ELECTRICITY GENERATION FROM NUCLEAR POWER: A PANACEA FOR MEETING THE SUSTAINABLE DEVELOPMENT GOALS

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Keywords: –
Millennium development goal, optimal generation mix, nuclear power generation

Article History: –
Received: January, 2019.
Reviewed: April, 2019
Accepted: May, 2019
Published: September, 2019

ABSTRACT

The expansion of national electric power supply to meet the overall energy demand of a country is indispensable for ensuring national growth and sustainable development. In Nigeria, the NEEDS prescribed growth rate of 7% GDP that will ensure the attainment of the Sustainable Development Goals of poverty reduction to 50% of the 2000 value by 2015 projected an electricity demand 45,055MW by 2030. In this paper, the contribution of nuclear power generation in the energy mix of electricity generation in Nigeria has been assessed under the high growth demand using dynamic modeling approach of MESSAGE. The simulations revealed that, within technical and economic reliability, both 'Light' water and 'Heavy' water pressurized reactors (NPP2 and NPP1) would be necessary in meeting the demand for electricity in the country as from 2024 with a total contribution of 5729MW. The paper also observed that at the prevailing demand evolution, the contribution of the nuclear generation in the country's generation mix would remain the same even if carbon emission restrictions are imposed.

1. INTRODUCTION

The World Summit on Sustainable Development (WSSD, 2002) agreed on a "Plan for Implementation", which called upon all countries to take joint actions and improve efforts to work together at all levels to improve access to reliable and affordable energy services for sustainable development. The summit particularly hinged on sustainable energy strategies in developing countries, compatible with their national development goals and priorities, which will thereby contribute to the attainment of the Millennium Development Goals (MDGs). Consequently, energy expansion planning has been a vital issue that must be addressed in meeting these set goals.

The expansion of national electric power supply to meet the overall energy demand of a country is an integral part of this planning process that is strongly pursued by most nations. In Nigeria, the NEEDS (2004) prescribed growth rate of 7% GDP that will ensure the attainment of the Millennium Development Goal of poverty reduction to 50% of the 2000 value by 2015 projects an electricity demand of 45,055MWe by 2030 (Mati, 2007). Given that by 2017, the estimated electricity generation potentials of the country from both hydro and gas power plants is 5000MWe and 9000MWe respectively (Iloeje, et-al. 2005), a short fall 4000MWe is expected, which will pose great hindrance in meeting the MDGs in Nigeria.

The most practical solution to minimizing this shortfall is by expanding the energy mix of electricity generation in the country to include among others, coal, nuclear as well as mass deployment of renewables. In this paper, the contribution of nuclear power generation in future electricity generation profile of the country based on technical and economic reliability has been analyzed using a system modeling approach.

2. CURRENT TRENDS IN NUCLEAR POWER GENERATION

The IEA (2004) survey shows that, significant improvements in operation and safety performance have improved the image of nuclear power and its future global prospects. For instance, the Atomic Energy Association of the USA (AEA, 2003) reported that the world's average nuclear power plant availability factor improved from 73 percent in 1990 to 84 percent in 2002, and average U.S. capacity factors improved from 71 percent in 1992 to 91 percent in 2002. Greater capacity utilization allowed the U.S. nuclear power industry to increase net generation by 19 percent between 1991 and 2001, despite a nearly 2-percent decrease in operable nuclear capacity over the same period. At the same time, considerable improvements in nuclear plant safety measures have been achieved globally. Nuclear power generation has also been advocated as a desirable option for reducing greenhouse gas emissions (AEA, 2003).

Today, nuclear power generation accounts for nearly 30% of total electricity generation in the EU and about 17% globally. Thus, even though many reactors in the industrialized nations will reach the end of their useful life spans by 2024, new reactors are expected to be built mainly in the developing world (IEA, 2004). Currently, several countries have already initiated a nuclear power program for electricity generation. Some of these include; Italy, Portugal, Norway, Poland, Belarus, Ireland, Turkey, Iran, Gulf states, Israel, Syria, Jordan, Egypt, Tunisia, Algeria, Morocco, Nigeria, etc (IAEA, 2007).

