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Evaluation of the decommissioning fund for a nuclear power plant in Brazil

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ABSTRACT

The decommissioning of a nuclear power plant is a costly and highly complex process, requiring not only a planning and rigorous chronogram execution as well as funds large enough to cost it. The Long-Term Operation of the plant is not only interesting since it allows the plant to keep producing energy with low-carbon footprint as well as postpone to future these expenses. Around the world several nuclear power plants are being evaluated for Long-Term Operation due to these reasons. In Brazil the oldest nuclear plant, Angra 1, is also being evaluated for Long-Term Operation, otherwise it should be retired/shutdown in next future. However, besides the technical reasons, also the plant's decommissioning fund seems to be not enough to cost its decommissioning. In the present work, the decommissioning fund of Angra 1 is evaluated considering two different interest rates and compared with the decommissioning cost. The results demonstrates that the Long-Term Operation is necessary and a good decision since it allow an additional time to the provisions on the decommissioning cost increase, avoiding the lack of funds.

Keywords: **Decommissioning, Costs, Funds, Reactor, Evaluation.**

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1. INTRODUCTION

The Nuclear Power Plants (NPPs) decommissioning is a process through the inherent risks offered by the plant is reduced after the end of its operational time. As consequence, large volumes of different kinds of wastes are produced, 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, which is typically of 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 should be updated periodically, considering changes of decommissioning costs over time caused by plant occurrences that increase the costs of decommissioning activities such as radioactive spills or contamination of buildings and soils, serious accidents and even a premature shutdown [[1]-[3]]. Notwithstanding, the periodic review of energy fees are necessary to include changes in regulatory framework, economical inflation, among others.

Several reasons could lead a plant to be retired/shutdown and decommissioned. The most common are technical and or economical unfeasibility as well as accidents. The retirement of a NPP could occur as planned or prematurely. In any case, the financial guarantees should be enough to cost the retired plant's decommissioning [[1]-[3]].

In Brazil, there are two operating NPPs and a third under construction (Angra 1, Angra 2 and Angra 3, respectively), which are located at the Central Nuclear Almirante Álvaro Alberto site (CNAAA) [[1]-[3]]. The oldest NPP, Angra 1, is under a project to attain Long-Term Operation

(LTO) aiming to postpone its retirement for 20 years [4]. However, as extensively discussed and detailed by [[1]-[3]], the CNAAA site is a multiple reactor site and it plants are highly interdependent, especially Angra 1 and Angra 2. In this manner, aiming to optimize the decommissioning of each of CNAAA plants, a hybrid decommissioning strategy is recommended. In this strategy, it is proposed to be decommission Angra 1 and Angra 2 according to the deferred dismantling approach while Angra 3 is proposed to be decommissioned according to the immediate dismantling approach [[1]-[3]]. Since in a multiple reactor site (as CNAAA) the decommissioning cost of each plant and of the site is strongly dependent of the decommissioning process duration, any life extension could affect it significantly [[1],[3]]. Despite of it, considering that each plant has its own decommissioning fund that should have enough provisions to cost the NPP's decommissioning, it is important to perform an evaluation of how large the fund of each plant is [[5]-[7]].

This work aims to present an evaluation of how the decommissioning fund of Angra 1 evolved through the time, comparing it with the estimated decommissioning cost of a hypothetical and similar NPP considering the immediate dismantling approach. The fund evaluation would be performed according to the current Brazilian regulatory framework, using data publicly available. The decommissioning cost of the hypothetical NPP was estimated considering previous works addressing the decommissioning and relevant data available for Angra 1 plant. The results obtained could be used by the Brazilian nuclear power site to support decisions about Angra 1 LTO as well as of its decommissioning in future.

2. MATERIALS AND METHODS

This work assesses the decommissioning fund of the Angra 1 NPP and compares it against the decommissioning cost of a hypothetical 640MWe NPP, similar to Angra 1 power plant, which is taken as benchmark for this cost estimation. From Angra 1, it was taken its interest rate and energy fee, as published in different sources [[8], [9]]. The total of provisions deposited in the decommissioning fund of Angra 1 would be compared with the decommissioning cost of a hypothetical and standalone plant, similar to Angra 1 (same type, power/size, operational schedule,

etc), estimated on the same basis as performed by [[1]]. The data and values used to assess the decommissioning fund are public as determined by current Brazilian laws [[8], [9]]. Regarding the decommissioning cost, the most relevant assumptions are as follows:

