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Ageing Management Program of Safety Components: A Systematic Procedure

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Abstract

Managing ageing and remaining lifetime of an industrial facility is a concern that must be taken in account by utility as soon as possible in daily activities.
The corresponding actions engaged in France are based on 3 major step that are described in the paper:

- routine maintenance,
- exceptional maintenance,
- systematic and periodic review of safety important components and structures sensitive to ageing to assure the effectiveness of the maintenance actions and maintain a high safety level of the plant with a good competitiveness.

Following different on-going programs on ageing management of different components, EDF developed its own approach, based on IAEA guidelines, in order to systematically review all the ageing management programs implemented on its 3-loop plants.
The methodology is done in 3 steps:

- selection of components and justification
- degradation mechanism analysis
- synthesis and consequences on maintenance programs.

After a presentation of each step of the procedure a quick overview of the status of application in France is done.
Comparison of the methodology with similar methodology used in different other countries is done to close the paper.

Keywords: Ageing, management program, safety, component, systematic procedure

Introduction

Managing ageing and remaining lifetime of an industrial facility is a concern that must be taken in account as soon as possible in daily activities. With that respect, comparison with the human body and health is totally appropriate: ageing is beginning very early; bad practices may be detrimental in the short as
well as the long term and the asset is of a considerable value.
EDF recognized very early the importance of that need for its nuclear facilities: 58 PWR units built on 20 sites are producing 75 % of electricity used in France; between 10 and 20 % of the generated electricity is exported in other European countries, so contributing for a large part to the French commercial balance; and 50 % of the investment is now amortized. Moreover, building new plants will certainly present much more difficulties than in the past. So that keeping these facilities in good operating conditions as long as possible is absolutely vital for the company which is going to face the reorganization and deregulation of the European electricity system.

And for nuclear power plants, "good operating conditions" undoubtedly means safety and cost-effectiveness.

Lifetime Management Policy

For some components, lifetime is given by the manufacturer as a guaranteed value. But in most cases, manufacturers give only some indications about what they consider as an "average technical lifetime", without any contractual commitment.
The pressure boundaries of the nuclear steam supply system represent a special case. Numbers of expected operating transients are input in the fatigue analysis required by pressurized component

regulation. The time to undergo these transients may be considered as a "regulatory lifetime" of the NSSS.
An other lifetime value is the one postulated to calculate amortization of the investment. And of course, in many countries, licensing period may be considered as a kind of "lifetime" although it is generally not related to any technical limitations. In France, such a limited licensing period does not exist. The idea is that safety is permanently under scrutiny with a complete review and reassessment every ten years but without formal authorization process. However, experience shows that this ten-year safety review, which is put under control of safety authorities, may represent a "re-investment" as big as a formal license renewal process.
In EDF, the lifetime management policy of the nuclear power plants is based on three principles:

- looking for excellence in daily operation and maintenance activities, with an effective experience feedback organization taking advantage of the high level of standardization of the units,
- every ten years, a complete review of each facility and an upgrading of its safety level through appropriate modifications while maintaining unit standardization in all the fleet,
- a Life Management Program, at corporate level, which permanently scrutinizes operation and maintenance activities to identify decisions which could impair plant lifetime and which surveys research and development programs related to ageing phenomenon understanding.

Maintenance Policy and Ageing Management Program

General considerations

The maintenance policy and ageing management program are based on:

- strategic organization at corporate level, including comparison with international similar approaches,
- routine daily maintenance,
- exceptional maintenance,
- 10 year ageing management program review and syntheses.

Exceptional maintenance

Because all the units are quite identical, large resources may be devoted to problem solving so that a solution found for one unit may be implemented on all the other units. But this high level of standardization could become a weak point if problems are not sufficiently anticipated. It is absolutely necessary to eliminate the risk of a generic problem that would affect all units at once and oblige to shut them down at the same time. For that, EDF must have a very prospective view of all major degradations that could impair component reliability or integrity with appropriate repair/replacement strategies. These strategies must cover periods of time consistent with the capacity of nuclear industry to develop methods and build components (between five and fifteen years).
The "Exceptional Maintenance Program" is dedicated to periodic review of design, fabrication and experience feedback of the 30 or 40 most sensitive components in order to identify possible future problems, to estimate potential consequences and to propose appropriate measures to be taken: simple surveillance, development of repair methods, early procurement of spare parts and, possibly, replacement in anticipation if the risk of having all the plants affected at the same time appears too high.
Decisions are made after performing a cost / benefit analysis of various strategies. Probabilistic approaches are often used. But it must be recognized that indirect consequences of some catastrophic scenarios are sometimes difficult to assess.
Of course, consequences of the "anticipation / no anticipation" choice must be integrated on the whole plant lifetime.
Finally, the Exceptional Maintenance Program allows identifying large maintenance works which will "probably" have to be performed and to take measures such that, at the proper time, impact on EDF fleet performances is minimized.
Consequences of a prediction error are minimized by a complementary "inductive" analysis: very low probability events are considered and countermeasures may be taken so that if these unlikely events occur, the consequences will be costly but not catastrophic for France electricity production.

