Design-Basis-Accident Testing of Low-Voltage Electrical Cables Retrieved from Nuclear Reactor Buildings

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ABSTRACT

A series of low-voltage electrical cables retrieved from CANDU nuclear reactor buildings were exposed to design-basis-accident (DBA) conditions to assess the resulting cable insulation degradation.

The insulation materials selected for DBA testing were PVC mildly aged in service, PVC severely aged in service, EPR mildly aged in service, EPR laboratory-aged to near-end of service, XLPE mildly aged in service and XLPE significantly irradiated in service.

Insulation degradation was assessed using tensile testing, and electrical diagnostic tests. Cable insulation condition assessment was performed at each stage of the process: in the as-retrieved condition, after DBA irradiation, and during and following application of a DBA temperature and pressure profile.

KEYWORDS

Cable insulation, cable degradation, nuclear reactors, design-basis accident, condition assessment, environmental qualification.

INTRODUCTION

In nuclear power plants, many cables are subjected to environmental stressors such as high temperature, radiation, humidity, or vibration during both normal and abnormal conditions of operation.

Research data and operational experience show that cable materials exposed to these environmental stressors will degrade over time; thereby, resulting in loss of dielectric strength, increased leakage current and changes in mechanical properties. The main stressors causing age-related degradation are elevated temperatures and ionizing radiation. Cables may degrade sufficiently under long-term exposure to normal service conditions and could potentially fail as a result of unplanned exposure to harsher environments (i.e., hot spots) or when called upon to operate under or following exposure to the severe conditions of a design basis event such as, for example, a loss of coolant.

At plant inception, environmental qualification (EQ) was performed for safety-related cables that could be subjected to service-life aging and to the harsh conditions of a potential design-basis accident (DBA). EQ was also conducted for cables associated with production-sensitive electrical equipment. The purpose of the EQ work was to demonstrate that cables and their interfaces were able to perform their safety functions when required at any time throughout their expected service life. The main objective of the initial EQ work was to confirm that cables would remain functional for a pre-determined service-life duration and there is consensus today that the initial EQ work performed was reliable for cables qualified for the targeted service lives of 30 to 40 years. However, it is difficult to rely on this initial EQ work to justify extending cable service life for up to 60 or 80 years. The main challenge when attempting to use initial qualification results for life extension is that, at plant inception, the condition of tested cables was not fully characterized throughout the entire qualification process [1]. Cables were usually aged for the equivalent of the targeted service life and then tested for accident conditions to be eventually declared qualified or not for the targeted 30-40 years of expected service (go - no go type of output results). Since it was not needed at the time, the scope of work did not include post-EQ condition assessments and there was no requirement to assess for how long cables could have remained for extended service beyond the originally-targeted service-life duration. There was no characterization of cable condition prior to and after the accident tests using various condition indicators and therefore no assessment of the additional cable degradation that resulted from exposure to accident conditions.

There is growing interest in producing test data to assess the additional cable degradation from exposure to DBA conditions and some relevant results have been published [2]. Such data contributes to improved means of predicting remaining cable service life. The intent of this paper is to disseminate test results pertaining to exposure to DBA conditions of polyvinyl chloride (PVC), cross-linked polyethylene (XLPE) and ethylene propylene rubber (EPR) insulated cable samples retrieved from CANDU® plant reactor buildings.

APPROACH

Over the past few years, Canadian Nuclear Laboratories (CNL) conducted several condition assessments of electrical cables retrieved from nuclear reactor buildings. Some of these retrieved cable samples were recently exposed to DBA conditions. The intent was to assess the additional cable degradation that would result from exposure to these accident conditions. Work for this latest study was conducted in collaboration with Kinectrics Inc.

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