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A NEW CONCEPT FOR ADDRESSING ENVIRONMENTAL QUALIFICATION OF INSTRUMENT AND CONTROL LOOPS IN NUCLEAR POWER PLANTS

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Lucrarea descrie un nou concept şi metodologia de aplicare a acestuia propuse de autori cu privire la procesul de calificare la condiţii de mediu de accident (Environmental Qualification - EQ), respectiv calificarea buclelor de comandă şi control asociate echipamentelor cu funcţie de securitate nucleară. Lucrarea prezintă un exemplu practic de aplicare a acestora prin realizarea unui studiu de caz pentru CANDU-6, utilizând Centrala Nucleară de la Cernavodă ca model. Acest nou concept, precum şi metodologia de aplicare propuse, au ca rezultat îmbunătăţirea modului în care centrala demonstrează îndeplinirea cerinţelor organismelor de reglementare în domeniu, prin demonstrarea capabilităţii sistemelor cu funcţii de securitate nucleară de a-şi îndeplini funcţiile postulate de securitate înainte, în timpul şi după un Accident Bază de Proiectare, creşterea fiabilităţii sistemelor cu funcţii de securitate nucleară, şi respectiv, din punct de vedere al producţiei de energie electrică, creşterea disponibilităţii centralei şi a performanţelor economice.

The paper describes a new concept and methodology proposed by authors regarding Environmental Qualification (EQ) of Control and Command Loops associated with Safety Related Equipment. The paper presents a case study for CANDU-6 using Cernavoda NPP as a model and gives practical example of work. This new concept and proposed approach results in benefits for the plant in terms of demonstrating the compliance with regulatory requirements for preserving the safety systems capability to perform their postulated safety-related functions before, during and following an Design Basis Accident. This increased safety system reliability is also expected to have a positive impact on Plant availability and consequently economic performance..

Keywords: EQ, Environmental Qualification, Instrument and Control Loops

1. Introduction

Environmental Qualification is required only for those components of a safety related system of a Nuclear Power Plant that either performs a safety function or whose failure may prevent a safety system from performing its function when subjected to postulated Plant accident conditions.

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Environmental Qualification is the process of providing and maintaining evidence that certain components are able to perform their safety related function before, during and after a Design Basis Accident (DBA); a High Energy Line Break accident (HELB); a Loss of Coolant Accident (LOCA) or a Main Steam Line Break (MSLB).

The paper describes a new concept and methodology proposed by authors regarding the Environmental Qualification (EQ) of Instrument and Control Loops associated to the Safety Related Equipment. Secondly the paper presents a case study for CANDU-6 using Cernavoda NPP as a model and gives practical example of application of this concept and methodology.

This new concept and proposed approach results in benefits for a Station in terms of demonstrating compliance with regulatory requirements for preservation of safety system capability to perform their safety-related functions before, during and following an Design Basis Accident. This increased safety system reliability is also expected to have a positive impact on Plant availability and consequently economic performance.

2. The Environmental Qualification Concept

2.1 General aspects

Based on international requirements developed by the International Atomic Energy Agency (IAEA) [1], the nuclear safety related functions to be performed by safety related systems are:

- The ability to shutdown the reactor and maintain it in a safe shutdown condition;
- The ability to remove the decay heat;
- The ability to maintain a barrier to limit the release of radioactive material;
- The ability to perform essential safety related control and monitoring functions.

The IAEA requirements have been adopted by various national and international standards and codes of rules. The Bibliography section lists the main codes, standards and guidelines used by the authors for this study [2], [3], [4], [12], [13], [14], [15], [16].

To comply with these codes and standards and to be able to perform required functions during and following a Design Basis Accident (DBA), the safety related systems must have equipment/component that remains functional in harsh environment generated as a result of DBA. This equipment/component must be to be qualified to work in such an environment.

