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Evaluation of the Decommissioning Fund for a Nuclear Power Plant in Brazil

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1. Introduction

The decommissioning process produces large volumes of different kinds of wastes, with different contamination and activation levels, requiring suitable management and facilities for nuclear waste storage and disposal. In certain situations, the storage and disposal facilities are not available at the time of the decommissioning while in others there are not enough funds or financial guarantees sufficient to carry out it as planned [1-3]. To avoid the mentioned difficulties it is important to assess the possibility to continue operation aiming at longer terms of operation up to 20 years or more. With a longer period of operation, not only the decommissioning expenses are postponed to future, but it allows more time to accumulate financial resources and to and prepare suitable disposal and storage facilities [3].

One important and basic requirement of a decommissioning project refers to the financial guarantees needed to defray its expenses. In the nuclear industry, the fund is formed by applying a fee on the energy tariff to consumers over the operational life of plant and responsibly the decommissioning expenses is not transferred to future generations [1-3]. The value of the required fee required should be updated periodically taking into account changes of decommissioning costs over time caused by plant occurrences that increase the decommissioning activities such as radioactive spills or contamination of buildings and soils, serious accidents and even a premature shutdown [1-3].

2. Metodology

The Angra 1 power reactor is under a project to attain long term operation which will postpone its decommissioning for 20 years [4]. The decommissioning strategy for the CNAAA plants considers the deferred dismantling approach for Angra 1 and Angra 2 and immediate dismantling for Angra 3. This CNAAA overall strategy places Angra 1 and Angra 2 into an extended safe storage configuration until it is time for Angra 3 to undergo decommissioning. At this time, all plants will undergo dismantling activities in sequence in order to reduce costs and environmental and radiological impacts. Angra 1 is planned to obtain an extended operational life of 20 years and to start its decommissioning activities in 2040, 5 years before its permanent shutdown, and ends it in 2085. Angra 1 is planned to stay under safe storage condition from 2048 to 2077 or 30 years. The deferred dismantling decommissioning approach will last 46 years [5]. Thus, there will be a long period for the decommissioning fund to accrue interest on the accumulated balance before defraying the expensive activities of decontamination and dismantling, waste processing, storage and disposal and project management.

Table 1 shows the expected decommissioning activities and their cost and duration for a hypothetical 650MW NPP in Brazil with data collected from public information about the Angra 1 power plant [5-8]. After the long safe storage period, the rest of the decommissioning activities, starting with decontamination and dismantling up to the end of the decommissioning process, will occur in the final 8 years. Their costs, which represent 85% of the total cost of the decommissioning project, were lumped in Table 1 because they are planned to occur in sequence.

Table 1: Decommissioning activities, cost and duration expected for the 650MW NPP. Data were collected from the Angra 1 power plant preliminary decommissioning plan. The costs figures refer to 2017 [8].

Activity Description	**Cost (millions of US$)**	**Duration**
Pre-decommissioning activities, transition and project management and engineering	25.3	2040-2044 (5 years)
Prepare for safe storage, project management and engineering	3	2045-2047 (3 years)
Safety storage period	60	2048-2077 (30 years)
Decontamination, dismantling, waste processing, storage and disposal, conventional dismantling, demolition, site restoration, project management and engineering, miscellaneous and project contingencies	513	2078-2085 (8 years)
TOTAL	**601.3**	**2040-2085 (46 years)**

This work assesses the decommissioning fund of a hypothetical 650MW NPP considering interest rates and decommissioning and energy fees published for Angra 1 from different sources [5-7]. The data and values are public as determined by current Brazilian laws [6, 7]. Each NPP has its own fund in Brazil and we took the one from Angra 1 as the reference data in this study. In the first set of data, the value of the fund in 2007 was US$ 59.1 million, its yield rate is benchmarked above 2% for each year, the annual deposits to the fund is 0.98% of the annual energy revenue or US$ 1.77 million per year [6, 7]. In the second set of data, the annual deposits amount to US$ 6.06 million per year [5].