- The provisions on the decommissioning fund would be evaluated conservatively, since the decommissioning cost considered as reference would be estimated considering the immediate dismantling approach [[1]-[3]];
- The decommissioning cost, of about US$408 million, was obtained by applying the same costs, tasks durations and correction factors as done by [1], as required by the Ger-Descom tool and Av-Descom model [1]. The values and correction factors used as reference are detailed in [[1],[3]];
- The site would be released for unrestricted use after the decommissioning finishes;
- There are no unforeseen events that forces the decommissioning process to stop;
- The occurrence of accident would not be addressed in the present work since it alters significantly the way in which the decommissioning should be conducted;
- Values of men-hour required, difficulty factors, etc, are the same as adopted by [[1],[2]];
- The men-hour cost was updated from the year of [[1],[3]] publications to the present year regarding the economical inflation [10].

Regarding the decommissioning fund, the additional assumptions are:

- Angra 1 has its own provisions on the decommissioning fund [[5],[6],[9]];
- The year 2007 was taken as reference. In this year, there are provisions deposited over previous years. The year 2007 was chosen as reference since it has a more complete data set available [[5]];
- Two different interest rates were used to assess the evolution of the decommissioning fund: the first rate is stated by the current Brazilian regulatory framework while the second was defined by the operator company [[5],[6]];
- It was assumed the nominal operational life for Angra 1 (40 years), with its retirement originally planned to occur in 2024 [[2],[5],[6][9]];
- The plant's insurance use is not allowed even in case of lack of funds.

2.1. Mathematical modeling

A simple model to estimate the value of provisions deposited in any year is the compound interest, which is suitable written as given by equation (1).

$$Provisons = Value_{initial}\,(1+i)^{n} + Deposits \tag{1}$$

in which $Value_{initial}$ is the previously deposited value in the decommissioning fund and could be taken as zero if no provisions are deposited in the fund. i is the interest rate that would remunerate the fund through the time. n is the time frame considered for the estimation (in years). *Deposits* is the value yearly deposited on the fund.

According to Angra 1 operator company reports as well as the reports of TCU (Tribunal de Contas da União) and ANEEL (Agência Nacional de Energia Elétrica), the deposits are made once a year. In this manner, the variable n in equation (1) refers to the year to which is desirable to calculate the provisions value [[5],[6],[9],[11]].

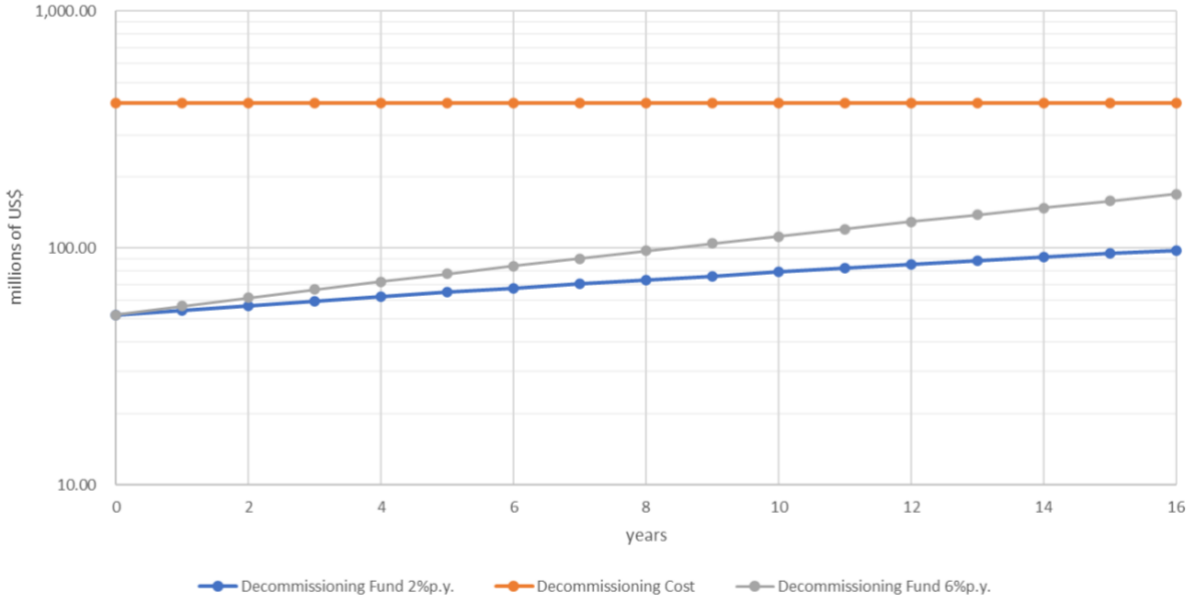
The value deposited yearly depends on the energy cost and the fee applied as well as of the total of the energy produced by the plant during a year. Based on the plant's operator company reports, the value of each provision to be deposited could be calculated [[9],[11]].

