AGING MANAGEMENT OF EDF NPP: FROM THE DESIGN PHASE UP TO END OF LIFE

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Abstract
This paper will present the different step developed for EDF NPPs, from design phase to take care of potential ageing mechanisms, to end of life of the plant to assure continuously safe and economical operation with ageing of the plant. It will consider: the potential changes in regulation, the design phase with regulatory aspects, Code and User requirements, the maintenance plan at design phase, the monitoring, surveillance, ISI and data collection, increase in knowledge considerations, the periodic safety review, the maintenance optimisation with plant ageing consideration, repair, replace or continue to inspect, an important challenge, the role of Codes & Standards in this process. A short review of international organisation support will be presented. All the major actions that are important and relevant to assure periodic justification of our Ageing Management Program will be discussed as a conclusion.

1. INTRODUCTION

Managing ageing and remaining lifetime of an industrial facility is a concern that must be taken in account as part of daily activities. Bad practices may be detrimental in the short as well as the long term and the capital assets are of considerable value.

Ageing management of Nuclear Power Plants is an essential issue for utilities, in term of safety and availability and corresponding economical consequences. Practically all nuclear countries have developed a systematic program to deal with ageing of components on their plants.

EDF recognised since the beginning of plant operation the importance of that need for its nuclear facilities: 58 PWR (Pressurized Water Reactor) units built on 20 sites are producing more than 75 % of electricity used in France (fig. 1). Keeping these facilities in good operating conditions as long as possible is absolutely vital for EDF.

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

In parallel, in 2001, USNRC (United State Nuclear Regulatory Commission) produced a specific document to be used for US utility license renewal: Generic Ageing Lesson Learns" (GALL report [1]). Different other countries are on the way to develop their own Ageing Management Program and the corresponding Safety Requirements, like: Japan, Netherlands, and Hungaria…

2. LIFETIME MANAGEMENT POLICY

At EDF, the lifetime management policy of the nuclear power plants is based on four principles:

- daily operation and maintenance activities, with an effective experience feedback organization taking advantage of the high level of standardization of the units,
"Exceptional Maintenance Program" is charged to identify possible future problems, to estimate potential consequences and to propose appropriate measures to be taken. Of course, consequences of the "anticipation / no anticipation" choice must be integrated on the whole plant lifetime.

- every ten years, a complete safety review of each group of similar plants, including ageing evaluation of Systems, Structures and Components (SSC)

- 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.

3. **Ageing management program 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 SSC life, of 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 on anticipation process bases.

This ageing management program review is formed of 3 steps [2]:

- 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 [3], the different French Codes & Standards, as RCC-M [4] and RSE-M [5] and the corresponding plant Final Safety Analysis Report (FSAR).

4. **French procedure for AMP review**

4.1. **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

Around 15000 components are concerned by plant. The selection is based on the different ageing degradation mechanism that can affect a part of each components and structures.

In order to do that systematically and with a minimum of references that support the decisions, we proposed a specific grid with one line per component, structures, or element for each
potential degradation mechanism. In the same time different other information's 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)?

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

- 0: no complementary studies
- 2: prepare a specific justification report to confirm the continuation of operation

A specific data sheet is attached to each line of the grid in order to collect all the references used to complete the grid.

4.2. 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 permitted.

This report has to collect and identify references and present it as follows:

- 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

4.3. Synthesis report

This synthesis report has to collect the major information of the 2 previous steps: selection and report to justify continuation of operation. A comparison is done with existing practices for the component or the structure (fig. 3).

IA set of recommendation based on the different information collected and the economic aspect of the decisions is finally done.

