AGING MANAGEMENT STRATEGY FOR SAFETY ASPECTS OF LONG TERM OPERATION (SALTO) IN KOEBERG NUCLEAR POWER STATION

Eskom intends operating Koeberg Nuclear Power Station (KNPS) beyond its assumed design life of forty years. This has become standard nuclear industry practice, by applying good asset management and performing a specific, plant ageing-related safety assessment, nuclear plant lifetimes could go beyond 60 years, without decrease of safety and availability of the unit and at the same time with reduction of maintenance and operating costs. For implementation of Aging Management Strategy for Safety Aspects of Long Term Operation (SALTO), Eskom decided to partner with Framatome, FRAMATOME, who owns required expertise for the assessment process and the engineering of responding, and has developed solutions based on state of science and technology.

HELMUT NOPPER

Senior Advisor and Engineering Expert

FRAMATOME GMBH,
AGING AND LIFETIME MANAGEMENT

ANDRE ZANDER

Manager for all issues related to aging and plant life management including obsolescence management

FRAMATOME GMBH,
AGING AND LIFETIME MANAGEMENT

RAÚL LATORRE FORTES

Responsable del desarrollo de negocio de Lifetime Management.

FRAMATOME GMBH,
AGING AND LIFETIME MANAGEMENT

INTRODUCTION

It has become standard in nuclear industry to extend the safe operating life of nuclear power plants (NPPs) beyond its assumed design life. By applying good asset management and performing a specific, plant ageing-related safety assessment, nuclear plant lifetimes up to 60 years, and in some cases beyond, are achievable.

KOEBERG NUCLEAR POWER STATION (KNPS)

The Koeberg Nuclear Power Station (KNPS) has been in commercial operation since July 1984. Eskom intends to operate KNPS beyond its assumed design life of forty years. For this purpose, ESKOM planned to review the existing Ageing Management Programme to ensure the availability of safety functions throughout the extended service life of the plant and to ensure that the existing Ageing Management Programme meets international requirements according to the SALTO guidelines, issued by the International Atomic Energy Agency (IAEA).

AGING MANAGEMENT PROCESS

The process of aging management itself is targeted at monitoring, assessing, and controlling of degradation effects which have the potential to compromise safety functions as well as reliability of the plant. The knowledge obtained during this process provides the necessary input for definition and implementation of the appropriate testing and maintenance measures. Once informed about the conditions of SCC this knowledge could be used for planning and preparation of optimized refuelling outages also.

In order to face those challenges, Koeberg Nuclear Power Station (KNPS) had partner with FRAMATOME to develop and implement Strategy for Safety Aspects of Long Term Operation (SALTO), with the purpose to manage plant components' lifecycle with the objective of reducing costs of operation and maintenance despite aging assets.

The Ageing Management rule by IAEA covers mechanical components, electrical and I&C systems and components, and civil structures and components. In each discipline passive and active components are addressed.

SALTO PROCESS FOR KOEBERG NUCLEAR POWER STATION

The overall objective of the SALTO is to ensure that ageing management

ESTRATEGIA DE GESTIÓN DE ENVEJECIMIENTO DE LOS ASPECTOS DE SEGURIDAD EN LA OPERACIÓN A LARGO PLAZO (SALTO) DE LA CENTRAL NUCLEAR DE KOEBERG

Eskom apuesta por la operación de su planta Koeberg Nuclear Power Station (KNPS) más allá de su vida de diseño de 40 años. Este tipo de prácticas se ha convertido en un estándar de la industria nuclear, ya que mediante la aplicación de una correcta gestión de los activos y la realización de una evaluación específica de los procesos de envejecimiento de los componentes relacionados con la seguridad las plantas nucleares pueden operar más allá de 60 años, sin detrimento de la seguridad y disponibilidad de la planta, al mismo tiempo que se pueden reducir costes de mantenimiento y operación. Para la implementación de su Estrategia de Gestión de Envejecimiento de los Aspectos de Seguridad en la Operación a Largo Plazo (SALTO), Eskom tomó la decisión de contar con Framatome (FRAMATOME) como socio tecnológico, quien cuenta con la experiencia y conocimiento necesario pata el proceso de evaluación e ingeniería, y ha desarrollado soluciones basadas en el estado de arte de la tecnología.

