Transactions **of the SMiRT 27**
Yokohama, Japan, March 3-8, 2024
Division VIII

I&C Aging Management in Paks NPP

Balázs Kocsis[1]

[1] Equipment engineer, MVM Paks NPP Ltd, Paks, Hungary (kocsisb@npp.hu)
Economist PhD student, University of Pécs

ABSTRACT

This study addresses the challenges of managing the ageing of instrumentation and controls (I&C) at MVM Paks NPP. Focusing on the specific aspects of material degradation in the nuclear environment, it emphasises the need to identify and mitigate external and internal ageing effects. MVM Paks NPP has an ageing management framework aligned with industry guidelines and regulatory frameworks to ensure the integrity of critical systems throughout their life cycle. The Maintenance Rule (MR) serves as a key regulatory tool that emphasises a systematic approach to the monitoring of maintenance activities. Although currently the Reactor Protection System (RPS) is the only I&C system covered by MR, ageing management practices cover all elements involved in age-related degradation. The study highlights the importance of the Failure In Time (FIT) metric in reliability planning, which allows informed decisions and targeted actions to optimize system reliability.

INTRODUCTION

Degradation of materials, in not only mechanical SSCs, indeed electrical equipment in a Nuclear Power Plant is a unique challenge. Many of these components work under harsh environments, such as high temperatures or sometimes exposed to radiation. Using the right material, choosing the most economical solution and maintaining it also gives hard work to the engineers and economists as well. There are many in-house practices about how to manage the reliability and profitability the plant, but we haven't a general solution for the processes. Changes in physical or mechanical properties of materials during an NPP lifetime is commonly named "aging" *(Tipping, P., 1996)*

Because fundamental causes of ageing and loss of reliability are real risks, we must try to identify and limit external and internal effects. Without being able to prevent I&C from ageing, we should try to slow it down as much as possible. It is essential to develop an appropriate policy for maintenance and MRO (Maintenance, Repair and Operation). Although based on relatively old technology, nuclear power plant I&C systems are still potentially susceptible to ageing, and in general, are still potentially susceptible to ageing, based on the time factor. Active components of plants manufactured in the 1980s and 1990s, provided they are state-of-the-art at the time, can be considered to have a lifetime of 50 years or more.

Lifetime of SSCs, although long, are roughly equivalent to the design lifetime of nuclear power plants. If the aim is to extend, it is necessary to ensure that the systems are operational throughout the whole time. For this reason, it is quite common that the difference between the total plant lifetime, the theoretical lifetime of the SSC and the actual lifetime of the components inside it can be quite large. Therefore, we need to adopt a number of good practices to limit degradation effects and be able to assess their ageing (if only to know whether new practices should be adopted, whether the system should be refurbished or replaced)

Good practices determined by several basic things. The most important is to limit external factors to prolong the life of equipment while keeping an optimum level of reliability.

They can be divided into three main categories: *(EPRI, 2010)*

- monitoring ageing (types of analysis, frequency, etc.),
- monitoring ageing processes
- examining factors to mitigate external influences

Like other power plants, Paks NPP has a number of procedures in place to monitor, mitigate or eliminate the impact of the environment on SSCs, mostly focused on mechanical parts, because performance monitoring is closely linked with the safety of Pressure Vessel. There is only one I&C safety system included to scope, the Reactor Protection System (RPS).

AGING MANAGEMENT FRAMEWORK FOR I&C

The high-level management should set overall goals, objectives and commitments for the plant and then communicate these goals, objectives, and commitments to the employees. The development of plant-specific policies, constraints and processes is essential to ensure that I&C ageing management processes are implemented in a way that is consistent with business objectives. (Kaneki et al., 2003) There is a relevant IAEA guideline in consistent with EPRI for I&C equipment, developed in the framework of the IGALL project under the reference AMP218, which addresses in detail with both on-site and periodic electrical measurements with independent mobile test tools.

Determine the scope

The scope of I&C's Ageing Management Framework includes a thorough and systematic approach to help ensure the integrity and functionality of critical systems as they age. The framework addresses the identification and prioritisation of I&C systems and components within a facility and includes the assessment of safety relevance and the identification of measures to mitigate ageing mechanisms and phenomena. The scope includes life cycle planning, which covers the design, installation, operation, maintenance, and decommissioning phases, with a particular focus on technology refresh and obsolescence management. Interactions with different systems, documentation, and inventory management, as well as training and competence programmes are also within the scope of the framework, which are necessary to address the challenges of ageing I&C systems, contributing to sustainable safe and reliable operations.

