THE NEED FOR MANAGING SPENT NUCLEAR FUEL IN BRAZIL

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Abstract

The paper has the purpose to introduce technical, informative and economic aspects about the managing of spent nuclear fuel in Brazil. The capacity of spent nuclear fuel inside the spent nuclear fuel pools from Unit 1 and Unit 2 of Angra nuclear power plant is almost reached. Also, the content in it will show the reader the importance of managing spent fuel in order to extend the lifetime operation of nuclear power plants, since the context of the country energy matrix until the technical solution found. The arguments presented are based on technical publications from different institutions. It aims to present the reader the strategy founded by the Brazilian nuclear power plant operator in order to meet the requirements to renewal its operational license addressed by the regulatory body.

1. INTRODUCTION

There are only two operating Nuclear Power Plants (NPPs) in Brazil and a third one is under construction. The first NPP, Angra 1, was purchased from Westinghouse in 1972 and its construction started in the same year. It started-off its commercial operation in January 1985. It has been injecting 640MWe in the electrical grid for more than 30 years. The design of both reactors uses light-water moderator and low-enriched uranium fuel, called PWR. The enriched uranium pellets are placed inside fuel rods. In Angra 1, 235 of these fuel rods are distributed in an assembly. The core capacity of fuel assemblies inside the reactor is 121. With a cycle of one year, approximately one-third of the assemblies are replaced, due to fuel burnup. Selected spent fuel assemblies are removed from the core and placed inside a spent fuel pool (PCU). There is an extreme need to have these fuel assemblies inside the pool, due to the radioactive decay heat that is still being generated by radioactive elements of the uranium decay chain.

2. BRAZILIAN ENERGY MATRIX

Due to its large quantity of rivers, Brazil's electricity basically comes from hydropower plants (HPP). According to the last studies of the Energy Research Office (EPE, in its Portuguese acronym), it represents 63.9% of capacity installed in the energy matrix [1]. HPPs can provide clean, carbon-free, renewable and baseload energy to the electricity system. It makes the country at top 2 ranked of renewable hydropower worldwide, only behind China [2].

Besides, there is a significant contribution of thermoelectric plants to the energy matrix, using coal, natural gas, diesel, oil and biomass as a fuel. These energy sources are responsible for almost every Greenhouse Gas (GHG) emissions in the country [1]. Due to that, the government has been investing in renewable sources, as wind and solar. Table 1 shows the installed capacity of Brazil's electricity generation by sources according to EPE.

TABLE 1. BRAZIL ELECTRICITY GENERATION INSTALLED CAPACITY (MW) [1]

	2015	2016	2017	Δ%	%
Hydropower Plants	91,650	96,924	100,276	3.3	63.9
Thermoelectric Plants	39,564	41,275	41,628	0.9	26.5
Nuclear Power Plants	1,990	1,990	1,990	0	1.3
Wind Power Plants	7,633	10,124	12,283	21.3	7.8
Solar Power Plants	21	24	935	3,836.3	0.6

Having HPPs as the major source of electricity is certainly a great point considering GHG emissions. However, being strongly dependent on a unique source is extremely harmful for the energy supply. As HPPs depend on natural characteristics of water, it varies its supply according to the period of time. Brazil had already experienced this before. The most impacting example is the drought that happened from 2013 to 2015, specially in the city of São Paulo. People were afraid of having blackouts or to undergo power rationing as they had in 2001 with the country's first energy crisis [3].

Wind and solar power plants has been receiving subsidies from the government since 2002 [4], which have helped the construction of new plants and considerably increased the contribution of these sources to the energy matrix. The big challenge of introducing them in the electrical grid is their intermittency characteristic. They also depend on natural conditions, as the wind pattern and solar irradiation. These sources need to have a baseload power plant in the backup, usually a thermoelectric plant. However, thermoelectric power plants, as mentioned before, are the main responsible for emitting GHG, polluting air and potentially causing damage to the environment and public health.

This is the point where nuclear energy plays a strategic key to avoid GHG emissions and sequentially climate change. It provides clean, carbon free and baseload energy, because it does not depend on any kind of weather condition. The capacity factor, which "is the percent of the total electrical power that could theoretically be produced during a specified period if the plant were operated at full power 100% of the time" [5], by Angra 1 and Angra 2 nuclear power plants was equal to 90.3% in 2017. In comparison to all hydropower plants, in the same period the capacity factor was 42.2%. It shows that nuclear energy can provide stability to the electrical grid, avoiding risks of another blackout. Besides, this measure does not vary considerably so that it is reliable. Figure 1 displays the capacity factor variation of the top four sources in Brazil's energy matrix from 2013 to 2017.