Consequently safety related equipment must be environmentally qualified in order to:

- Operate reliably under normal service conditions in such a manner that it should be able to perform its required safety function(s) in case of DBA;
- Perform its required safety functions during and following any resultant environmental transients due to the postulated accident.

2.2 Requirements

Environmental qualification must be viewed as a continuous process that begins at the design stage of the plant and continues throughout the entire operating life.

First phase - plant, system and equipment design - defines the input data, criteria and requirements necessary to qualify plant equipment and systems. This information includes the safety classification of the systems components, demonstration of equipment performance under DBA as well as normal and abnormal service conditions. At the end of this phase, systems and equipment are selected; a master EQ Equipment List is generated and qualification requirements are specified.

The second phase consists of the following major activities:

- **equipment design verification activities**, in which qualification is accomplished. It consist of qualification testing; engineering analysis; evaluation of operational experience and generation of tests or qualification; and defining required surveillance, maintenance and replacement practices;
- **aquisition and use activities**, in which the equipment is procured and installed. It refers to the range of activities resulting in the purchase, installation and initial operation of the qualified equipment;
- **qualification preservation activities**, that encompasses activities such as inspections, testing and preventive maintenance during the entire life of the plant.

Once the plant is “In Service” it is necessary to perform those activities to ensure that the installed equipment remains qualified throughout its installed life. These activities include preventive maintenance; inspections, surveillance, testing and condition monitoring; equipment replacement and use of qualified spare parts.

2.3 Environmental conditions

Based on the definition provided in ref. [4] and [5], a "Design Basis Accident (DBA) "is a postulated accident selected from the plant safety analysis and is used to establish the acceptable performance criteria for systems, structures, and equipment".

Safety related system and components are required to perform their safety functions in an environment that is classified as either "Normal Service Conditions" or "Accident Service Conditions".

Particularly for CANDU 6 Nuclear Power Plants [5], the environmental parameters values, both for Normal Service Conditions and for Accident Service Conditions inside the Reactor Building, are as follows:

<u>Normal Service Conditions:</u>

I. *Outside the Reactor Building:*

- ✓ Temperature 5 to 50°C
- ✓ Relative Humidity up to 95%

II. *Inside the Reactor Building:*

- ✓ Temperature 30 to 70°C
- ✓ Relative Humidity up to 95%
- ✓ Radiation $2.7*10^{-5}$ Gray/s (10 Rad/hr) and up to $2.7*10^{-4}$ Gray/s (100 Rad/hr) in Feeder Cabinets
- ✓ Pressure - Atmospheric (or slightly less)

<u>Accident Service Conditions, inside the Reactor Building</u>

- ✓ Peak temperature 121°C
- ✓ Peak pressure 1050 mmHg (g)
- ✓ Radiation 10^5 Gray (10^7 Rad), that includes:
  $7x10^4$ Gray ($7x10^6$ Rad), integrated dose over long term following a LOCA
  $3x10^4$ Gray ($3x10^6$ Rad), integrated normal dose over Station life of 30 years
- ✓ Relative humidity 100%

