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Technical note

# Station Blackout in unit 1 and analysis of the wind field in the region of Angra dos Reis

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ABSTRACT

Since the Fukushima accident a lot wondered on if a nuclear reactor is really safe and, specifically, if the Plants of Angra are trusted to a severe accident as occurred in Japan. The initiator event in Fukushima was a tsunami which in turn affected the external power system and then the internal power system, through failure of the diesel generators. In the case of Angra dos Reis the initiator event would be by sliding slope, the event most likely to occur, which affect the external network, common fault for all three units and later the internal network in this case, the plant most likely fault on your internal network is the unit 1, due the generators GD1 and GD2 have higher probabilities failure of departure and failure to continue to operate $2.86 \times 10^{-2}$ and $2.4 \times 10^{-3}$, in comparison with the generators GD3 and CD4, respectively $1.74 \times 10^{-4}$ and $9.06 \times 10^{-4}$. With relationship to the dispersibilidade of the pollutant in an eventual liberation for atmosphere, it is inferred by the results of the analysis of the winds of the area that the area presents low capacity dispersive.



## 1. Introduction

A Nuclear Power Plant has systems, devices and equipment requiring electrical power to put them into operation in various conditions.

In normal operation, this energy feeds the systems of refrigeration, monitoring, control systems, lighting and other routine services. In emergency conditions it activates the systems and safety devices, called CLASS I, ensuring a safe forced shutdown in an eventual accident.

After reactor shutdown, the residual heat from the radioactive decay of fission products, must be removed to prevent melting of the fuel rods, thus preventing the release of radioactive materials into the atmosphere.

However, in a Station Blackout, the pumps of removal of heat of the reactor would not work and this would gradually increase the temperature in the core causing a severe accident at the Plant.

Severe accident is one that exceeds the design basis (set of information that identifies the specific functions to be performed by an item from a nuclear facility or specific values chosen for controlling parameters as fundamental reference data for the project) and it brings faults in structures, systems or components, thereby preventing cooling of the reactor core, as designed, leading to a significant degradation of the same, (CNEN-NE-1.26, 1997).

Severe accidents have frequency or probability of occurrence less than $10^{-7}$ per reactor-year, in other words, the equivalent to an accident at 10 million years, depending of successive operational flaws and of the several systems of safety of the Plant.

It is not trivial to emphasize that the probability that Angra 1 and Angra 2 come to suffer simultaneously severe accidents is of the order of $10^{-13}$ to $10^{-14}$, which completely removes this hypothesis of the scenarios considered in the risk analysis.

An accident at one of the Plants, on the other hand, does not have as propagate to the other, not being like this plausible to consider effect of the type domino.

## 2. Latent failures in nuclear complex

### *2.1. Failure external power system*

The external electric system consists of two transmission lines of 500 kV and three 138 kV, as shown in Fig. 1. The system of 500 kV is independent of the one of 138 kV. The two lines of 500 kV interconnect Angra 1 to the substation of Cachoeira Paulista, distance of 80 km, and of Adrianópolis, distance of 120 km.

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The main function of these lines is transmitted to the external network power from Angra 1. However, if the main generator not producing energy and if stay isolated of the electric system, the lines of 500 kV can supply energy to feed, through the auxiliary transformer, T1A1, the loads of the auxiliary system, acting as an alternative source of external energy.

In the substation Adrianópolis, there transformers that reduce the voltage of 500–345 kV and 345–138 kV.

The substation is connected to the *Cachoeira Paulista de Campinas* and *Poços de Caldas* through 500 kV lines.

In the last two substations, transformers reduce the energy transmitted 500–345 kV and 138 kV. Besides the lines of 500 kV, three lines of transmission of 138 kV, with extension of 80 km, interconnect the Nuclear Power Plant to the *Santa Cruz thermal Plant*.

This pertains to Furnas system and is located in the municipality of Rio de Janeiro. Part of the electricity generated by it is dedicated to the *Angra Nuclear Complex – CNAAA*, constituting the main source of external power for electric busbars of security.

The energy provided from the main generator of Angra 2 via 500 kV substation, it possesses a ramification for the transformer auto *TA* and it represents one more source of feeding of the substation of 138 kV.

The region of Angra dos Reis is characterized by the frequent occurrence of sliding slope. According to Pimentel (2010), the region has a set of physical-environmental variables that have a high fragility against dynamic slope processes, both natural and induced by pressure and occupation.

The historic of events of each annual period of rainfall, especially from November to March, affirms the high natural susceptibility of the area of Angra dos Reis front to the dynamic processes in hillsides.

