Acceptance criteria in nuclear power plant cable qualification

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ABSTRACT

Nuclear power plant (NPP) equipment qualification is a fundamental process to test whether safety systems and equipment can perform their intended functions during normal operation, as well as during postulated accidents (DBE). In the process of qualification all samples are subjected to diagnostic measurements to test whether the equipment fulfils all previously defined acceptance criteria. The criteria are usually limit values of certain properties beyond which the degree of deterioration is considered to reduce the material´s ability to withstand stress encountered in the course of the regular service and/or DBE. The extent of measured properties and the acceptance criteria may vary and, generally, they depend on a specific cable application in each respective NPP. The most commonly tested parameters are insulation resistance, voltage withstand and mechanical properties of polymeric insulations. The acceptance (failure) criteria shall be, on the one hand, conservative enough to sufficiently cover margins and uncertainties and, on the other hand, they shall not be too demanding to give needlessly negative results. In this paper some acceptance criteria are explained and proposed.

KEYWORDS

qualification, cable, acceptance criteria, nuclear power plants.

INTRODUCTION

It is fundamental for the safe operation of commercial NPPs and for the protection of public health and safety through regulation to ensure that safety systems and equipment are able to perform their intended functions during normal operation, earthquakes, and postulated accidents (DBE – design basis events) which may e.g. include the loss-of-coolant-accident (LOCA). Such an accident results from the loss of reactor coolant from breaks in the reactor coolant pressure boundary including a break equivalent in size to the double-ended rupture of largest pipe of reactor core system. The conditions of DBE are characterized by high level of radiation, rapid increase of temperature and temperature a spray solution application. The DBE can follow in post-accident period, which may take up to 1 year and the cable must be all the time able to fulfil required functions.

The process of demonstrating that safety systems and equipment are able to perform as required is called “equipment qualification” [1]. The equipment can be qualified using one of the following methods or a combination thereof: testing, analysis of existing data and operating experience. Testing refers to a sequence of tests which are all performed on the same sample [1-2]. The first set of tests is designed to simulate in-service ageing in order to predict the equipment condition at the end of its service life. The second set of tests is intended to simulate the service conditions encountered during extreme design base events (both seismic and accident events) which may occur during any time of NPP regular operation.

The basic goal of qualification is to demonstrate that the material is capable to fulfil its functions until the end of its planned service life, during and subsequent to DBE. Therefore the equipment is exposed to accelerated environmental conditions to bring it into the same condition as after a long time ageing in service and DBE period.

The usual cable qualification procedure is performed in the following specific order:

- Visual inspection
- Measurement of initial functional properties
- Simulation of ageing in normal operation (pre-ageing)
- Testing of functional properties
- Simulation of the accident and post-accident period
- Measurement of final properties
- Final visual inspection

The setup of test parameters to simulate the service ageing, as well as postulated accidents, can be relatively easily derived from standards and/or recommendations [1,2,4,5]. However, it is more complicated to identify the appropriate functional properties to be tested and their acceptance criteria. This means to select the properties and their values that will confirm the functionality of the tested cable in the real service, as well as during accident(s) and post-accident period.

FUNCTIONAL PROPERTIES

During the qualification the cables are subjected to a diagnostic measurement procedure. The extent of the measured properties may vary and, generally, the procedure is based on a specific cable application in the respective NPP. The most important are electrical and mechanical properties of polymeric insulation materials. In general, the functional properties to be measured are those that demonstrate the basic properties and behavior of the cable during its service life and during postulated accidents. Moreover, the extent of the testing shall not be uselessly excessive. Usually, an engineering analysis should be used to justify the critical characteristics for specific NPP applications.

ACCEPTANCE CRITERIA

Setting the appropriate acceptance criteria is often one of the most difficult parts of the qualification. The criteria are usually the limit values of properties beyond which the degree of deterioration is considered to reduce the ability of the cable to withstand stress encountered in normal service and during accidents. The acceptance criteria shall be, on the one hand, conservative enough to