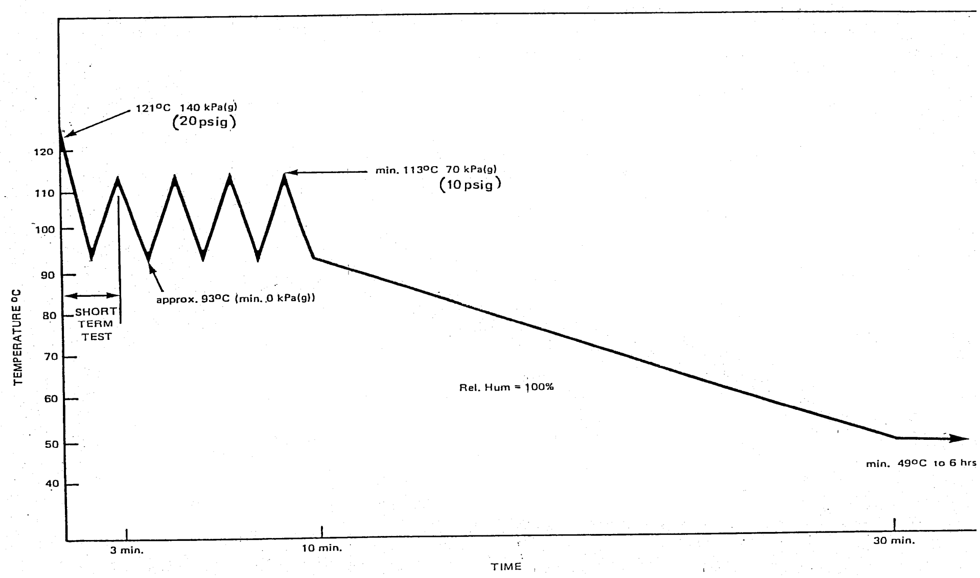

Fig. 1. CANDU-6 generic DBA profile

Fig.1 presents the theoretical evolution of environmental conditions, inside of CANDU 6 reactors containment versus time, during and after a DBA [5].

3. Qualification of EQ equipment loops

3.1 Necessity

The relevant standards, IEEE 323-2003 [3] and CAN CSA N290.13-05 [4], provide guidance on how to qualify and maintain the qualification of safety-related equipment respectively, but do not address the qualification of the Instrument and Control Loops to the subcomponent and accessory level..

Based on operating experience, provided by a large range of US and other foreign Nuclear Power Plants, most plant operators' use a simple equipment qualification process, and only consider qualification of the whole loop. Evaluation of this approach shows a gap in providing the assurance of the integrity and functionality of the loops during and following a DBA to perform required function(s).

The main findings of this evaluation are:

- I&C Loop components and accessories such as control instrumentation, cables, racks, connectors etc were not qualified;
- Cross connections between test reports and equipment was improper;
- Testing documents were for varied plants (varied DBA condition) and incomplete;

- Equipment was not qualified or only partially qualified;

The major issues regarding these past approaches is that they did not consider the qualification of the loop constituents as a result the plant staff would be unable to demonstrate that the safety-related equipment is able to perform it's required safety function.

The ability of equipment to perform credited functions is determined by two main factors:

1. Main equipment ability to perform their safety-related function in postulated environmental conditions;
2. Loop subcomponents and accessories ability to transfer, in postulated environmental conditions, the signal and/or provide power to/from main equipment in supporting that equipment to perform the required safety-related function

It can be easily seen that the traditional qualification methodology addresses only the first factor, and doesn't take into consideration the loop subcomponents and accessories. A new concept proposed by the authors, "Loop Qualification", covers the gap by taking in consideration all components from loops exposed to harsh environment and qualifies the Instrument and Control Loop as one entity.

3.2 EQ Equipment Loop Assessments

The concept proposed by the authors provide a methodology for identifying loops sub components and documentation necessary to demonstrate qualification of control and command loops starting with safety related equipment from safety analysis. The new concept is expected to increase the reliability of the loops that have a major impact in term of safety and operational costs (maintenance costs and forced shut-down).

Additionally, the evaluation process are used for completing the EQ main equipment list and also the EQ Data base "Spare parts and replacement interval", in order to identify and establish preventive maintenance activities related to qualified components, as part of EQ Program and Preventive Maintenance Program.

The evaluation process for environmental qualification of I&C loops is a complex process, which requires assessment of design documentation, safety analyses for postulated accidents, operating documentation, systems and equipment modification history and equipment history.

The work-flow diagram used by authors in the case study for CANDU 6 is illustrated in Fig. 2.