The key regulatory framework used by the Paks Nuclear Power Plant is based on the Maintenance Rule (MR) codified by the US Nuclear Regulatory Commission (NRC) at 10 CFR 50.65 and Industry Guideline NUMARC-9301. This performance-based regulation introduces a systematic approach to monitoring and evaluating maintenance activities, with an emphasis on the operability of safety-critical structures, systems, and components (SSCs). Licensees are required to categorise and prioritise SSCs based on their safety relevance, develop adaptive planning processes, and conduct regular assessments to ensure continued effectiveness. If weaknesses are identified, corrective action should be taken. Documentation and reporting play a crucial role. By promoting a proactive and systematic approach to maintenance, the maintenance rule is a vital role in maintaining the safety and reliability standards of the nuclear power plant.

As it is written before, the RPS is the only one I&C system that the plant has included to the scope, so it is the part of the MR. Obviously, ageing management covers all elements involved in age-related degradation processes, but the monitoring of their performance degradation is limited to the technical, maintenance departments. Those systems that have a dedicated role and are under the MR scope are also supervised by the systems engineering department. There are many mechanical systems included in the scope, that is clearly visible in the *Figure 1*., their performance monitoring is driven by same method as RPS.

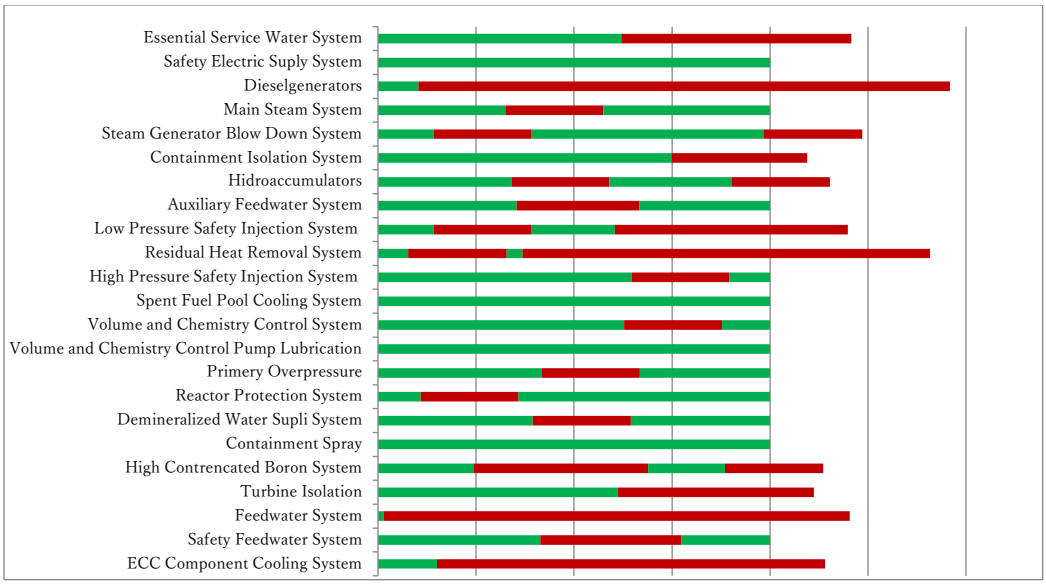

Figure 1. Systems included in MR with performance chart.

Selection of performance indicators

In the area of reliability planning, the correct use of the Failure In Time (FIT) metric is key for the maintenance department. It is a critical metric for assessing the reliability of components and systems. A single FIT represents one failure in one billion hours of operation. The relationship between FIT and failure rate over time (λ):

$$\lambda = \frac{FIT}{10^9}$$

For example, if a component has a Time Failure Rate of $1\,x\,10^{-6}$ failures per hour, its FIT value would be $1\,x\,10^{-6}x\,10^{9} = 1{,}000\,FIT$.

This allows organisations to make informed decisions based on predictive modelling and risk assessment. To harness the power of FIT, daily data collection practices need to be aligned with the principles of the metric. Maintenance teams focus on data collection, including failure occurrence, duration, and environmental conditions, which is a basic requirement for strategic data collection. Using this methodology, it is possible to focus on common failures, identifying patterns of failures that affect the overall FIT rate. This approach allows targeted actions, addressing the most significant failure modes and optimising system reliability.

A sample chart is visible in *Figure 2* generated from the collected and predefined data. The approach facilitates predictive modelling, allowing organisations to forecast failure rates under different conditions. By using historical data and incorporating environmental factors, maintenance teams can anticipate potential failure scenarios and proactively implement preventive measures. Corrective actions are thus given a level of accuracy that goes beyond immediate problem resolution by targeting root causes, effectively increasing overall system reliability. This concept aligns maintenance efforts with long-term reliability goals.