Analyzing the territory of Angra dos Reis under such a view, it is observed from Fig. 2 that shows the distribution of slips between the years 2007 and 2010, there was an intense activity of movement, what configures an important temporary space to evaluate the periodicity of such events and your intensity.

In order to evaluate the vulnerability of the region of Angra dos Reis from the point of view of the sliding, the Fig. 3 shows the susceptibility of the region in relation to dynamic processes of hillside.

The result shows regions with areas of high and very high susceptibility, with predominant occurrence next to the coast, most densely occupied area line, and especially near the access roads, where is concentrated large part of occurrences.

We can observe by the Figs. 2 and 3 that the region has a high rate of slip that besides harming the flow in the highway BR-101, in a possible escape route, it also presents a serious problem with relationship to the supply of energy to the Plant.

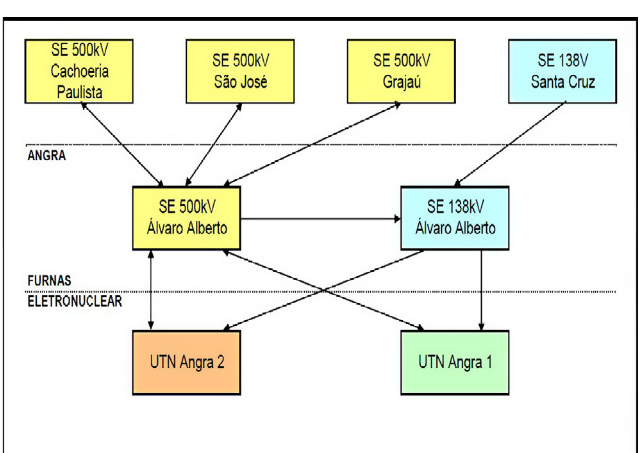


**Fig. 1.** Transmission lines of 500 kV and 138 kV.

The great problem, in this scenario presented, is that the power grid passes exactly in those risk points, doing with that there is a latent flaw in relation towards feeding the Power Plants Angra by external power system.

The External Power System feeds the electrical system (*SE*) of 500 kV and 138 kV which in turn feed the busbars service and security.

Occurring energy loss in busbars of service *1A1* and *1A2*, due to loss of *SE* 500 kV, has the stop of *Reactor Coolant Pump – RCP* and thus the primary coolant circulates by natural circulation that according to the technical specifications of FSAR (2011), is maintained so that the Core Residual Heat Removal System get into the action.

However with successive failures, a Station Blackout in the Plant becomes something imminent, event that will commit the system of residual removal of the nucleus and your integrity.

## 2.2. Failure internal power system

The system of electric supply of emergency of Angra 2 is subdivided into four redundant, partial and independent trains each other, each with 50% of capacity of supply of the potency requested for the execution of safety's functions.

The trains are redundant by virtue of the consideration of the case of flaw of a coincident redundancy with the isolation for maintenance of another redundancy, so that, being $4 \times 50\%$, in the unavailability of two trains the other ones two are enough to control an accident postulate, which considerably decrease a Station Blackout at the Plant.

On the other hand, the electric system emergency supply of Angra 1 is divided into two trains each with 100% capacity supply the power required for the performance of security functions. However, that system $2 \times 100\%$ increases the probability of departure flaw, what turns latent a Station Blackout in this Plant.

Due to this, we will understand as will start a Station Blackout at unit 1. In the internal electrical system of electricity distribution Angra 1, stand out:

- The main generator.
- The main transformer.
- The auxiliary transformer and of service.
- The emergency diesel generators.
- The service busbars and security.

In normal operation, the safety busbars are powered by the lines of 138 kV. In case there is loss of this, attempt is made to fast or slow transfer of T1A1 to T1A2, so that these pass the alimentary the bars 1A3 and 1A4.

These bars are connected to class of loads IE that refers to the essential electric equipments to the shutdown and maintenance of the unit in safe conditions, or to the limitation of the radioactivity liberation for the environment. The classes of loads IE are respectively connected to the busbars 1A3 and 1A4 that are also called, respectively, by *train A* (*branch A*) and *B train* (*branch B*).

The safety bars are redundant, physically separated, independent and electrically isolated to avoid common cause failures. However, with the lack of external power, the main transformer T1 will become inactive, preventing the release of energy to the interconnected system, for the T1A1 auxiliary transformer, which feeds the busbars of service 1A1 and 1A2 and the service transformer T1A2, which feeds the busbars of security 1A3 and 1A4.

In this, each bar of safety is connected to a generator emergency diesel to guarantee the feeding of the essential loads to the safety of the Plant.