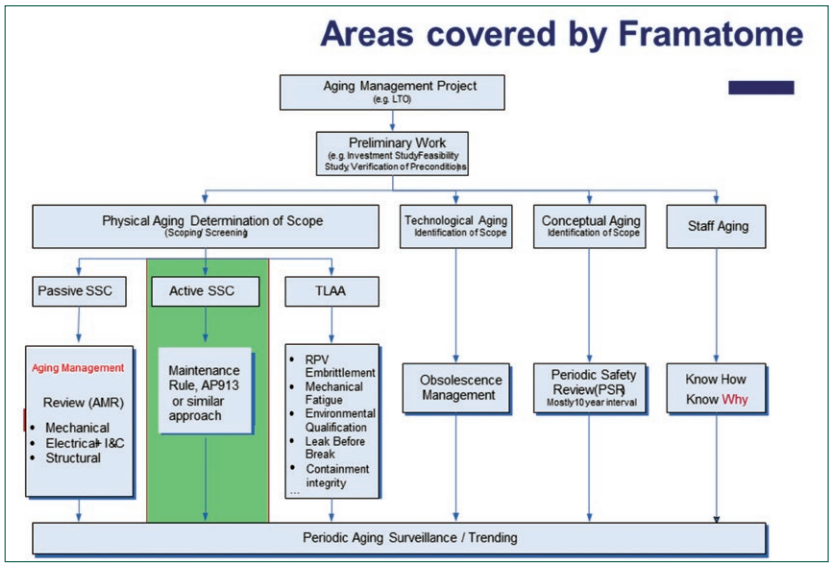

Figure 1.

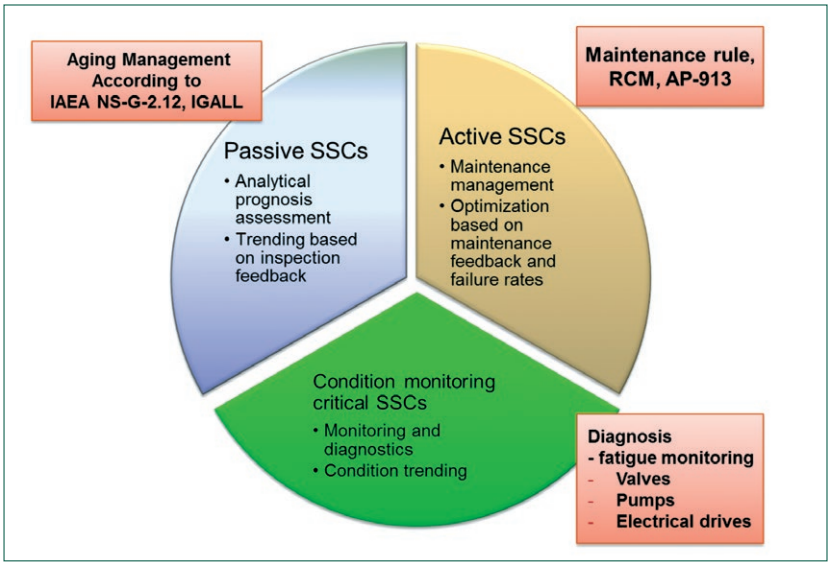

Figure 2.

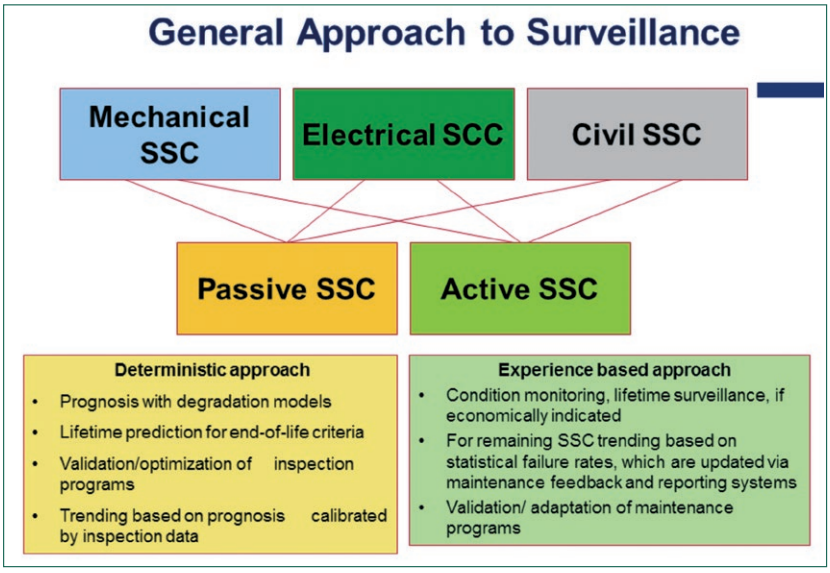

Figure 3.

