The perspective of small and medium size nuclear power reactors in the Brazilian isolated electricity grids

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Abstract

As a consequence of the international crisis that has shaken the nuclear industry almost all over the world during the late 1980s, new academic contributions, which could settle a new basis for the nuclear energy in Brazil, have been scarce. This paper aims to partially fulfil this gap. We discuss some perspectives for the nuclear option to regain some prominence in the Brazilian energy matrix. Recent developments in the nuclear industry, including advances in plant design, have been opening interesting markets for small and medium nuclear power reactors (SMNPRs). We access the suitability and feasibility of such new technology in the Brazilian isolated electricity grids. We conclude by saying that, although the difficulties are still huge, SMNPRs may be a good strategy for Brazil to revitalize its nuclear policy.

Introduction

After the boom of the 1960s and 1970s, the international nuclear industry has, to a large extent, plunged into a long period of deep reflection. Most of the technological, economic, political and energetic promises that had sustained the strong development of nuclear energy have proved baseless. The cost reduction expected from higher levels of economies of scale has been questioned. Increasing capital costs for building new large nuclear plants have been making the financing of such units something very hard. In addition, large nuclear plants (1,000 to 1,200 MW(e)) have been loosing competitiveness as compared with other energy alternatives based on fossil fuel and, primarily, on natural gas. Most of these difficulties have appeared due to increasing political problems for licensing new nuclear units. Higher direct costs and longer construction time, very often associated to bad management and higher operational costs, have substantially diminished the competitive advantage of nuclear vis-a-vis to other energy options. We are very far from the dream proposed by the American President Eisenhower when he has launched his "Atom for Peace" program in the 1960s, seemingly offering to the world an unfailing source of energy.

During this period of reflection, the nuclear sector has been making important improvements in all the steps that constitute the industry. Those include improvements on projects, engineering and construction, as well as the definition of better regulatory and licensing procedures. Among the different research axes that have been proposed, the downscale of the plants to much smaller units (300 to 600 MW(e)) dare the traditional opinions that usually favor "the big is beautiful solution". However, new concepts of

SMNPR seem to have been progressing in several countries and mainly in the United States. By accelerating construction times and increasing reliability through new systems of passive safety, SMNPRs can overcome the cost problem of scale, becoming a serious option for the nuclear industry of the 21st century.

We have therefore decided to analyze whether or not such new concepts of SMNPRs may make sense and be a viable solution for the Brazilian energetic reality. To achieve that, we have focused our attention on a very specific segment of the Brazilian electricity system, that means, the so called "isolated grids". In the following section, we describe this segment. Then, we access the suitability and feasibility of such new nuclear technology in a very sensible area of the Brazilian territory.

Principal characteristics of the Brazilian electricity system

With an area of 8.5 million km^2, a population of 158 million inhabitants and a GDP of US$740 billion, Brazil consumes about 272 TWh/year of electricity (that means 1,722 kWh/year per capita). As shown in the **figure 1**, the national electricity grid is constituted by a South/Southeast/Central-East integrated system, which accounts for about 79% of the national total electricity consumption, a North/Northeast integrated system, which accounts for about 19.5% of the total consumption. Those integrated systems are strongly based on hydropower generation. In addition, we also find some more than 300 small and very small isolated systems, mostly situated in the Amazon region, which account for 1.5% of the total consumption (Carraro, 1998).[1]