As assumed, in the present work two different interest rates were considered (the i value in equation (1)). The value stated by the current Brazilian regulation is 2% p.y. (per year) while the value used by Angra's 1 operator company is 6% p.y. The operator company has adopted a higher rate from the reference year aiming to increase the provisions for the decommissioning since them were considered not enough to cost its decommissioning process, thus avoiding lack of funds [[5],[6]]. A comparison among these two interest rates and which is better would be addressed in section 4 together with the other results and conclusions.

3. RESULTS AND DISCUSSION

The decommissioning fund evolution to each interest rate is presented in Figure 1 against the decommissioning cost, estimated on the basis of the assumptions detailed in section 2 and using the Ger-Descom tool and its mathematical model (Av-Descom). The red line refers to the decommissioning cost of the hypothetical NPP (of about $408 million) taken as benchmark.

Figure 1: *Decommissioning fund evolution for Angra 1 and the decommissioning cost comparison*.



As could be observed in Figure 1, the provisions deposited at the decommissioning fund of Angra 1 is not enough to cost its decommissioning process if the assumptions considered being verified and the monetary values being representative and considering that it would operate as it is designed (for 40 years). In this manner, otherwise the energy fee or the interest rate applied changes, there would be lack of funds.

This result is important since it supports the decisions to evaluate Angra 1 for LTO. Notwithstanding, it justifies the management practice adopted by the operator company regarding an interest rate higher than that stated by rule in Brazil [[5],[6]]. It is possible to observe that with the stated interest rate, there would be about a quarter (1/4) of the provisions required to cost the decommissioning after 16 years – see blue line (the year zero corresponds to the reference year – 2007 – while the 16th year corresponds to that in which Angra 1 was originally planned to be retired and shutdown permanently – 2024). With the operator company interest rate applied, it is possible

to observe that the lack of funds is reduced, although it is still significant: the provisions evolves by a hundred percent (100%), but covers only about a half of the cost estimated – see gray line. In this manner, if Angra 1 could not operate further after 2024 and being permanently shutdown, the operator company would have to adopt some of the several options discussed by [1], such as postpone the decommissioning for some years, aiming to rise funds to cost the process.

Besides these important conclusions, there are some additional remarks:

- The insurance was not considered to be used even in case of lack of funds. It is interesting to open a discussion regarding its use among the NPP operator company, regulatory bodies and insurance company aiming to allowing the use of it in case of lack of funds;
- The LTO not only allow the provisions to accumulate and being remunerated for an extended period but also postpone to the future the decommissioning expenses. In this manner, the Angra 1 LTO project is not only interesting from the technical point of view but also necessary regarding the economics features;
- The results consider only what the Brazilian rules states regarding the decommissioning. It does not evaluate the possibility to reduce the decommissioning cost if the multiple reactor approach, as proposed by [2], being implemented. This evaluation is subject of a future work;
- A change in the interest rate should be considered as well as in the energy fee. Even with Angra 1 operating for an extended period, a higher interest rate and/or energy fee is interesting since them make possible the provisions to accumulate in the decommissioning fund at higher rate and be available to be used, if necessary, sooner. This is important since unforeseen events could occur and lack of funds could take place. The interest rate and energy fee should be adjusted to allow the provisions increase enough to cost fully the decommissioning project.

4. CONCLUSION

The present work evaluates the evolution of the decommissioning fund of Angra 1 NPP considering two different interest rates: 2%p.y. as stated and 6%p.y. as adopted by the plant's operator company. The results demonstrates that even with the highest interest rate, if the plant could not be able to operate for an extended period and with its decommissioning being performed as a standalone plant, there would be lack of funds. Some suggestions to avoid this includes: the possibility to use the plant's insurance, the flexibility to make changes in the interest rate and energy fee as needed aiming to let the provisions to accumulate at a higher rate. It should be mentioned that, even with the LTO, these suggestions are important since unforeseen events could require the plant's retirement and permanent shutdown at a time in which the funds could still be not enough to cost the decommissioning. For future works, the evaluation of the decommissioning fund against a decommissioning cost estimated according to the multiple reactor approach is planned.

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