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Hybrid Emergency Power Systems for Research Nuclear Reactors

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1. Introduction

In Brazil, there are 4 nuclear reactors directed to research, the most powerful of which is the most powerful of which, the IEA-R1 until the commissioning of the RMB (Brazilian Multipurpose Reactor) that is being developed at the navy technological center in Iperó, expected to be 30 megawatts. These reactors are mainly used for scientific research and manufacture of radiopharmaceuticals. The researches take place in several aspects, where most of them, in a generic way, it comprises of radiating evidence previously prepared to analyze the effects of radiation on materials.

To ensure the continuity and integrity of the research taking place in these reactors, an efficient emergency power supply system (UPS-Uninterruptible Power Suply) must be installed, so that the reactor does not stop operating uninterruptedly, nor allow SAG, SWELL and flicker to cause accidental shutdown of the reactor, and may compromise the tests under test.

The safety shutdown of the reactor used for research generates several drawbacks, such as the problem with the research developed there, because some require the test to be radiated continuously for a certain period of time. In addition, there is reporting, since the shutdown must be documented. It also generates the risk of creating xenon in a way detrimental to the nuclear reaction [1].

In this way, one must wait for the decay of the xenon, and this can take more than 24 hours compromising all the research work that is taking place in the nuclear reactor at that time. [2]

These factors underlie the need to have an effective emergency system of electricity supply, which maintains the attributes of current, voltage and phase of the electrical energy that feeds vital and essential circuits of the reactor, unchanged. This is achieved with effective electrical generation systems and diversifying the generation sources, in order to ensure continuous and quality supply.

For the analysis, the bibliography referring to the theme was considered. The NBR5410 calls "security services", the electrical installation that, for safety reasons, economic or administrative, can not suffer interruptions. [3] And in this context, there are nobreaks to both combustion generators and battery banks. Linard in his work presents that ups (Uninterruptible Power Suply) systems with the online feature continuously provide power to the load, even when there is a lack of power from the utility or disturbances in the supply of electricity. It should thus provide energy to the load so as not to alter its operation.

2. Methodology

The IEA-R1 nuclear research reactor has a load division fed by 3 distinct classes of circuits: a) essential circuits; b) vital circuits; (c) common circuits. This occurs for the classification of loads, as to the unavailability due to interruption in the supply of electricity. This safety rating follows international standards such as classes A, B and C. For loads, and class A loads are essential for operation, safe shutdown or isolation of the nuclear plant and interruption in the operation of these loads can result in accidents with radioactive material. Class B is made up of loads that tolerate minor power outages because they are not directly connected to the safety or insulation of radioactive material, but in a way, they cannot spend much time disconnected for safety reasons. [4]

The CNB-V-02 generator is the emergency power system that guarantees the continuous electrical supply of the reactor's vital circuit, keeping the primary circuit and valves 16 and 18 in operation. These valves are motorized valves responsible for the core emergency cooling system. The Emergency Cooling

System is guaranteed by the GDG-E-02 generator, of 220V, and by the CNB-V-01 nobreak of 220V redundantly, which feed the command of the motorized valves of this system in case of lack of the concessionaire. This same redundant system ensures the operation of the reactor control room. The motors of pumps A and B, although they are equipment in circuits with other loads, meet their well-balanced current and voltage phases. Such pumps feed the primary circuit and have the cacracteristics described in Table 1.

Manufacturer: KSB do Brasil	
Rotation: 1760 rpm	Current: 111A
Power consumed: 57kW	Flywheel diameter: 650mm
Drive: Electric motor Arno AR 315 aB	Flywheel width: 210mm
Power: 100hp / 73.6 kW	Moment of Inertia of the steering wheel: 29 kgf.m²
Voltage: 440V - 60Hz	

Tabela 1. Características da bomba utilizada no circuito essencial. Fonte: o autor.

The current emergency power system of the IEA-R1 nuclear reactor is made up of diesel generators with inertia wheels that support vital and essential circuits as shown in Figure 1.