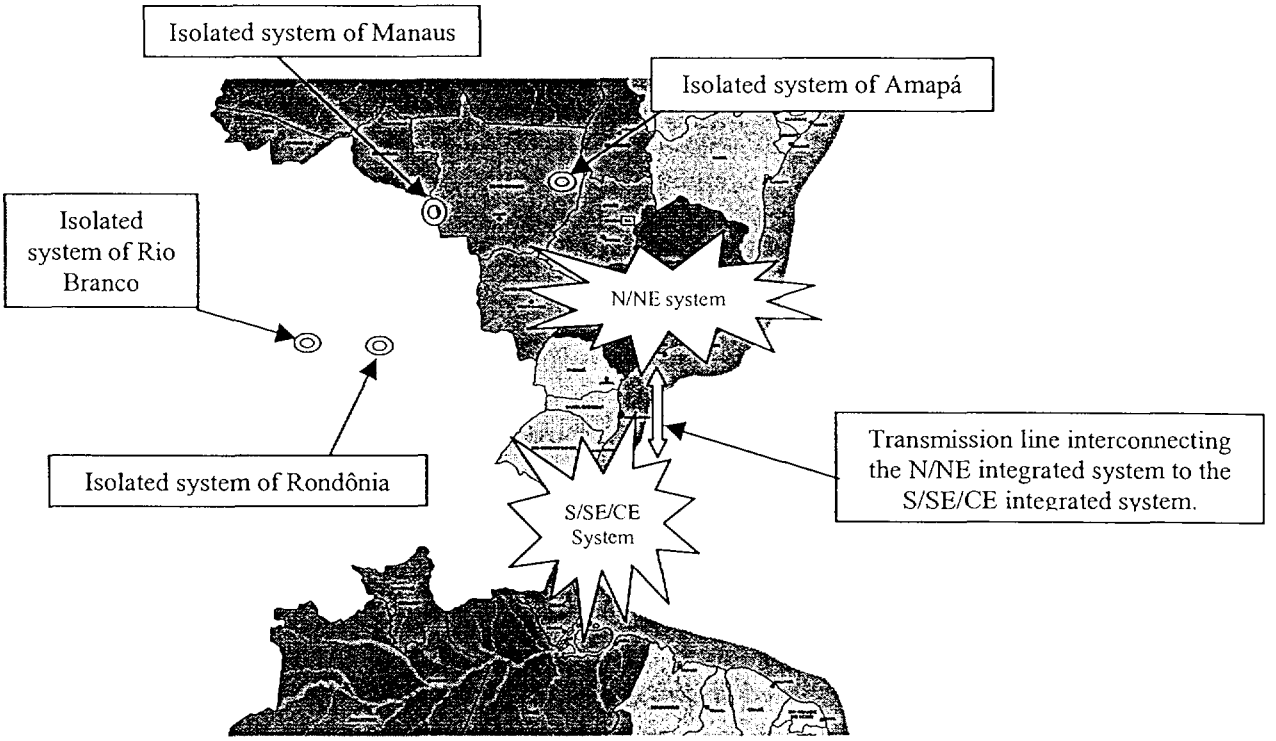
Although small as compared with the two large integrated systems, the isolated systems in the Amazon region are expected to expand at much higher rates. The total electricity consumption in all the isolated systems is expected to grow from 5 TWh/year in 1997 to 13 TWh/year in 2007. This represents an average annual grow of 10%, which compares with the average annual grow of 5% expected for the whole country. Currently, the isolated systems are primarily based on small, inefficient, strongly subsidized and expensive diesel power plants. Those units cost about US$ 400 million/year for the country. They also weigh heavily against the national trade balance since Brazil is a major diesel importer (Carraro, 1998).

As shown in the **figure 1**, among the isolated systems four sub-systems prevail: (i) the isolated system of Amapá whose major consuming center is the city of Macapá; (ii) the isolated system of Manaus in the state of Amazonas; (iii) the isolated system of Rio Branco in the state of Acre; and (iv) the isolated system of Rondônia whose major consuming center is the city of Porto Velho.

By the end of 1999, there might be operating a new 230 kV transmission line connecting the cities of Rio Branco (Acre) and Porto Velho (Rondônia). At the same time, other small cities in the south of the state of Rondônia such as Vilhena and P.Bueno (which are currently supplied by independent power machines) may be hooked up into the larger isolated system of Porto Velho. There will therefore be three major isolated systems in the country. For the perspective of this text, only the isolated system of Manaus and the new isolated system of Porto Velho/Rio Branco are real and possible targets for SMNPRs.

[1] With the construction of a new 1,000 MW, 500 kV transmission line connecting the cities of Imperatriz, Sobradinho and Miracema, in the Northeast region of Brazil, to the city of Brazilia, in the Central-East region, the two large integrated systems will be hooked up into one so that they may exchange electricity each other. This line is expected to start operating in December 1998.

Figure 1: Basic characteristics of the Brazilian electricity system



Source: (Carraro, 1998)

Pressures of energy demand in the two major Brazilian isolated grids

Both the Manaus isolated system and the Porto Velho/Rio Branco isolated system are edging their collapse. The city of Manaus has experienced a strong urbanization process with the arrival of many industries and a fast modernization of households. Its electricity supply is deficient with blackouts occurring almost every day. Furthermore, the future may reserve even more problems since the population is still growing rapidly and the city needs to attract new investments and create new jobs to compensate to the end of past economic privileges that used to support the regional economy. Without substantial improvements in the metropolitan energy infra-structure, Manaus will hardly find a new sustainable economic route. New investors will be expelled and the city will likely dive into a long term economic crisis that might turn into social conflicts.

Incited by the governmental policy that has willed to promote a eastward occupation of Brazilian borders, the states of Rondônia and Acre have become during the 1970s and 1980s the Brazilian most advanced agriculture frontiers. The regional population has multiplied many times in less than ten years as well as its energy and electricity consumption. Although migration incentives have been substantially reduced in the early 1990s, the regional economic boom is still far from diminishing. In particular, the cities of Porto Velho and Rio Branco are experiencing a precocious urbanization expansion, keeping attracting people from the South and Southeast regions of the country which are enforced to leave their lands and open more room for mechanization.

The electricity supply in all the Porto Velho/Rio Branco isolated grid is expensive and not reliable. Again, a deficient energetic system may represent a huge obstacle for a sustainable economic grow in the region. Moreover, it may put additional pressures on the local environment, which is already strongly punished with huge forest burning due to the advance of the agriculture frontier. The environment would hardly accept additional pressures owed to a wild use of the forest for energy purposes.

The supply options in the two major Brazilian isolated grids

If we take into consideration the last "Indicative Plan" of the Brazilian government for the expansion of the national electricity system (see Carraro, 1998), we may easily apprehend that differently from the two large integrated systems, which will see a substantial increase of thermopower generation, but will continue to be mainly hydropower system, the Manaus and the Porto Velho/Rio Branco isolated grids will keep being supplied by thermoelectricity.