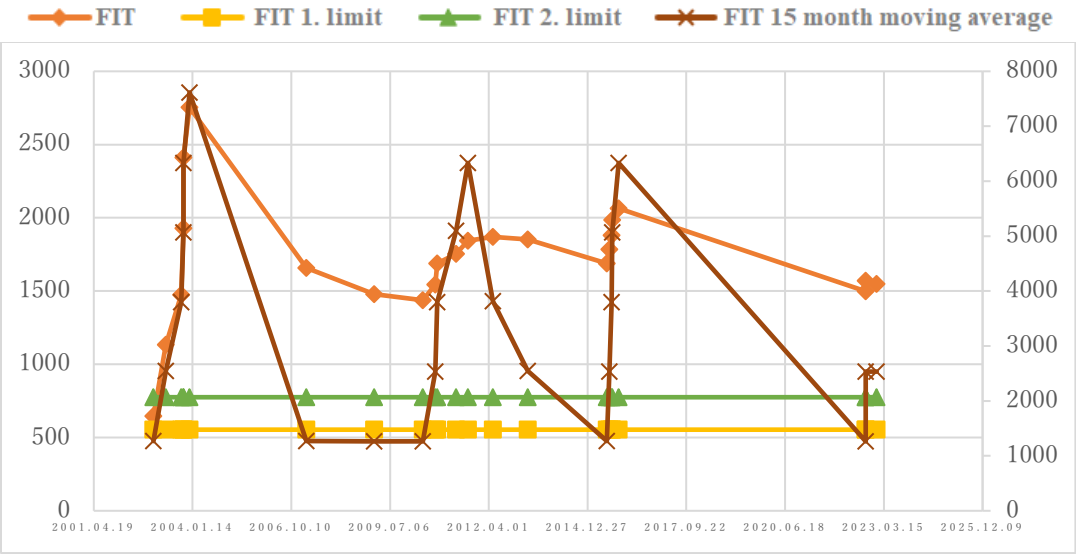

Figure 2. Sample chart from the software of maintenance department

In the context of the system-level assessment of equipment and components, several key aspects have been identified. First, the abbreviation "EF" draws attention to the potential loss of functionality of the equipment or component and urges an examination of whether there are any deficiencies. The second consideration, referred to as "MRFF", focuses on the criticality of the component. It encourages an assessment of whether the failure of a component could result in loss of system operation or degradation of redundancy, emphasising the importance of maintaining backup systems. Finally, the third aspect, abbreviated "MPFF", covers the area of maintenance planning. These three factors could be identified easily in the software of system engineering department on the *Figure 3*. It examines whether there is an established Aging Management (AM) or Preventive Maintenance (PM) Programme for the component in consideration. This highlights the importance of proactive maintenance strategies to ensure the continuous reliability and operability of critical components within a wider operational framework. Together, these assessments form a comprehensive approach to managing equipment integrity and strengthening system reliability.

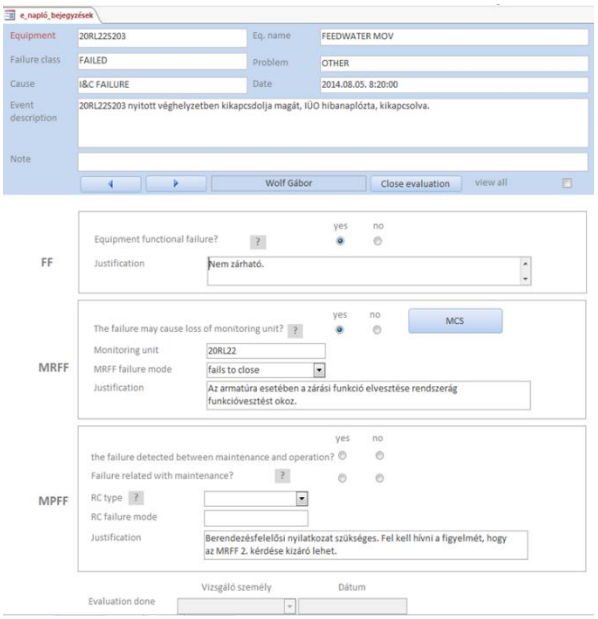

Figure 3. Sample screen from the software of system engineering department

Initiate corrective action programme

Initiating a corrective action programme for I&C ageing management involves the systematic application of a plan-do-check-action (PDCA) cycle. The first step in the planning phase is to identify in detail the challenges associated with ageing of instrumentation and controls (I&C), highlighting material degradation and potential reliability issues. Clear and measurable targets are then specified for a corrective action programme to mitigate the effects of ageing and ensure compliance with regulatory guidelines. A multi-disciplinary approach is required to implement the plan, which is why a multi-level oversight structure has been developed, consisting of component engineers, maintenance experts, system engineers, which provides a collaborative force to address the complex problems of I&C ageing. (José Antonio B. et al, 2009)