5. Status of French application

The oldest French plant has been 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, discussed herein, led to around 31 locations on different components in category 2, 260 in category 0 and 115 in category 1 (intermediate situation that needs few short-term complementary analyses. The corresponding 12 "Component report to justify continuation of operation" were made for the end of 2004, and are to day in improvement process for some of them.
Finally, for a large list of components and structures the existing AMPs, developed at the plant level, are adequate. The list of category 2 location/damage can be attributed to 12 components and structures where existing AMPs have to be reviewed for, and if necessary, improved upon for certain aspects:
- reactor pressure vessel
- reactor pressure vessel internals
- steam generator
- pressurizer
- main coolant line of primary system
- auxiliary lines connected to primary system
- reactor coolant pump
- containment
- other civil engineering structures
- I&C components
- cables for "hot points" only
- electrical penetration in the containment
6. **Comparison with International approaches**
The EDF approach has been compared with AIEA guidelines [6,7,8], GALL report and similar programs in Japan, Switzerland or other countries [13].

6.1. **Comparison of GALL report applicability to French PWRs**
For example for the GALL report [1]:
- the approaches are similar but some degradation understandings are different
- different objectives: Licence Renewal / Periodic Safety Review
- larger scope in GALL report (PWR and BWR, safety and non-safety SSCs)
- similar, but not identical list of components, locations, degradation mechanisms for PWRs
For mechanical components: different regulation, different Codes & Standards, specific AMP leads to difficult comparison. For the same degradation mechanism different solution can be used by Utilities.
Different understanding of some degradation mechanisms between EDF practices and GALL report proposals, as:
- limited “potential” degradation based on laboratory knowledge in the GALL report, more in EDF practices
- GALL report is more based on USA than International field experience; more international cross checks in EDF approach
- more environment effect in fatigue in GALL report than in EDF practices
- less thermal ageing in GALL report than in EDF practices
- no high cycle thermal fatigue in GALL report

6.2. **IAEA reports supporting development of AMP review**
In the past 15 years IAEA- Nuclear Safety has developed different documents for ageing management and long term operation: programmatic documents, technical documents on ageing of components and some good practice technical documents (fig. 4, 5).
Figure 5 present the generic scheme proposed by IAEA to develop an AMP.
In parallel, IAEA- Nuclear Power has developed different documents on technical best practices [14, 15]. Some of these documents are under revision process regularly, like the procedure for Reactor Pressure Vessel (RPV) residual life evaluation procedure [16].
A special program has been launch on Long Term Operation (LTO) of VVER plants [17].

6.3. **Other support organisation**
2 other organisations have play a role in supporting AMP activities:
- OECD-NEA- IAGE group developed programmatic synthesis [9], best practice documents [12], state of the art document and comparison of AMP practices in different countries [11]
- European Community supports Research activities [10,18] and programmatic documents [19]

7. **Integration of AMP experience in new plant design and all along the plant life**
It's a very important issue for utilities that are in the process of construction of new plants; more attention has to be taken on ageing of components, in particular for new design life of 60 years or more.
As presented in figure 6, the AMP has to follow the life of the plant from pre-design up to decommissioning.

All along the life of the plant, degradation mechanism understanding and corresponding models will be improved, surveillance, monitoring and In-Service Inspection (ISI) performance will increase, the field experience is larger and larger for all type of SCCs. Consequently, the AMP needs periodic review and update. Different processes are used for that in different countries: the Licence Renewal process mainly used in USA, the periodic safety review in an other large number of countries. Some countries (VVER utilities) are developing 2 phases in their process: AMP during the initial design life, completed by a long-term operation phase (LTO).

EDF uses the process that leads to add a specific AMP review with the periodic safety review done every 10 years, without any licensing limit: acceptance is done on the next 10 years with some complementary highlights for more than 10 years. All the results of this review are submitted to French safety authority (ASN) for comments and acceptance to continue operation.

For new design, all the lessons learned on ageing of SCCs have to be taken into account as early as possible in the pre-design and design phases. The Utility has to clearly and precisely defined the planned operating conditions in order to assure Designer and Manufacturer can analyse, predict, adapt the design, the material selection, the fabrication process and the end of fabrication control to assure.