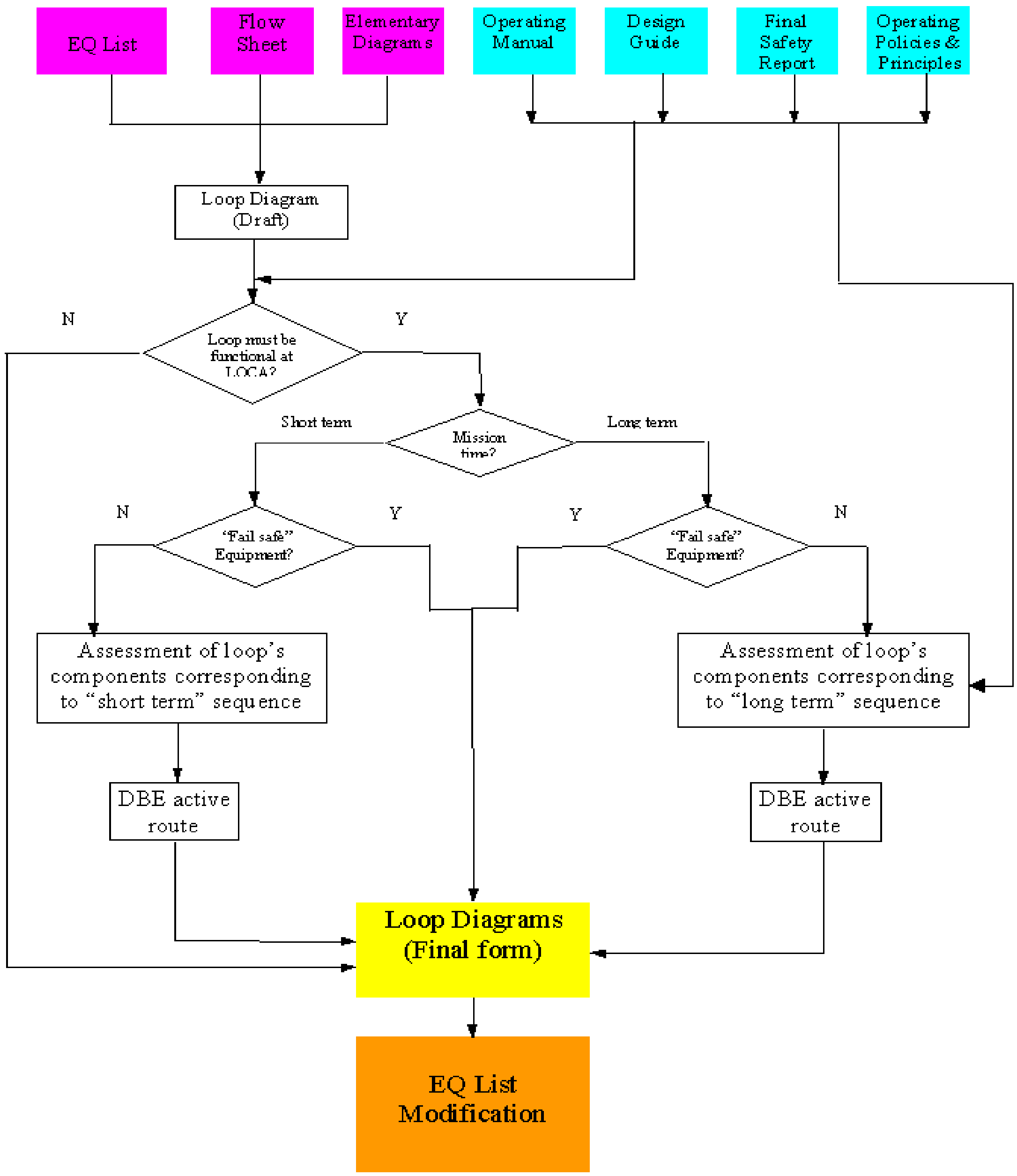

Fig. 2. Qualification of EQ Equipment's Loops – Work-flow diagram

First step of this process is to identify the EQ equipment's Instrument and Control Loop. Identification of loops is based on EQ Equipment List, Operating Flow Sheets and Elementary Diagrams. Based on the EQ List, main equipment (valves, pumps, motors etc.) are identified and related Instrument and Control Loop are documented showing subcomponents and accessories Preliminary loops diagram can then be issued (Fig. 3) [6].