Involving the implementation of corrective actions driven by the PDCA cycle, need to be identified in the design phase. This includes strategies such as increased monitoring of ageing components, technology upgrade initiatives and proactive maintenance approaches. Transparent communication of these activities to all stakeholders is crucial, emphasising the importance of addressing the challenges of ageing. To ensure effective implementation of corrective actions, it is necessary to ensure appropriate resources, including personnel, tools, and technology. The monitoring phase will include continuous monitoring and evaluation, focusing on assessing the effectiveness of the measures implemented. This includes collecting and analysing data on the performance of components, comparing the results with the objectives set and making any necessary adjustments to optimise the results. The final phase, Action, involves standardizing successful processes and documenting lessons learned. Additional actions will be initiated as needed, ensuring that the corrective action programme remains adaptable and responsive.

OPERATION EXPERIENCE

The TELEPERM XS SLLM L2 interconnection module is built in a rugged metal housing as visible in *Figure 4*, for optical PROFIBUS fieldbus networks, the TELEPERM XS system. It connects electrical PROFIBUS interfaces to optical PROFIBUS interfaces and vice versa. The module has four separate channels, two electrical and two optical channels, powered by 24 V DC supply. The signal contacts (relay with rocker contacts) are used for sign various module failures to a central station.

Figure 4. Siemens SLLM module

Average failure rate (FIT) given by the manufacturer Siemens for the SLLM L2 contact module:

- At 40°C: 1100 fit
- At 28°C: 480 fit

This indicator gives the number of failures expected on the system under test during 109 hours of operation. Based on this definition, Siemens allows for a failure rate of between 0.48 and 1.1 per 1 million operating hours for SLLM modules, depending on the operating temperature. The operating temperature of the modules is between 28°C and 40°C. *(Siemens, 2017*)

Number of failures of the SLLM modules installed in the RPS is below the manufacturer's values, at 38.61% of the 480 allowed failures per 28°C. However, the number of failures has been increasing since 2014, which is the basepoint of our measurement. If we take the accumulated operating hours for the last period, we obtain 11.85 million operating hours, giving a FIT of 421.94, which still corresponds to the manufacturer's permissible value for an operating temperature of 28 °C.

The successor of Siemens for the TELEPERM XS range is Framatome, which no longer produces SLLM modules, but we have enough spare parts, totalling 132, which is 75 % of the installed quantity in continuous operation. However, due to the increase in the number of failures since 2014, to avoid reaching the FIT value specified by the manufacturer and to ensure reliable operation, it is necessary for the maintenance department to monitor the trend in terms of number and type of failures and to define intervention levels, which, if reached, require a decision on the introduction of further measures.

CONCLUSION

In the challenging environment of I&C ageing management, collaboration between engineering and business professionals is proving to be key. The unique challenges posed by materials degradation, particularly in the context of electrical equipment, require a strategic and integrated approach. Recognition of ageing as a fundamental risk underlines the importance of identifying and limiting external and internal impacts. While the complete prevention of I&C ageing is a challenge, the development of strategies to slow it down is essential.

In line with industry guidelines and regulatory frameworks, MVM Paks NPP has implemented an ageing management framework for I&C that includes a thorough and systematic approach. This includes the identification, prioritisation and safety assessment of systems and components throughout their life cycle. The scope covers technology upgrades, obsolescence management and interactions with different systems, contributing to sustainable safe and reliable operations.

REFERENCES

EPRI (2010). Guidance for Aging Management of Instrumentation and Control (I&C) Circuit Cards and Components Based on Electricite de France (EDF) Experience

José Antonio B. Carvalho1 , Paulo F. F. Frutuoso e Melo2 and Pedro L. C. Saldanha1 (2009). A Proposal of Safety Indicators Aggregation to Assess the Safety management Effectiveness of Nuclear Power Plants, INAC 2009, Brazil

Kaneki NARIKUNI, Kazuhide TOMITA (2003). How to Lead the I&C Modernization Project Example of Genkai 1&2, 31 March – 5 April 2003, Helsinki, Finland

Siemens (2017). Teleperm XS User Manual, TXS Core-SW Release 3.6.7

Tipping P. (1996). *Lifetime and ageing management of nuclear power plants: A brief overview of some light water reactor component ageing degradation problems and ways of mitigation*, International Journal of Pressure Vessels and Piping, Volume 66