The French RCC-M [4] includes a large part of these lessons learned, but some complementary non-codified analysis remains necessary. The ASME Code has a too large scope to include rules to take care of these lessons learned through Code rules. In parallel some Safety Authorities are requesting more than in the past at the design level in order to assure the reduction of safety risk level during all the life of the plants. It's the case in France and Finland for the EPR plants under constructions.

8. Conclusions

EDF has developed a specific writing procedure to review how the plant ageing is considered on its 58 PWRs. It was finished in 2004, 12 "Analysis report to continue operation" has been selected. Some of them are under improvement. All these analysis and syntheses are parts of the 10-year periodic safety review of the plants. These generic reports are done for a group of plants (34 3-loop, 20 4-loop 1300 MWe and 4 4-loop 1450Mwe). They are finished for the 3-loop plants, under preparation for the 4-loop 1300Mwe plants. They will be revised every 5 years. They will be completed plant by plant by some local specific situation. All the results are included in the surveillance and inspection program of the plants, for all type of SCCs. An AMP implementation has to be implemented as early as possible in the plant life in order to assure relevant data collections and pro-active behaviour of the utility.

An effective AMP has to consider all SSCs (mechanical components, civil engineering structures, electrical and I&C components), and not only class 1 mechanical components.
It's important to compare these activities with the similar activities in other countries and to include work done by different international technical support organisations (IAEA, OCDE-NEA, EC in particular).

All the lessons learned in these programs have to be included in the new design of NPPs. The corresponding Codes & Standards has to be probably improved to take it more in consideration.

All these analyses are presented to Safety Authorities for review and a long process of instruction is in progress in many countries. Some of the Safety Authorities develop a specific set of requirements for Plant Life Management.

Acknowledgment

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References

FIG. 1. Service operation date of French NPPs

![Graph showing the service operation date of French NPPs.](image.png)

FIG. 2. Selection criteria of SCCs

<table>
<thead>
<tr>
<th>Degradation mechanism</th>
<th>Encountered</th>
<th>Predicted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing maintenance program</td>
<td>OK</td>
<td>OK</td>
</tr>
<tr>
<td>Repair and replacement difficult</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Repair or replacement not difficult</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

0: nothing, without any new information
2: prepare a detailed ageing analysis report
FIG. 3. Synthesis procedure of AMP review

Step 1/2 results
- Synthesis report for a component or a group of components

Present practices
- Maintenance guidelines

Recommended Practical complementary action

Final Ageing Management Program in "Maintenance guidelines"

FIG. 4. IAEA document support on AMP

Nuclear Safety Standards
- Safety of Nuclear Power Plant Design NS R-1
- Safety of Nuclear Power Plant Operation NS R-2

Nuclear Safety Guides
- Safety Guide on PSR

Nuclear Safety Guidelines
- Component Specific Guidelines (9+4)
- Ageing Management Review guideline (1)
- Guidelines on Integrity of Reactor Pressure Vessels (2+2)
- Guideline on activities for effective life management (2)
- Guideline for Research Reactors (1)

Output from IAEA's Extrabudgetary Programme Safety Aspects of Long Term Operation (EBP SALTO)
FIG. 5. AMP general procedure proposed by IAEA

- Safety maintain or increase
- Knowledge increase
  - Collected data
  - Field experience nat. & internat.
  - R&D results
- ASN requirement improvements

FIG. 6. AMP along the plant life

- Specific requirements: up to 40Y or more ???
- With uprate or not
- Complete detailed review of AMP

- Update all the design data and regulatory requirements
- Update the stress report and define concerned / sensitive locations to different damages
- Update the ISI and data collection program
- Develop R&D programs for optimisations: RI, Integrity, deg., rate, fitness for service, ISI performance

- Design stress report, transient list, material data report, and of fabrication report
- Define an ISI and data collection program
- Analyze the pre-service phase: pre-service inspection and pre-service data (transients, temperature measurements, gap measurements, vibration measurements)