Below we assess the evolution of the decommissioning fund of a 650MW NPP over time for two situations: 1) annual revenue of US$ 1.77 million per year and 2) annual revenue of US$ 6.06 million per year. For both cases, we assume that the balance of the fund in 2007 is 59.1 million and that the yield rate of the fund is 2% by year.

3. Results and Discussion

Figure 1 shows the fund evolution for a NPP with 650MW with the same characteristics of Angra 1, considering the assumptions detailed in Section 2. The evolution of the fund with deposits of US$ 1.77 million per year is not sufficient to meet the costs of decommissioning and presents a negative balance greater than US$ 200 million in 2086. The fund with deposits of US$ 6.06 million per year after 2017 presents a positive balance around US$ 150 million in 2086 after completion of all decommissioning activities.

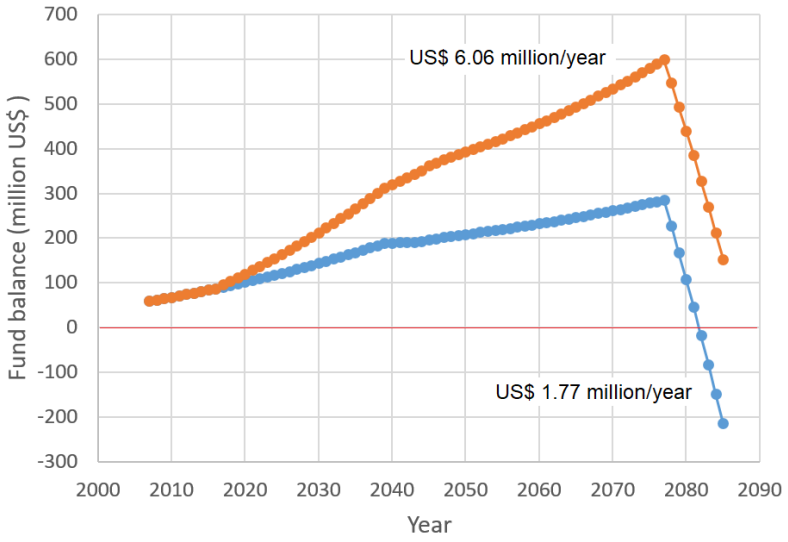

Figure 1: Evolution of the decommissioning fund over time for two different yearly deposits after 2017.

The fund yield is assumed 2 % per year and a fund balance in 2007 of US$ 59.1 million. The extension of life and the long safe storage period for the 650 MW power plant allow the fund to accrue important balance to meet the decommission costs. Depositing US$ 1.77 million per year is not sufficient to meet the decommissioning costs indicated in Table 1.

The evolution of the fund depends heavily on the yield rate accrued along the decommissioning period and on the adopted strategy. Long periods of safe storage and NPP long term operation favor increasing the balance of the fund. If the second situation analyzed holds true over 46 years, the financial guarantees presented in the documents will suffice to defray the decommissioning project. In addition, as demonstrated by [3], the decommissioning cost is highly dependent on radiological decay and the difficulties to perform the required activities. Postponing the decontamination and dismantling activities and the radioactive waste management activities to 2078 helps the economic sustainability of the project. On the other hand, it is necessary to take care of the power plant site for 46 years, which increases social and environmental concerns.

The actual cost of decommissioning activities in 2078 could greatly decrease with the advancement of automation technologies. The most difficult activities to be carried out are those in a hostile environment due to radiological, chemical and possibly contaminated dust in the air. The use of protective equipment makes these activities more time-consuming and tiring for workers and therefore to cost more. By 2078 it is very likely that all these activities could be done by robots or remotely controlled by workers. In this situation, the costs of decommissioning activities itself may be drastically reduced, which contributes to the feasibility and certainty of success of long term decommissioning projects. This is already occurring in Europe and the United States where many nuclear power plants were decommissioned at costs less than the balance available in their decommissioning funds.

4. Conclusions

In the present work the decommissioning project funding and its relationship with project length, strategy and deposits were evaluated. The results demonstrate that, depending of the deposits made, the decommissioning fund could not be enough to cost the decommissioning project, requiring changes in project strategy, deposit value or an extension in NPP's operational life.

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