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Nuclear Power Reactors Ageing Monitoring

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Introduction

The global nuclear power industry is being forced to deal with the difficulties of ageing, caused by stressors like temperature, humidity, radiation, electricity, and vibration, in key instrument & control components like pressure transmitters, temperature sensors, neutron detectors, and cables. This is due to pressure to improve plant efficiency and maximise safety as well as the ageing of existing NPPs. Traditional ageing management techniques called for shutting down the process in order to replace old equipment. Online monitoring (OLM), a group of recent ageing management technologies, gives plants the ability to keep an eye on the health and ageing of their installed I&C while the plant is in operation. These OLM techniques were created through global R&D projects and comprise low- and high-frequency approaches that rely on already-existing sensors, like noise analysis, as well as methods based on test or diagnostic sensors. The Electric Power Research Institute (EPRI), the International Atomic Energy Agency (IAEA), and the Halden Reactor Project (HRP) in Norway are a few examples of national and international organisations that support the nuclear power industry and have led R&D efforts to comprehend NPP ageing, come up with ageing management strategies, and meet industry regulations. For instance, EPRI's Materials Degradation/Aging Action Plan for 2011 focuses on the following four thrusts: PWR steam generator management, primary systems corrosion research, pressurized water reactor materials reliability, and boiling water reactor vessel and internals. Similar to this, HRP's research on cable ageing led to the development of a method that is currently used to determine whether and how much industrial cable insulation has been compromised [1,2].

Description

The deterioration of the transmitter's accuracy and reaction time are its two main effects. The transmitter sealing materials may degrade due to ageing brought on by heat and humidity, allowing moisture to enter the transmitter housing. This may result in high-frequency noise and calibration shifts at the transmitter's output, making it unreliable or inoperable. According to failure data for nuclear power plant I&C, calibration drift is responsible for anywhere between 59 and 77 percent of all age-related pressure transmitter failure. A temperature sensor's response time is influenced by installation and process parameters, particularly temperature and flow. RTD and thermocouple seals that are getting old can dry out, shrink, or crack, allowing moisture into the sensor and reducing insulation resistance. Long-term exposure to the heat, humidity, vibration, temperature cycling, mechanical shock, and/or other taxing conditions present in NPP settings is what causes the typical ageing of temperature sensors. Due to the varying thermal-expansion coefficients in the RTD sensor material, the effect of temperature is most significant. Every time the temperature fluctuates, this makes the element stressed. The resistance of the sensing element typically rises under tensile stress and falls under compression stress. RTDs made for nuclear applications may have calibration drift, response-time degradation, lower insulation resistance, irregular output, and other issues. The most crucial capabilities impacted by ageing, however, are the sensor calibration and reaction time, just like with pressure transmitters [3,4].

Flux detectors made of Boron Trifluoride (BF_3) may malfunction due to ionic attack on the central wire in the ionisation chambers. The deterioration of insulating resistance can alter the sensitivity of the sensor in fission couples, fission chambers, or self-powered neutron detectors. Each type of flux detector's sensor has a characteristic response curve function, and the response curve is typically altered by the ageing mechanism. Age often causes neutron detector response times to rise. Due to their hostile surroundings and weak signals, neutron flux detectors are also susceptible to cable and connector issues. Finally, the detector manufacturer will have an impact on the ageing sensitivity of neutron detectors. Some manufacturers suggest replacing detectors every five years. The breakdown of a sensor and the lack of knowledge of this issue by control room staff both played major roles in the disaster sequence. The TMI catastrophe prompted additional research and development in the areas of I&C system design, signal validation, and the contribution of human error to the comprehension and application of I&C data. Before TMI, NPPs had adopted a "event-oriented" approach to handling accidents, in which operators first established the reason for an incident before making sure that safety-critical limits weren't exceeded. Following TMI, a "symptom-oriented" mentality developed, requiring operators to check that safety-critical criteria were not being violated before identifying causes [1,5].

OLM methods can be divided into groups based on the equipment on which they are applied. Since mechanical equipment, such as pumps, valves, motors, and compressors, makes up the majority of the equipment in nuclear reactors, vibration monitoring is the main component of condition monitoring programmes for most plants. Oil analysis, infrared thermography, and ultrasonic testing are also employed. Motor Current Signature Analysis (MCSA), which can be used both when a process is running and when it is shut down, can be used to monitor electrical equipment. The condition of electrical equipment can also be checked using infrared thermography and ultrasound. For immovable parts like tanks and vessels, visual inspection is a useful technique to keep an eye on their status. Non-destructive Testing (NDT) methods are another. The ageing of crucial Instrumentation and Control (I&C) parts such pressure transmitters, temperature sensors, neutron detectors, and cables has become an increasingly important concern due to recent efforts to increase plant efficiency and promote safety as well as the advancing age of existing NPPs. Utilizing Online Monitoring (OLM) approaches, plants may keep track of the installed I&C's ageing while they are running. OLM techniques include low- and high-frequency approaches that rely on already-installed sensors, like noise analysis; approaches based on test or diagnostic sensors; and approaches based on active measurements, which involve injecting a test signal into the component being tested, be it a sensor, a cable, or another object [2, 4].

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Conflict of Interest

The authors reported no potential conflict of interest.

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