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EQ Qualified Life Extension Using Plant Real Data

Marcos C. Silva[1], Grazielle F. Muzitano[2], and Danielle F. Motta[3]

[1]*candeia@eletronuclear.gov.br, Rua da Candelária, 65, Centro, Rio de Janeiro, RJ 20091–906*
[2]*grazi@eletronuclear.gov.br, Rua da Candelária, 65, Centro, Rio de Janeiro, RJ 20091–906*
[3]*dfmotta.concremat@eletronuclear.gov.br, Rodovia Procurador Haroldo Fernandes Duarte BR101 km 521,56 – Itaorna, Angra dos Reis – RJ 23948–000*

1. Extended summary

The Environment Qualification (EQ) Program for Electrical Equipment for Angra 1 Nuclear Power Plant (NPP) aims to assure that the electrical, including instrumentation and control (I&C), equipment can withstand the harsh condition that can happen in case of an accident inside containment.

This type of program started in United State of America after the Three Mile Island 2 accident (1979) when the instrument and electrical equipment used inside the containment of this NPP did not have the intended response because the environment conditions were harsher than expected.

The United States Nuclear Regulatory Commission (NRC) issued a Federal Law 10 CFR 50.49 that obliged all light water reactor to adopt a program to qualify all electric equipment important to safety inside the containment for the expected harsh condition.

This program should cover the equipment necessary to remain functional during and following Design Basis Events (DBE) to ensure:

a) The integrity of the reactor coolant pressure boundary;

b) The capability to shut down the reactor and maintain it in a safe shutdown condition; or

c) The capability to prevent or mitigate the consequences of accidents that could result in potential offsite exposures.

The DBE are defined as conditions of normal operation, including anticipated operational occurrences, design basis accidents, external events, and natural phenomena for which the plant must be designed and that are normally described in the Final Safety Analysis Report (FSAR).

Equipment important to safety are equipment that perform the following functions:

a) Safety-related electric equipment that shut-down the nuclear reactor and start the Engineering Safety Features (ESF);
b) Nonsafety-related electric equipment whose failure can affect the safety-related equipment, and
c) Certain post-accident monitoring equipment.

To assure that the equipment for the EQ program can perform its intended function they are submitted to a process called qualification process.

This process determines if the equipment can withstand all conditions that can be found in normal and abnormal conditions.

Factor like temperature, pressure, humidity, radiation, submergence, chemical effects and aging are considered in the qualification process.

There are several methods to perform the qualification process but the most commonly used is the type test,

In this method, one or more samples of an equipment type are submitted to laboratory conditions that simulated that expected to be found in normal and abnormal operation conditions.

The equipment used inside containment that are classified for use in "harsh" environment that is defined as that environment that modifies its condition in case of an accident.

Natural or artificial (accelerated) aging to its end-of-installed life condition must precondition them and this parameter is very important in the qualification process.

The most common stressors used are temperature and radiation level normally found in the containment during normal operation.

Using the Arrhenius equation the accelerated temperature aging is done putting the equipment in a heat chamber during certain time at an elevated temperature to simulate an equivalent qualified life.

The lowest activation energy of the materials used in the equipment determines how long and in each temperature an equipment should be aged to simulate, for example, a qualified life of 10 years' operating at 50 ^{o}C.

A similar approach is used to pre-age the equipment for radiation, placing them in an irradiation chamber with a gamma ray source.

All the steps done in the qualification process are normally registered in a Qualification Report for each equipment type.

If the qualification process is successful, the manufacturer can produce similar equipment that are used in the plant.

However, to assure that the equipment is within its qualified life, it is necessary to monitor the conditions in normal operation to verify if a higher temperature or radiation can accelerate the aging and reducing the qualified life.

As Angra 1 NPP is approaching its licensed life of 40 years, Eletronuclear started a process with the Brazilian Regulatory Commission (CNEN) to extend the licensed life to more 20 years, called the Long Term Operation (LTO).

The LTO has several steps but one important step is that the EQ program should verify the capability of the existing equipment to operate for this extend period.

One possibility to minimize the replacement of the equipment whose nominal qualified life expires shortly after the 40 year licensed life is to use the real temperature and radiation levels that occurs in the local where this equipment are installed.

For example, if an equipment have a nominal life of 10 years at 50 ^{o}C it can has its qualified life extended for several years if the operation temperature is 35 ^{o}C using the Arrhenius equation.

The same approach can be done with the radiation levels. If an equipment is qualified for 400 Gy Total Integrated Dose (TID) for 40 year operation time and the real radiation level in the place it is installed is 2 Gy per year, it could be used, theoretically for 200 years operating time.

Another approach is to replace some age sensitive parts of the equipment periodically or at the end of the qualified life to refurbish and extend the qualified life.

The aim of this article is to describe the actions that are taken at Angra 1 NPP to monitor the qualified life and with this approach prepare the necessary steps to extend the licensed life of Angra 1 for more 20 years of operating time.