related programmes are in place to sufficiently provide preventive and/or mitigation measures to monitor and manage ageing effects for the intended period of operation.

The SALTO process aims to assess systems, structures and components (SSCs) of the plant, which are important to safety. The target is to:

- identify all plant SSCs considered safety relevant (scoping)
- define Commodity Groups (screening)
- identify lifetime limitations by design and evaluate continued acceptability (TLAA)
- evaluate commodity groups regarding potential degradation effects (AMR)
- to validate existing plant programmes and to ensure that all preventive actions are in place to manage ageing effects (AMP).

Integration of aging management into planning and preparation allows for optimization of the scope of inspections and maintenance while maintaining or even improving the safety margin. This ambiguous approach calls for a comprehensive approach, requiring systematic collection and evaluation of various aging, safety and availability relevant data on a plant-wide basis. A comprehensive solution should cover all relevant areas as demonstrated in the Figure 1.

For Koeberg Nuclear Power Station (KNPS) the scope of the assessment procedure comprehensively covers safety- and availability relevant systems and components of the nuclear steam supply system, the conventional island, cooling water, and auxiliary systems. The assessment covers mechanical, electrical and I&C systems as well as civil structures (Figure 2).

The surveillance strategy is drafted in Figure 3.

Objectives of aging management program are:

- To identify systems, structures and components sensitive to aging,
- To elaborate suitable mitigation measures,
- To identify need for modernization enhancements,
- To optimize planning, preparation and execution of maintenance and refuelling outages,
- To improve awareness regarding plant conditions and preparing of life-time extension projects.

Precondition for implementation of successful aging management is the identification of the critical for

safety SSC. The initial assessment results in a list of approximately 500 items for KNPS. The criteria derived from the role of the respective SCC in the plant's safety system. SCC of the highest possible importance are those with impact on:

(a) The integrity of the reactor coolant pressure boundary,
(b) The capability to shut down the reactor and maintain it in a safe shut down condition,
(c) The capability to prevent fuel criticality.

In accordance with IAEA guidelines (e.g. Safety Report 57 [5]), a clear set of plant unit specific criteria shall be defined during the process of scoping. During the following screening process for Koeberg Nuclear Power Station (KNPS) the actual boundaries for in-scope SSC were determined. Based on this, commodity groups for all disciplines were defined, and depending on the discipline, detailed lists of components subject to aging management are prepared. Related design specification and all aging related data are maintained in a dedicated aging management database [7].

In order to quantify the effect caused by extended operation time on the structural integrity of major systems and components, so-called time-limited ageing analyses (TLAA) have to be carried out.

The TLAA for Koeberg Nuclear Power Station (KNPS) do consider given time and ageing; and do involve SSC within the scope of ageing management. In this case TLAA include:

- Stress- and fatigue analysis related to the nuclear island ;
- Reactor vessel neutron embrittlement;
- Leak-before break, flaw tolerance calculation,
- Thermal aging analysis;
- Environmental qualification of electrical equipment;
- Concrete containment tendon pre-stress analysis;
- In-service local metal containment corrosion analyses.

TLAA are reviewed to determine continued acceptability of the analysed component or structure for the LTO period. According to IAEA IGALL [6] corrective measures shall be implemented in case the TLAA will indicate findings.

Fatigue might be a limiting factor for the lifetime of a nuclear power plant. Operation modes were determined in a way that specified thermal loads and their occurrence met a design life of usual 40 years. TLAA shall demonstrate that an extension of service life will not compromise plant safety in respect to fatigue effects. As a relatively new aspect environmental factors became part of the fatigue assessment. For a lifetime extension as a rule fatigue needs to be reassessed for 60 years.