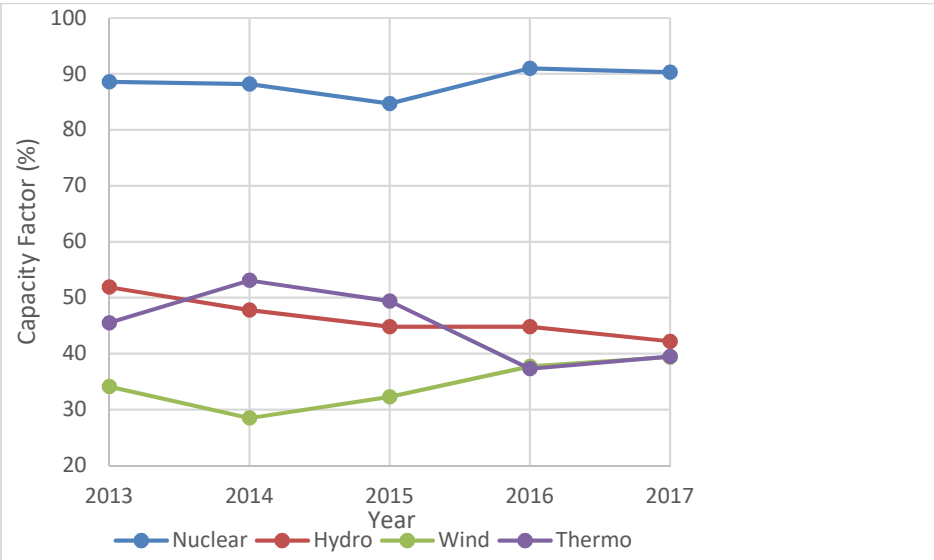

FIG 1. Time evolution of the mean annual capacity factor divided by source [1].

3. THE IMPORTANCE OF ANGRA 1 TO THE SYSTEM

Based on information given earlier, NPPs can afford a large quantity of power with a high capacity factor, making them more reliable. In Brazil, the first nuclear reactor has been producing electricity for more than 30 years and accumulates more than 90,000GWh of energy since its first commercial year [7]. The site of Angra NPPs is located in the city of Angra dos Reis, which is considered as a strategic location due to its proximity to the two most energy consumption cities of Rio de Janeiro and São Paulo. This fact helps the electric power transmission system operator (ONS, in its Portuguese acronym) to manage the distribution of electricity, saving transmission costs.

Furthermore, the energy price of Angra 1 was set up to BRL247.47 per MWh by Brazilian Electricity Regulatory Agency (ANEEL, in its Portuguese acronym) for 2019 [7]. In comparison to other thermoelectric power plants, as natural gas for example, the price is highly competitive. The tendency of the price of natural gas power plants is to become cheaper while new plants are connected to the grid. On the other hand, the price does not regard the potential costs to public health due to air pollution caused by operation of these plants. Besides that, others thermoelectrical plants as diesel and oil are extremely expensive.

Angra 1 is deeply important to keep the grid stability and maintain low carbon emissions. It also helps to preserve the main price of thermoelectric plants competitive with renewable sources, as wind, solar and hydro. Due to these facts, it is essential to safely review the aspects of long-term operation in order to extend the plant operating lifetime. The license deadline will be in 2024 and there are considerable efforts needed to achieve the extension for more 20 years of operation.

4. SPENT FUEL POOL STORAGE

Within a cycle of 1 year, approximately one-third of assemblies from a nuclear reactor core are replaced. The nuclear reactor core of Angra 1 has a capacity for 121 fuel assemblies. Since its first commercial operation in 1985 until 2016, 945 assemblies were stored in the spent nuclear fuel pool [8]. The capacity of its pool is up to 1,252 assemblies. It means that around 75.5% were filled at that year. Assuming that 80 assemblies were placed there in the last two years, due to refuelling, the projection shows that 81.8% are currently occupied.