It is true that Brazil still has a huge hydroelectricity potential (about 259 GW) that can be explored. Most of those resources (about 50%) are located in the Amazon region and could by far fulfil the regional energy needs. However, given the inappropriate geographic conditions in the region, which is not very suitable for big dams, which would certainly flood huge areas of tropical forests, we may not expect that potential to be fully developed. Furthermore, most of those potential projects are located at very long distance from the two major Brazilian isolated grids. Hence, we may expect the Amazon region to become a large exporter of hydroelectricity to the rest of the country while keeping the thermoelectricity basis in its own isolated systems.

Regarding the Manaus isolated system, power generation is strongly based on diesel. The system holds the hydropower unit of Balbina, but this plant's capacity to generate energy is far less than initially projected, proving once again the difficult of building hydropower units in the region. The governmental "Indicative Plan" for this isolated grid initially previews three 90 MW thermoelectric plants based on natural gas. Those units would respectively be available by the years 2001, 2002 and 2002 (see table 1). The gas is supposed to come from the natural gas fields of Juruá and Urucu, which has been discovered and are being developed by Petrobrás, the Brazilian national oil company. With a production of 4 to 5 MM m^3/day, Petrobrás actually expects to supply with natural gas, during more than 20 years, a plant of 460 MW that should be built in Manaus. The major issue here is to overcome the long distance and the high transportation cost that separate the market and the natural gas fields in the middle of the jungle.

In what concerns the Porto Velho/Rio Branco isolated grids, the energy alternatives besides the present diesel systems are still more restrained. The governmental "Indicative Plan" initially suggest a gradual shift from diesel to natural gas with the construction of a series of small and middle size thermoelectric power plants based on gas (See table 1). However, as well as the case of Manaus, the whole plan will depend upon whether or not Petrobrás will be able to cross about 500 km of tropic jungle with a 12 inches gas pipeline that will bring the natural gas from Urucu and Juruá fields to Porto Velho and Rio Branco. In the perspective of Petrobrás, the project would only be economically feasible at larger power capacity, that means, a plant of about 230 MW in Porto Velho and another of 100 MW in Rio Branco (Vertis, 1997).

The Brazilian government Indicative Plan for thermoelectricity generation based on natural gas in the isolated grids of the Amazon region		
The plant	Power capacity (MW)	Beginning operation (year)
Manaus isolated grid		
Manaus I	90	2001
Manaus II	90	2002
Manaus III	90	2002
Porto Velho isolated grid		
Porto Velho I	35	1999
Porto Velho II	130	2000
Porto Velho III	60	2001
Porto Velho IV	60	2003
Porto Velho V	60	2004
Porto Velho VI	60	2005
Rio Branco isolated grid		
Rio Branco I	15	2000

Source: (Carraro, 1998)

The perspectives for SMNPRs in the two major Brazilian isolated grids

Taken into account the demand and supply pictures presented in the last sections, it seems for us that SMNPRs could find important market niches in the two major Brazilian isolated grids. A 300 MW nuclear power plant could dispute against the natural gas option both in the Manaus isolated grid and the Porto Velho/Rio Branco isolated grid. A 450 MW plant could dispute against natural gas in the Manaus isolated grid, but it would likely be already to big for the Porto Velho/Rio Branco system. It is very difficult to discuss about costs and prices of whatever large scale project in such inhospitable place. International standards for costs can certainly not be adopted straightforward for plants to be built in the Amazon region. We had better preview some multiplication factor to correct current values found in the literature.

Nevertheless, we may try to define what is the bottom line for the economic competitiveness that those nuclear plants must present to be considered as a realistic energy option for the region. Currently, with diesel plants, the average cost of electricity in the Brazilian isolated systems is about 110 to 130 US$/MWh. By shifting to natural gas and supposing an average cost of 3.0 US$/MMBtu for the gas, those costs are expected to decrease to about 60 to 70 US$/MWh, which is still too expensive, but represents already a great reduction of costs and subsidies for the country. In our perspective, this should be the bottom line for any SMNPR. If initial studies may prove us that this line is something achievable, it would certainly be worthy to deepen the economic research on this option.

Conclusion

This paper has presented a very simple study regarding the potential competitiveness of SMNPRs in the Brazilian isolated electricity grids. As we have shown with much more details in another previous work (see Dos Santos, 1992), the revival of the nuclear industry in Brazil is not a very easy task, having several political, economic and environmental barriers that must be crushed before a new national nuclear policy for energy uses can be defined and sustained in the long term.

However, we did find what we can call the economic bottom line for SMNPRs to be competitive in the Brazilian isolated electricity grids. If we can generate electricity with a modern and reliable nuclear technology at 30 to 50 US$/MWh, in a very wild region where construction costs tends to escalate without control, the energy cost in the major isolated Amazon regions would be driven to similar lower levels usually found in the rest of the country. That would improve the general competitiveness of the whole region. In this case, SMNPRs would likely become a serious and very defensible options.

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