In respond to this FRAMATOME advises implementation of hardware instrumentation to measure local thermal loads and software for calculation and assessment of thermal loads where no instrumentation is available. Using heat transfer models and historic measurements from archives the complete thermal load history could be calculated.

The reactor pressure vessel is the key component of any nuclear power plant. Irradiation surveillance programs are introduced to monitor the change of the mechanical strength and toughness of the RPV in the core beltline region after specific neutron irradiation and to verify experimentally the tensile and fracture toughness properties of the RPV material at assessment or design fluence rates according to the safety standards (ASTM E-185, KTA 3203, and others). The TLAA shall demonstrate that extension of service life will not compromise the safety of the RPV due to the effects of reduced fracture toughness.

Assessment for is executed on the basis of evaluation and material tests with specimens installed inside the RPV. Respective services include specification of the specimens, withdrawal of capsules, transportation services, opening of capsules, evaluation of temperature monitors, activity determination of fluence rate detectors, testing of specimens, final evaluation and consultancy during discussion with the Regulator.

Alternatively scraping samples from the inner RPV wall may be analysed in case specimens are not available.

Plant life management of I&C and electrical systems, components, and equipment (SCE) focuses on ensuring a sufficient degree of availability for normal operation and event mitigation. With electrical equipment in nuclear power plants the respective level of required low failure rate of system functions is reached efficiently by a redundant system design. Where necessary for achieving very low failure rates for a system function, it needs to be combined with additional surveillance measures for early detection of degradation or failure of components or with measures to limit degradation. Within the frame of the TLAA it needs to be demonstrated to the regulator, that an extension of service life will not compromise the safety of the plant in respect systematic aging effects experienced with electrical equipment of the plant (Figure 4).

FRAMATOME SOFTWARE SOLUTION (COMSY) FOR AGING MANAGEMENT PROGRAM

In order to support activities for SALTO process, FRAMATOME implemented an integrated software platform which was provided to Koeberg Nuclear Power Station (KNPS) with a licensing basis. The respective software platform is designed to manage aging issues and life cycle management activities. The software platform – christened COMSY- comprises functions for all mechanical components, electrical, I&C system, civil structures, and monitoring & diagnostic applications.

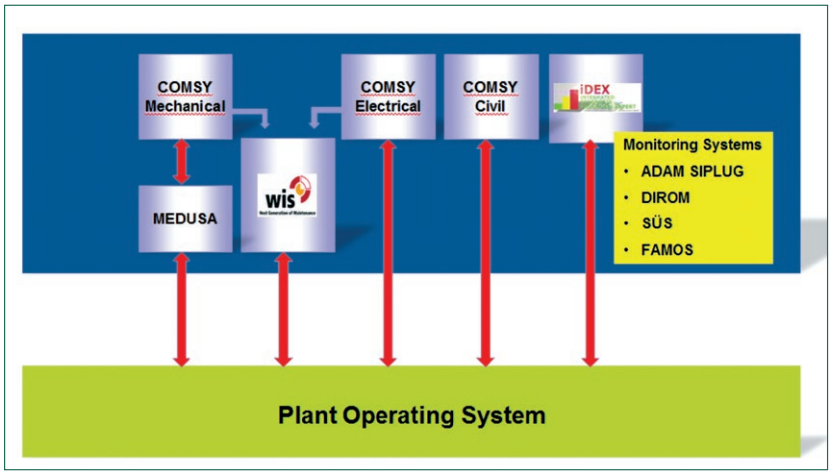

Figure 4.

COMSY [7] supports Koeberg (KNPS) SALTO process by systematic collection of data (in online from diagnosis systems as well as manually filled) and embedded degradation assessment function. Findings during maintenance and inspection and results of non-destructive examination can be collected, stored and validated in respect to their significance for degradation. Thanks to embedded evaluation criteria COMSY delivers aging management reports.

The aging management program (AMP) implemented for Koeberg (KNPS) identifies: (a) effective and appropriate actions and practices for managing aging that provide for timely detection and mitigation of ageing effects in the structure or component; and (b) indicators of the effectiveness of the program. Thus the effectiveness of current practices should be confirmed in light of applicable ageing evaluations and condition assessments, and/or improvements to current practices should be recommended, as appropriate.