The Nuclear National Regulatory Agency (CNEN, in its Portuguese acronym) determines that the area of spent fuel storage must meet the minimum capacity of one full-core at any time of plant operation lifetime [9]. It leads to an estimated capacity exhaustion of the spent nuclear fuel pool in 2021. This scenario is also happening in the Unit 2 of Angra NPPs. According to the United States Nuclear Regulatory Commission (NRC), the minimum storage capacity of a spent nuclear fuel pool should be equal or exceed the amount from five years of operation at full power plus one full-core discharge [10].

In order to extend the operation lifetime of Angra 1, and further of Angra 2, CNEN is working on the development of regulatory decisions of license renewal. NRC has started its studies for license renewal in 1982 and since its first publication in 1991 until now it has renewed 89 commercial nuclear reactors in the United States [11]. Taking this fact into account, the experience of NRC from operation lifetime extension review process will certainly be important for CNEN decisions in Brazil. Besides, there are several publications from the International Atomic Energy Agency (IAEA), as the Safety Reports Series No. 57 – "Safe Long Term Operation of Nuclear Power Plants" and the IAEA Safety Standards Series No. SSG-48 – "Ageing Management and Development of a Programme for Long Term Operation of Nuclear Power Plants", that could help CNEN in its decision.

Based on that, the operator of Angra NPPs – Eletrobrás Eletronuclear, which is a state-owned company, usually called Eletronuclear, is investing all efforts in a way to remove a certain quantity of spent fuels from the pool so that they could adequate the plant to regulatory standards. As CNEN has not taken a decision for the final deposition of spent fuel, the current policy is to keep it in safe storage, avoiding or mitigating any kind of impact for the environment and the population. The solution found by Eletronuclear is to store the spent fuel with a technology of complementary dry storage, using dry canisters or casks, due to industrial know-how, compatible agenda and competitive costs [8].

5. DRY STORAGE CASKS

This technology is used in about 70 NPPs around the world. There are approximately 2,400 dry storage devices based on canisters [8]. It is seen as an appropriate solution, due to its worldwide acceptability. The canisters have the ability to confine the spent fuel, to ensure a subcritical state inside itself and to provide enough heat transfer to keep the spent fuel cooled through natural convection.

In addition, the operation of removing the fuel from the PCU and transfer it to the dry storage facility is careful and must be conservative in order to keep the minimum radioactive release, mitigating the absorbed dose by workers. The company responsible for the dry storage facility should offer the service cask transfer, providing radiation shielding and appropriate structural stability to maintain the integrity of the fuel in the processes of loading, unloading and transporting.

The canisters are stored in what is called storage modules, which can be vertical or horizontal. These storage modules must meet the requirements of providing radiation shielding and physical protection during the storage period. Also, they must provide appropriate heat transport between the canister and the environment. Moreover, the dry storage facility must be monitored following the safeguard standards published by IAEA, with restricted access, gatehouses, warehouses and others features to ensure the quality of the installation based on international standards.

Eletronuclear decided to contract a well-known company called Holtec, which is specialized in dry storage technology around the world [8]. They are responsible for almost every spent nuclear fuel dry storage in the United States and worldwide [12]. The first project predicted the removal of 5 fuel operation cycles, using 15 dry canisters, in order to meet the specifications of CNEN, based on the requirements defined earlier by NRC. It includes 220 spent fuels from Angra 1 and 280 spent fuels from Angra 2 [8].

However, in November 2018, the company presented an addendum for the environmental report to extend the size of the Dry Storage Complementary Unit (UAS, in its Portuguese acronym) from 15 to 72 canisters [13]. This new decision will theoretically be sufficient to extend the operation lifetime of Angra NPPs for 25 years. It meets the removal of approximately 2,400 spent fuels from the PCU to UAS, 1,100 from Angra 1 and 1,300 from Angra 2.

6. CONCLUSION

The construction of the UAS is extremely important to keep Angra NPPs in operation to meet the horizon predicted by EPE in its 2050 Horizon National Energy Strategy [14]. In this publication, EPE foresees the extension of lifetime operation for Unit 1 and Unit 2 of Angra and also the operation of Unit 3, which is still under construction.

The project for 72 canisters has a budget of BRL246 million [13]. According to the price set up by ANEEL, the estimative of revenue by Angra NPPs for the next year is BRL3.409 billion [7]. The construction of UAS will represent 7.2% of all this receipt. In conclusion, it can be inferred that the solution for the spent nuclear fuels found by Eletronuclear is adequate to continue producing baseload, reliable, clean and carbon-free energy regarding technical and economic aspects.

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