demand in 2030 exceeds the maximum amount of electricity which can be obtained from the West Africa gas pipeline, estimated to be 2500MW considering conventional combined cycle technologies. The results in fig 2 also indicate that even in the business as usual scenario i.e. low economic growth scenario, the electricity demand is about 22000GWh (2511MWy). Fig.3. compares the MAED study with other energy planning studies in the country. It is also worth noting that the government has a policy to export power to the neighbouring states.

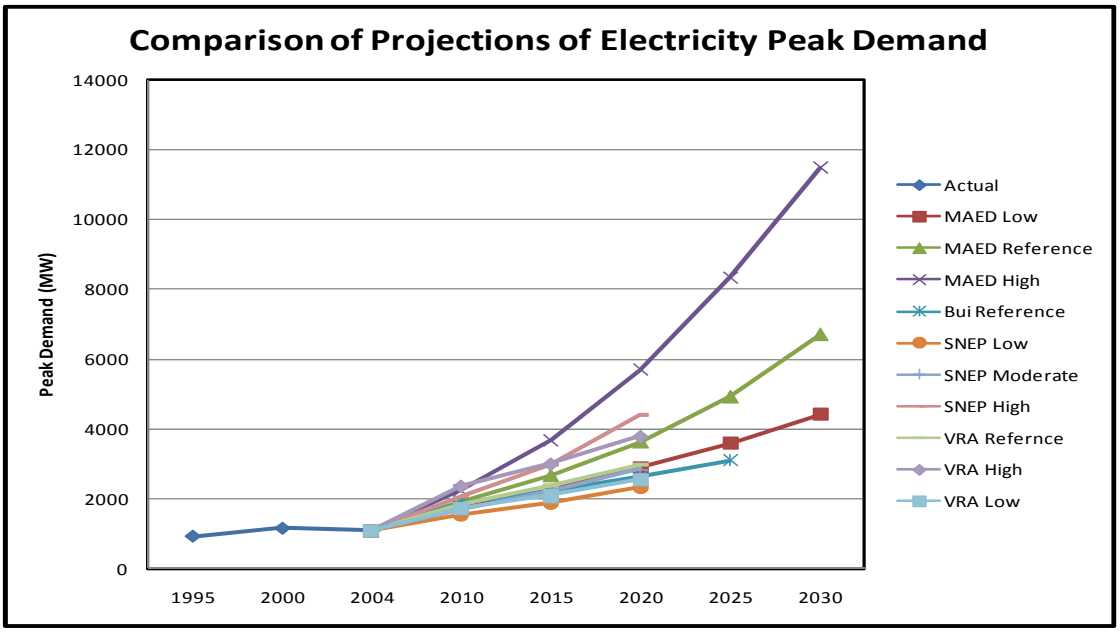

Fig. 3. Comparison of projected peak electric power demand

Ghana has no coal reserves. Oil was discovered in commercial quantities in 2007. The general consensus among energy planners is to use the oil for the transport sector and use the associated gas

for power generation. It has been estimated that the proven gas reserve, which is 880 billion cubic ft can run a 400MW plant for 30 years.

Meeting the high anticipated demand in electricity clearly requires the introduction of the nuclear option in the energy mix of the nation. The other alternative base load options are liquefied natural gas (LNG) and coal. In both cases the issue of energy security arises due to high volume of fuel that has to be imported. In contrast, nuclear power requires small quantity of fuel which can be store for a very long period. In addition, both options require additional infrastructural set up. In case of coal there is the need to construct a mini-harbour or extensive expansion and upgrading of existing port facilities in the country. In the case of LNG there is the need to construct re-gasification terminal along the coast to facilitate the importation of LNG.