AMP types are:

- A degradation mechanism specific AMP (e.g. flow accelerated corrosion, stress corrosion cracking, thermal ageing, buried piping, etc.);
- A structure or component specific AMP (e.g. reactor coolant pumps, control rod drive housing, etc.).

The generic attributes of an effective AMP are:

- Scope of the ageing management program based on understanding ageing.
- Preventive actions to minimize and control ageing degradation.
- Detection of ageing effects.
- Monitoring and trending of ageing effects e.g. NDT.
- Mitigating ageing effects.
- Acceptance criteria.
- Corrective actions.
- Operating experience feedback and feedback of research and development results.
- Quality management.

Koeberg Nuclear Power Station (KNPS) aging management program requires deep knowledge and experience in all technical areas such like degradation assessment, corrosion, water chemistry, NDE, electrical and I&C qualification. As provider of service and engineering for more than 200 nuclear power units worldwide – to a big extent these are third party plants – and member of high- level committees (ASME, KTA, RCC-M, IAEA), FRAMATOME provides the expertise needed for the application of a reliability program based on INPO AP-913 and the RCM process and provides implementation support and the knowledge basis needed based on the current state of science and technology.

AP-913 is a methodology for maintenance and reliability surveillance of system components depending on their significance to safety and availability. It combines practices of periodic maintenance, condition-based maintenance and corrective maintenance.

RCM is a strategy which focuses on the determination of critical components with the intension to optimize the resources available for, in a way such that the components whose failure causes relevant damages concerning safety or losses concerning availability will undergo more comprehensive maintenance tasks than components whose failure is less relevant and thus provoke less disturbances in the production of electricity.

FRAMATOME provides the COMSY software as key success factor for aging and plant life management to Koeberg (KNPS). The software enables the design and setup of a computerized power plant knowledge base with analytical capabilities. The multi-disciplinary software product has a modular architecture, which is designed in a way where each module can be operated independently or in combination with any number of further modules.

The software program COMSY is designed to provide prognosis of degradation processes in the technical equipment of power plants. The program does not only store and manage data, but also provides a number of analytical functions for degradation prognosis. Based on the input data, it provides prognosis of e.g. critical points; predicts degradation rates and performs lifetime analysis for components. On this basis the in-service inspections and maintenance activities can be optimized.

All aging-relevant component data are compiled and allocated via an integrated power plant model. Owing to existing interfaces to other software solutions and flexible import functions, COMSY is compatible with most existing plant databases.

CONCLUSION

The requirements for a comprehensive aging management are very demanding and require a sound knowledge base for the periodic evaluation of systems, structures and components with respect to degradation effects. Applied systematically the aging and plant life management strategy provides remarkable economic benefits.

For SALTO process implementation Koeberg Nuclear Power Station (KNPS) decided to partner with FRAMATOME, who has developed methodologies to manage the life cycle of plant components and to optimize plant safety, availability, reliability and operating costs while meeting strategic business objectives. Engineering and expert consultancy services are available in the field of Aging and Plant Life Management for mechanical equipment, electrical and I&C components and civil structures, also covering the elaboration of maintenance rules for active components and environmental qualification (EQ) of electrical and I&C equipment.

REFERENCES

[1]. NEI 95-10, Rev. 6, Industry Guidelines for Implementing the Requirements of 10 CFR Part 54– the License Renewal Rule, Nuclear Energy Institute, June 2005.

[2]. IAEA Safety Reports Series No. 15, Implementation and Review of a Nuclear Power Plant Ageing Management Program, International Atomic Energy Agency, 1999.

[3]. Safety Guide No. NS-G-2.12, Ageing Management for Nuclear Power Plants, International Atomic Energy Agency, 2009.

[4]. Equipment Reliability Process DescriptionAP-913, Revision 2 INPO, General Distribution, December 2007

[5]. IAEA Safety Reports Series No. 57, Safe Long Term Operation of Nuclear Power Plants, International Atomic Energy Agency, October 2008.

[6]. IAEA Approaches to Ageing Management for Nuclear Power Plants: International Generic Ageing Lessons Learned (IGALL) Final Report, IAEA-TECDOC-1736

[7]. COMSY software platform for LTO and aging management COMSY Product Information by FRAMATOME GmbH, September 2014