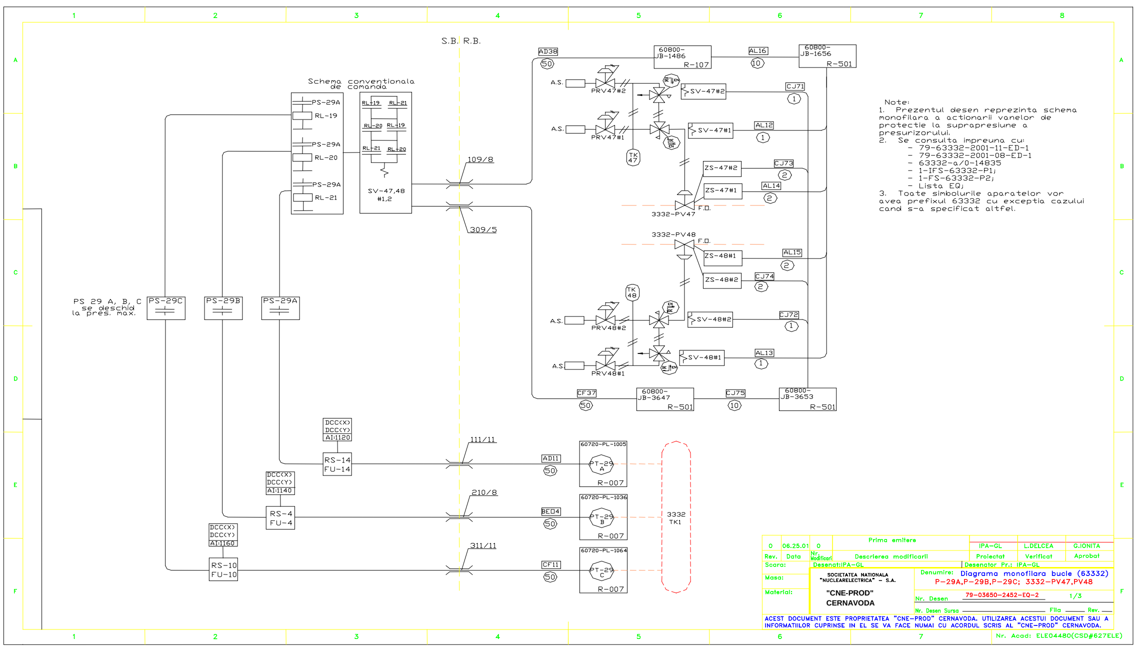

Fig. 3. Loop Diagrams

After the loop diagrams are completed, by using safety analyses, loop functional role ca be identified on the main component/equipment before, during and following a LOCA/MSLB, assessment shall be done after that for each loop's equipment/components. As input date, for loops and loop's component assessment, it will be used data from systems design documentation, operating documentation, Final Safety Report and field data.

The assessment processes start with failure mode analyses for main equipment and it's related safety function. Assessment is made only for those parts of the loop and components located in the Reactor Vault.

If main equipment is not required to operate during and following a DBA or its safety function is passive – fail open or fail close. Then related loop components do not need to be qualified.

If main equipment must operate during and following a DBE, all loop components located in the Reactor Building must be qualified, including cables, connectors, junction boxes, racks, boosters, quick exhaust, etc.

4. Conclusions

The new concept and methodology proposed by authors should result in benefits for the stations in terms of demonstrating the compliance with regulatory requirements for preserving the safety systems capability to perform their postulated safety-related functions before, during and following an Design Basis Accident, increase systems reliability and from plants production point of view have a positive impact into the plant availability and economic performance.

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