3. NUCLEAR POWER

3.1. Research Reactor Project

The country's effort to utilize nuclear energy dates back to the early 1960s. In 1961 the government initiated the Kwabenya Nuclear Reactor Project as a means of introducing nuclear science and technology into the country and to exploit nuclear energy in its peaceful applications for the solution of problems of national development [4]. The Ghana Atomic Energy Committee was set up to implement the Kwabenya Nuclear Reactor Project. This committee was later on replaced by the Ghana Atomic Energy Commission (GAEC) by an Act of Parliament in 1963. The research reactor project involves the construction of a 2MW Soviet reactor for the production of isotopes as well as training the requisite manpower for reactor operations and research into nuclear science and technology. During the launching of the reactor project President Nkrumah, Ghana's first President stressed the on the peaceful nature of the project by stating that; "The Ghana Atomic Energy Programme is destined for peaceful purposes.....Neither this reactor, therefore, nor the laboratories attached to it, nor indeed any other nuclear facilities in Ghana, will be directed to development of devices for war" [5]. Unfortunately, the nuclear programme has not developed as expected due to various socio-economic and political factors.

The nation's quest to acquire a research reactor came into fruition in 1994 when a 30kW slowpoke reactor was constructed under a technical co-operation agreement between the Ghana Government and the IAEA. The purpose of this project which is operated by GAEC is to gain practical insight into reactor science and technology and to train the manpower for a nuclear power project in the future. In addition the reactor is used for elemental analysis through neutron activation analysis.

3.2. Nuclear Power Project Implementation

The government took a critical look at the nuclear option in 2007 during the occurrence of the third energy crisis. There was a shortfall of about 400MW in power supply from the hydro system. The import bill of crude oil soared due to high price on the international market and the supply of gas from Nigeria had delayed. The President in May 2007 therefore set up an eight member committee to advise government on the potential use of nuclear energy for electricity generation and develop a roadmap, which must culminate in a pre-feasibility study. After its assessment, the committee concluded that since nuclear energy is a mature technology, which has witnessed significant improvements in economic performance and operational safety in recent years, it is capable of providing safe, reliable and economically competitive electricity with very low carbon emissions. A roadmap was developed, which proposed the formation of Presidential Commission on Nuclear Power Development and a 400 MW nuclear power plant to start commercial operation in 2018. A Cabinet decision was taken in early 2008 to proceed with the roadmap [6].

As part of the preparations being made towards the implementation of the nuclear power project a technological assessment on the type of reactor to be used is being made based on the following criteria, economics, technological maturity, suitability to the Ghanaian and West African grid size,

passive safety and standardization of design. The results obtained indicate that a medium size pressurized water reactor (i.e. a PWR with capacity 300MW to 700MW) is the most favourable type of reactor. The addition, GAEC and the University of Ghana with the assistance of IAEA, have established the Graduate School of Nuclear and Allied Sciences to train the manpower for the nuclear project. The necessary steps are also being taken to strengthen the existing regulatory body, the Radiation Protection Board which currently regulates to installation and use of ionizing radiation sources and devices to regulate the utilization of nuclear power plants in Ghana. The IAEA has also approved a technical cooperation project GHA/0/011 which is meant to undertake a comprehensive nuclear power planning study for Ghana.

3.3. Challenges

Funding is one of the major challenges envisaged to face the Ghana nuclear programme. Being a developing country obtaining the necessary funds to run a nuclear power project, which is capital intensive is not easy. In addition, new legislative instruments have to be set up in connection with nuclear power operation. This is normally lengthy and time consuming. Also the country's level of industrialization is low. Due to the low industrial base of the country, most of the components of the power plant have to be imported.

4. CONCLUSION

Electricity supply security is a pre-requisite for industrialization, sustainable development and improvement in social well-being and therefore it must be a key policy agenda for the government. In order for Ghana to attain high levels of economic growth and social well-being in the future, electricity consumption and production will have to increase significantly.

The current and future primary energy supply potential for the country cannot guarantee this magnitude of future electricity demand and supply unless nuclear energy is considered and a comprehensive long term primary energy supply strategy developed, to ensure the availability and accessibility of primary energy at affordable prices.

Nuclear power is therefore expected to play a crucial role in the sustainable development of country as well as meeting the millennium development goals. There are however challenges in the deployment of nuclear power for electricity generation in the country. The future deployment of nuclear power therefore requires comprehensive planning and development of an appropriate implementation strategy.

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