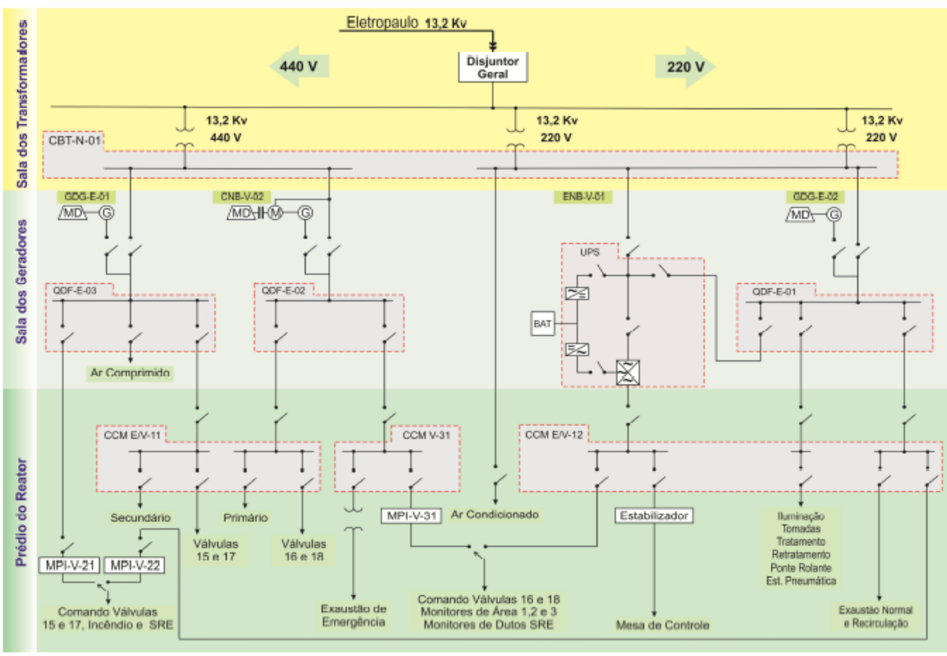

Figure 1. Squeamatic design of the iEA-R1 reactor electrical system. [5]

One can supply the lack in electrical smoothing by the concessionaire through a hybrid system of serial nobreaks with diesel generators, in order to supply the aliemnation of electricity for some time where most of the faults occur, and eliminated undesirable effects such as SAG and SWELL.

In Nobreaks by battery bank, two stages of energy conversion. In the first, there is a rectifier that operates as ac voltage converter in DC voltage and in the second stage, the inverter converts DC voltage into AC for output. Thus, the output voltage will have amplitude, frequency and phase independent of the input, thus being constant and ideal. Being a UPS (Uninterruptible Power Suply) architecture that protects the load against major electrical grid disturbances.

Also, the author analyzed several topologies for the UPS (Uninterruptible Power Suply) and concludes that for high power loads it is recommended the topologies of half-bridge inverters and full bridge, discarding the push-pull topology because it is not indicated for large powers. [6]

In these cases preference should be given to systems with 12-pulse rectifiers. These generate harmonics, and this is inevitable, but in greater order, bringing a minor disturbance to the system. The battery-based NOBREAK system is basically made up of rectifiers and inverters, which rectify the ac to direct current and charge the battery banks. They also transform the direct current of the batteries into alternating to use in the electrical installation when there is a lack of the concessionaire. During rectification, rectifiers and inverters generate harmonic stresses. It happens that between the opening and closing of the thyristors, for a fraction of seconds, there is a short formed by the short circuit condition between thyristors. At this point the short-circuit current provides an RMS voltage drop (SAG or DIP if it lasts more than half a cycle). According to the consulted bibliography, this voltage drop can reach from 0.1 to 0.9 pu.

In these cases, in addition to the emergency system protection system and vital to be able to consider the shutdown of the reactor, it still compromises the service life of the connected motors. An interesting alternative is the use of a parallel system in operation together with the utility's power supply. This is possible with the connection in parallelism. This uninterrupted supply in parallel, taking advantage of the fact that the loads already prove to be balanced, can be guaranteed by renewable energy systems.

It is a requirement for parallelism between two energy sources, that there is the synchronism between them regarding voltage and frequency. Thus, both the parallelism between two nobreak units, and between the nobreak unit and the entry by the concessionaire, must be in sync. One of the units is considered as a reference, and the second unit is monitored for timing.

In relation to the entrance of the concessionaire, this will be the reference. Then, after the timing is complete, the timing circuit breaker is authorized. [7]

3. Results and Discussion

Research reactors are mainly used for scientific research and manufacture of radiopharmaceuticals. The researches take place in several aspects, where, in a generic way, they understand in irradiating evidence prepared previously to analyze the effects of radiation on materials.

These reactors, not designed for power generation, depend entirely on the external power provided by the concessionaire. However, uninterrupted supply of electricity to reactor systems cannot be guaranteed, and there should be emergency power systems, including tactics to mitigate failures in the supply of electricity.

This research aims to mitigate the lack of electricity supply by the use of various solutions in UPS (Uninterruptible Power Suply) systems that have less environmental impact and ensure energy efficiency to the electrical systems of the nuclear reactor. Thus, it analyzes the possibility of using battery nobreaks as UPS together with diesel generators to reduce the number of starters of these generators.

The parallelism of generators with the upturn to batteries is a solution to the disruption that slanding causes in the network. Squealing can generate harmonic voltages that impair the proper functioning of the system. The protection systems of a nuclear reactor do not tolerate such variations. However, it is necessary to remember that there are skeyed generators where the manufacturer ensures a harmonic distortion of less than 5%

4. Conclusions

In order to mitigate the occurrences of these safety shutdowns and ensure the safe operation of the reactor, maintaining the quality of research, a thorough analysis is necessary to adapt the best option to emergency feeding.

The Vital and Essential System of the IEA-R1 nuclear reactor can be supplied by a UPS formed by a battery-powered NOD together with the diesel generator. This can occur in parallelism, where the Battery System, connected online, supports the energization of the reactor circuits immediately after the power outage of the concessionaire. This maneuver occurs only for the start of diesel generators, which should take on average, up to 2 minutes. This would be a considerable upgrade, where the faults that last a few minutes, can be supplanted by the battery banks without the need for the start of diesel generators.

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