Ageing management program (AMP) review

The major objectives of this 10-year basic activity is to justify that all the safety important systems, structures and components (SSC), concerned by an ageing mechanism, remain in the design and safety criteria, including all feedbacks from the field.
This ageing occurs along normal operation, including periodic tests and routine maintenance activities (like opening and closing of components).
This ageing of SSC's is considered under control through different actions:

- prediction and detection, early in the SCC life, degradations that can affect design rules (integrity of barriers) or safety function of the plant (final safety analysis report: FSAR),
- definition of mitigation and corrective actions (including repair, replacement) to assure the safety level of the plant and the economic competitiveness of the final decision.

This ageing management program review is formed of:

- selection of structures and components,
- specific report to continue operation of the more sensitive components and structures
- synthesis report.

All these reports have to be prepared in accordance with the French regulation, as the decree for surveillance of primary and secondary system [1] and the different French Codes & Standards, as RCC-M [2] and RSE-M [3].

French Procedure for AMP Review

Structure and component selection
The selection is based on the FSAR that defines rules for safety importance of components and structures:

- mechanical components: class 1-2-3
- electrical components: class 1E
- civil engineering structures: connected to safety

All the other aspects are considered as: seismic classification and qualification requirements; but this paper is focused on passive components and structures.
After a review of around 15000 components by plant, the selection is based on the different ageing degradation mechanism that can affect these components and structures.
In order to do that systematically and with a minimum of references that support the decisions, we proposed a specific grid (table 2) with one line per components, structures or sub-part of them for each potential degradation mechanism. In the same time different other informations are collected through the columns:

- is the degradation mechanism potential or encountered in French or International similar plant?
- did we encounter difficulties that can have affected a safety function?
- is the degradation mechanism analyzed in the design report? If yes, what is the expected life in this report?
- is the present maintenance program adapted, easy to adapt or un-adapted for this degradation mechanism?
- is the repair easy or difficult for this degradation mechanism and this location?
- is the replacement of the component easy or difficult? Do we have any risk of obsolescence of the components (no vendor available or no manufacturer of this type of components)?

Around that grid a specific procedure document has been issued and complementary information are attached:

- list of safety functions (around 15),
- list of degradation mechanisms (more than 30 different mechanisms)
- list of consequences of degradation mechanism, like crack, thinning, lost of mechanical properties…

After the fill up of the grid each component or group of components (with similar function or similar degradation or similar design…) is affected in 3 categories: 0-1-2:

- 0: no complementary studies

- 1: complementary analysis to rank it as 0 or 2
- 2: prepare a specific justification report to confirm the continuation of operation

The basis of this categorization is presented in the following table 1.
A specific data sheet is attached to each line of the grid in order to collect all the references used to fill up the grid.

Report to justify continuation of operation
For the category 2 components or structures, a report has to be produced to justify on what basis continuation of operation can be done.
This report has to collect and identify references and present it as follow:

- introduction
- description: design, materials, fabrication process, water chemistry
- design basis: regulation, codes & standards, specification and guidelines
- operating experience and ageing mechanism
- assessment methods of corresponding ageing mechanisms
- inspection, monitoring, leak detection
- mitigation, repair, replacement
- synthesis of ageing management program recommendations

	Potential ageing mechanism		
maintenance	adapted	easy to adapt	difficult to adapt
Repair **and** Replacement difficult	**0**	**1**	**2**
Repair **or** Replacement easy	**0**	**1**	**1**
	Encountered ageing mechanism		
maintenance	adapted	easy to adapt	difficult to adapt
Repair **and** Replacement difficult	**2**	**2**	**2**
Repair **or** Replacement easy	**0**	**1**	**2**

Table 1: Selection of components and structures

Synthesis report
This synthesis report has to collect the major information of the 2 previous steps: selection and report to justify continuation of operation in order to compare with existing practices for the component or the structure.