3. METHODOLOGY FOR ELECTRICITY GENERATION EXPANSION MODELING

The necessity for power generation expansion may be evaluated using two techniques; deterministic and the probabilistic approach. In this work, the deterministic approach of MESSAGE has been employed, since the main thrust of the work is premised on energy mix optimization.

3.1 Probabilistic method

Probabilistic methods for power system expansion are typically based on loss-of-load probability, in which an expected failure of the system is calculated or expected-unserved-energy methods. ENPEP and WASP models have been built on this approach. Here the models evaluate the reliability of the power system in terms of reserve margin, loss-of-load probability and expected-unserved-energy (Jusko, et-al, 1996).

3.2 Deterministic method

Here, the necessity for power generation expansion is modeled by simple rule-of-thumb criteria., where the total power capacity requirement is expressed as a function of the maximum (peak) power actually to be generated, say, on annual basis. The size of the power system must exceed this maximum demand, either by a percentage or by fixed value. Some of the most popular models built on this approach include MESSAGE and MARKAL. MESSAGE is an optimization model which from the set of existing and possible new technologies select the optimal in terms of selected criterion mix of technologies able to cover given country (or other) demand for various energy forms during the whole study period (IAEA, 2003). In MARKAL (Fishbone, et-al, 1983), reserve capacity of power sector is expressed as a fraction of the capacity required to meet the electric demand in the time interval with the largest load. This fraction can be defined by the user in the data input tables. Thus, in MARKAL, a distinction is made between peak power and other units, whereas MESSAGE does not.

The main criterion of MESSAGE optimization are based on reliability and cost minimization, which is mathematically expressed as (IAEA, 2003); The minimization function (Ct) for each period(t) is given by

$$
\begin{aligned}
C(t) = {} & \Sigma k\{Invcost(r,t,k)*INV(r,t,k)+ \\
& Fixom(r,t,k)*CAP(r,t,k)+ \\
& Varom(r,t,k)*\Sigma s,sACT(r,t,k,s)+ \\
& \Sigma c(Delivcost(r,t,k,c)*Input(r,t,k,c)*\Sigma s \\
& ACT(r,t,k,s))\} + \\
& \Sigma c,s\{Miningcost(r,t,c,l)*Mining(r,t,c,t)+ \\
& Importprice(r,t,c,l)*Import(r,t,c,l)- \\
& Exportprice(r,t,c,l)*Export(r,t,c,l)\}
\end{aligned}
$$

There are two conditions for an optimal solution for the equation given by;

i. Capacities * efficiencies * availability ≥ activity (for each load region)

ii. Production of energy form ≥ demand

The availability of electricity is a function of plant factor and operation time of power generating capacities in the system (on the capacity screen).

4. MODEL SIMULATION

The nuclear power generation is simulated from the primary energy level to useful demand level, where the demand has been defined exogenously from another model, the MAED. Two types of nuclear power plants were assumed, namely the Heavy Water Pressurized Water Reactor (NPP1) and the Light Water Pressurized Water Reactor (NPP2). The base scenario, which is the application data base (adb) has been defined as the case with a high growth electricity demand dictated by 7% GDP growth and no carbon emission restriction imposed. The second scenario is the case with carbon emission restriction imposed (CABREST) at the prevailing demand evolution as in adb scenario. The activity and capacity data base evaluated in the technology screen is as shown in Figures 1 to 3. The activity data for both NPP1 and NPP2 have been assumed to be the same.

5. RESULTS AND DISCUSSION

The result of the simulation for the adb scenario is as shown in Figure 3 and 4, while Figure 5 and 6 depict the result for CABREST scenario.

For the adb scenario, (where carbon restrictions have not been imposed), the results in Figures 4 and 5 shows that the contributions of NPP1 and NPP2 would be 2455MW and 3274MW respectively as from 2025. This is despite the projection of 6770MW, 5460MW and 4713.1MW to be contributed from gas IPP, existing gas plants as well as Mambila large hydro plants respectively. The electricity generation capacities from coal plants during same period have also been projected to be 10,940MW. Thus, it shows that even without any carbon emission restriction imposed, the current energy mix of electricity generation in the country cannot guarantee adequate electricity supply to meet the demand of the country except with generous injection nuclear power plants.