It has to propose a set of recommendation based on the different information collected and the economic aspect of the decisions.

Status of French Application

The French oldest plant is in operation since 1977 and EDF is preparing the 3rd 10-year shutdown for this plant and a group of 28 similar plants (3-loop PWR).
The first application of the procedure lead to between 20 and 40 components in category 2, and we are planning the corresponding "Report to justify continuation of operation" for the next 2 years.
The list of category 2 components and structures includes:

- reactor pressure vessel
- reactor pressure vessel internals
- steam generator
- main coolant line of primary system
- auxiliary lines of primary system
- reactor coolant pump
- containment
- I&C components
- Alloy 600 components

Comparison with Similar International Approaches

Different comparison are done on the basis of public documents in a 1st step, some more detailed comparison with utilities is planned before end of this year.
The major comparisons are done with:

- AIEA guidelines and TEC-DOC reports on ageing [4, 5, 6]
- the Generic Ageing Lessons Learned (GALL) report from NRC [7]
- different reports from OECD-NEA-IAGE group [8]

These comparisons confirm roughly the list of components sensitive to ageing and safety important, but the understanding of some degradation mechanism can be different through different countries (like stress corrosion cracking of some material or thermal ageing or high cycle thermal fatigue). It's probably a key issue for future international cooperation program.

Conclusions

A detailed, systematic and documented procedure is now available in France. The corresponding results are expected for a 1st group of plants before 2 years in order to confirm, or update if necessary, the actual practices (routine plus exceptional maintenance).
The key issue for the success of this type of review is a perfect understanding and quantification of the different ageing mechanisms that has to be improved at the international level.
Plant life management is a very important issue for any utility, and particularly for EDF. And to correctly handle this issue, appropriate measures have to be taken on a good timeframe. Many of these measures are of technical and/or industrial nature but the importance of personnel and manager awareness should not be neglected.
The fact that, in an evolving context like deregulation or changes in nuclear plant policies, this type of program and corresponding conclusions will be well accepted only with a high level of utility credibility. This credibility may only arise from excellence in daily safe and cost-effective operation.

References

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Table 2: Typical grid for selection of components and structures sensitive to ageing

	Ccc.zz.d.X		1/2/3/ NC/1E/ GC		Mechanism/No	Y/N	Y/N	life/ No	AE/AA/DA	L/M/H/ Not possible	L/M/H -	Y/N	0/1/2
Priority	**Data sheet number and indices**	**Component/ Structure**	**Safety class**	**Element/ zone**	**Potential mechanism**	**Encountered mechanism**	**Safety function affected**	**Design life in years**	**Routine maintenance considered**	**Repair**	**Replacement**	**Obsolescence**	**Status**
Primary System	001.01.1.A	Compon. 1	1	shell	Embritl.	Y	N	40	AE	M	H	N	2
	001.02.1.A	Compon. 1	1	Outlet nozzle	Fat.	N	N	40	AE	M	H	N	0
	001.02.2.A	Compon. 1	1	Outlet nozzle	Th. Ag.	N	N	N	AA	H	H	N	1
	002.01.1.A												
Secondary System	005.01.1.A	Compon. 5	1	shell	Embritl.	Y	N	40	AE	M	H	N	2
	005.02.1.A	Compon. 5	1	Outlet nozzle	Fat.	N	N	40	AE	M	H	N	0
	001.02.2.A	Compon. 5	1	Outlet nozzle	Th. Ag.	N	N	N	AA	H	H	N	1
Civil Eng. Structures	012.01.1.A	Compon. 12	1		Embritl.	Y	N	40	AE	M	H	N	2
	012.02.1.A	Compon. 12	1		Fat.	N	N	40	AE	M	H	N	0
	012.02.2.A	Compon. 12	1		Th. Ag.	N	N	N	AA	H	H	N	1
I&C components	021.01.1.A	Compon. 21	1		Embritl.	Y	N	40	AE	M	H	N	2
	021.02.1.A	Compon. 21	1		Fat.	N	N	40	AE	M	H	N	0
	021.02.2.A	Compon. 21	1		Th. Ag.	N	N	N	AA	H	H	N	1