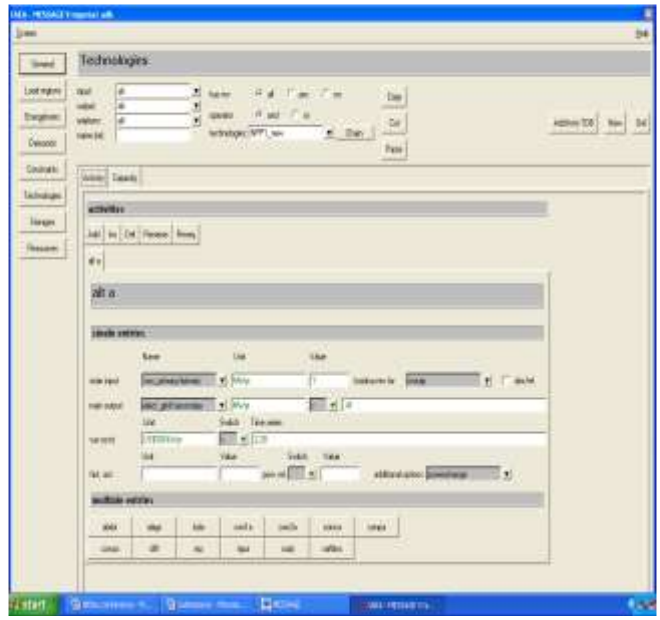

Figure 1: Activity screen for NPP1

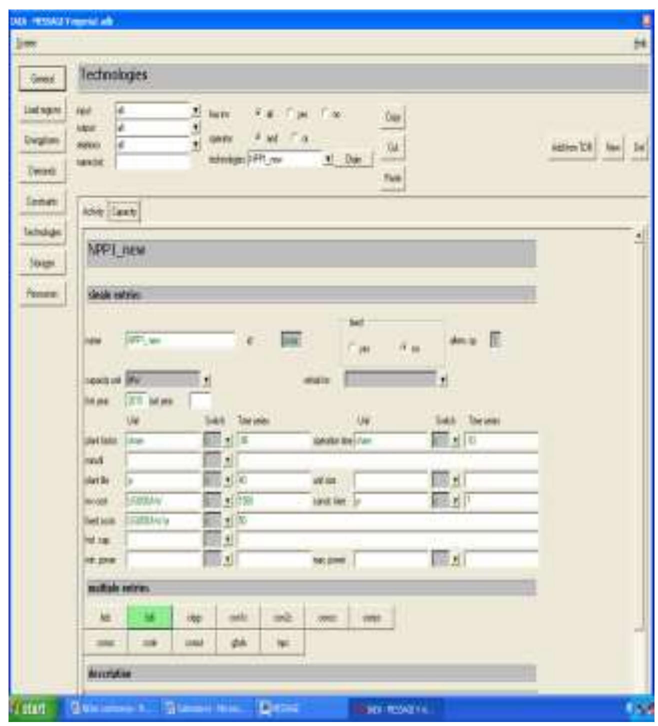

Figure 2: Capacity screen for NPP1

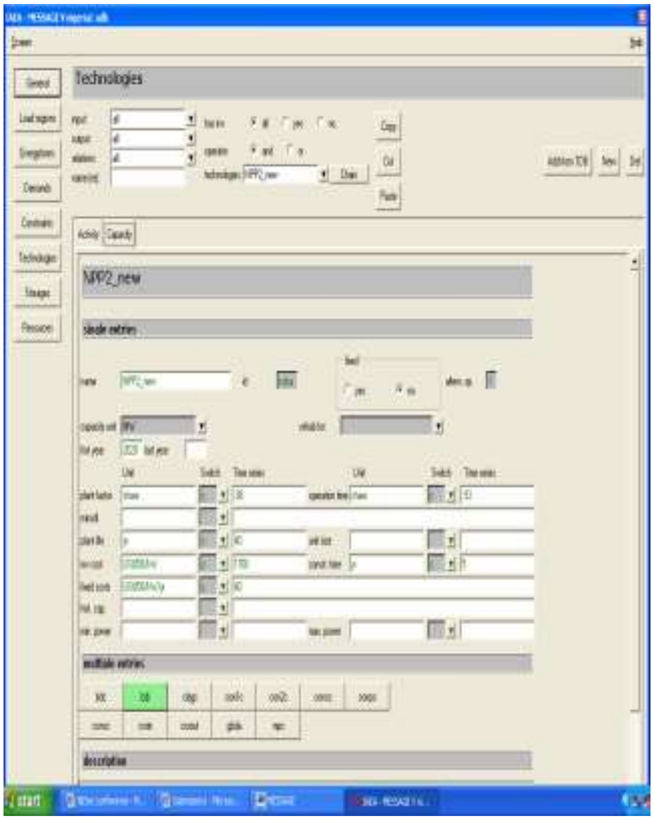

Figure 3: Capacity screen for NPP2

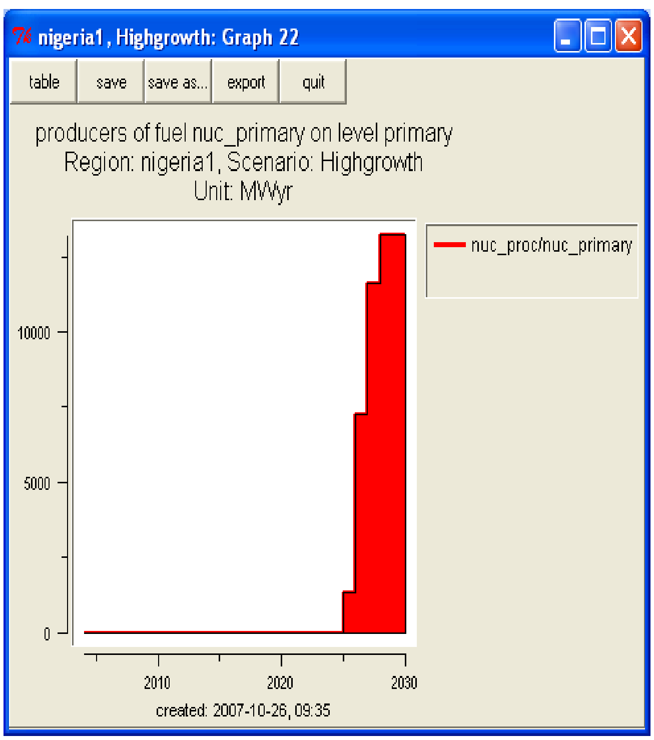

Figure 4: Nuclear generation at primary level for high growth scenario

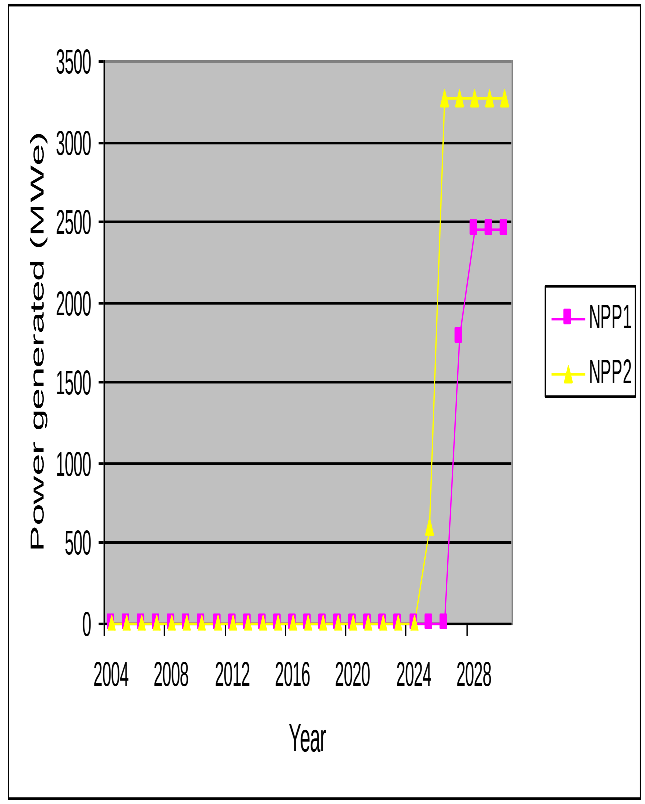

Figure 5: NPP generation for adb scenario

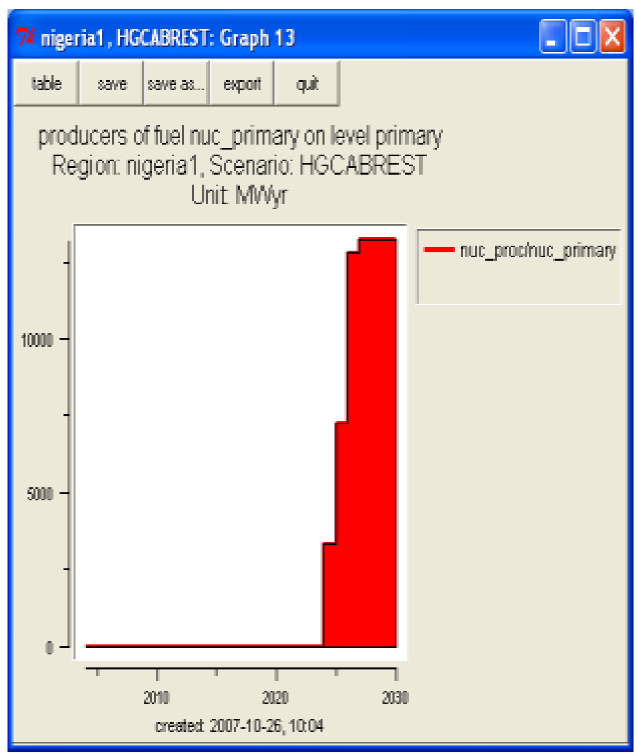

Figure 6: nuclear fuel generation at primary level for high growth cabrest scenario

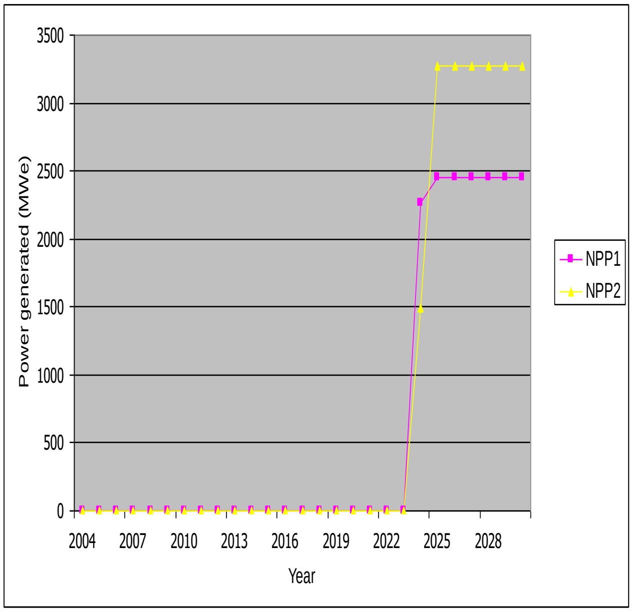

Figure 7: NPP generation for high growth cabrest scenario

With carbon emission restriction imposed as in CABREST scenario shown in Figures 6 and 7, the results show that the nuclear power plants NPP1 and NPP2 still maintain their maximum contribution of 2455MW and 3274MW respectively. However, they are required to be on board earlier than the adb scenario. This is despite the projection of 2115MW electricity import from West African Power Project and maximum exploitation of 7266MW from the entire large hydro potentials in the country. Since we know that the new large hydro capacities cannot be stretched to this limit, more NPPs may in fact be necessary.

6. CONCLUSION AND RECOMMENDATION

The contribution on nuclear power generation in the energy mix of electricity generation as a panacea for meeting the MDGs in Nigeria has been assessed using dynamic LP modeling approach of MESSAGE. The simulations revealed that, within technical and economic reliability, both 'Light' water and 'Heavy' water pressurized reactors (NPP2 and NPP1) would be necessary in meeting the demand for electricity in the country as from 2024. With a contribution of 3274MW and 2455MW respectively from NPP2 and NPP1, it implies that gradual harnessing of the nuclear potential in country should commence in earnest since it is almost impossible to inject these power requirements at a go.

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