ASSYSTEM'S APPROACH TO PLANT LIFE MANAGEMENT FOR NPPS LONG TERM OPERATION

Cédric CUILLANDRE
ASSYSTEM Energy & Infrastructure
Paris, France
Email: ccuillandre@assystem.com

Gilles DESVERGNES
ASSYSTEM Energy & Infrastructure
Paris, France

Abstract

In France but also around the world, Nuclear Power Plants (NPPs) are increasingly aging. Long term operation (LTO) of existing nuclear power plants is crucial in order to at least maintain the energy production, while new plants are being constructed. The French nuclear fleet operated by EDF was mainly commissioned in the 80’s with an initial design lifetime of 40 years. As a consequence, the NPP’s safety and control systems are also ageing. These systems are complex and must always show compliance with heavy regulatory constraints. Therefore, remodeling and modernizing them every ten years would mean having to fully requalify the global system through a strenuous process like it was done originally when the plant was first commissioned. This would be time consuming and costly compared to the systems life extension management. When it comes to systems that are expected to have a long life cycle, that have an important safety aspect, that implement proprietary technologies and that represents heavy investments, it is advisable to define and to implement a support strategy to guarantee the system’s availability during a chosen life expectancy by optimizing the Return On Investment. To achieve this, ASSYSTEM offers Long term maintenance and sustainability solutions to the nuclear industry, with a particular focus on security and monitoring systems’ LTO management for NPPs. Since technological obsolescence can become a very important risk factor for an optimal continuity of operation, ASSYSTEM studies and implements maintenance strategies for these complex systems. Our industrial maintenance approach has for objective to guarantee, on the long term, the systems performances regardless of the technological evolutions since the original design. But, Long term operational maintenance doesn’t necessarily mean dealing only with old technologies. Upgrades and improvements are also part of the PLM process by integrating new technologies (like Eco-design, digital and Cybersecurity).

1. INTRODUCTION

It’s stating the obvious that Nuclear Power Plants (NPPs) are increasingly aging with more than 270 reactors in the world currently being older than 30 years. As a result of the Fukushima Daiichi accident, construction of new nuclear power plants has slowed down. Also time to market for new Nuclear Power Plants (NPPs) is increasing more and more. The average time taken to build the reactors that are operational today was approximately more than 7 to 8 years. Long term operation (LTO) of existing nuclear power plants is therefore crucial to at least maintain the production of energy the world is increasingly craving for.

In this paper, we will first mention the reasons for having LTO for NPP control systems, and then we’ll give a brief overview of Assystem’s positioning when it comes to maintenance activities on the French Nuclear power reactors. We’ll describe more specifically our company’s approach for NPP control systems long term maintenance, while introducing new technologies added in our LTO activities.

2. THE REASONS FOR INDUSTRIAL MAINTENANCE FOR NPPS

2.1. General context

As one of the world’s most nuclear powered country, France has 58 nuclear reactors all operated by EDF, resulting in a total installed capacity of about 63 130 MWe. In 2016, they generated about 72.3% of the total electricity production in France. The French nuclear fleet was mainly commissioned in the 80’s with an initial design lifetime of 40 years, even if, according to the French regulatory framework, there is theoretically no time limit for NPP operation.
Studies show that in nearly all cases, the continued operation of NPPs for at least ten more years is profitable even taking into account the additional costs of post Fukushima modifications.

The French reactors are divided into four types:
- 900MWe → 34 reactors
- 1300MWe → 20 reactors
- 1500MWe → 4 reactors (N4)
- 1600MW → 1 reactor (EPR, in construction)

All the French reactors fall into one of these four classes, with all reactors in the same class having the same construction. For major portions of systems across the fleet, similarities of systems between the units simplify management of the obsolescence process (less effort required to identify, screen and resolve obsolescence issues). On top of this, there are examples of systems which transcend the various reactor types and are implemented across a number of the reactor variants. Additionally, this systemization approach allows introducing economies of scale when replacement equipment is required or when equipment redesign is required.

During the French NPP’s life cycle, the maintenance is organized on 3 levels:
- **Daily**: The various equipment of the power plant are under surveillance in order to make the adjustments or the necessary repairs.
- **Programmed**: Approximately every 18 months, every unit is stopped during 5 to 6 weeks to reload part of the core reactor with nuclear fuel.
- **10 year cycle**: Every ten years, a detailed and complete inspection of the unit is made, in particular the main components (reactor vessel, circuit primary, steam generators, containment chamber). It’s at the end of this assessment that the French Nuclear Safety Authority gives the authorization to pursue the operation of the reactor.

For the plant to be able to last ten more years, an effective LTO policy has to be in place, especially when it comes to electronic or computerized control systems that usually have shorter life time expectancy, than other mechanical or static equipment.

Because NPP safety and control systems are complex and must always show compliance with heavy regulatory constraints, remodelling, changing and modernizing them every ten years would mean having to fully requalify the global system through a strenuous but effective process like it was done originally when the plant was first commissioned. This would take months/years to fulfill and the cost would be outrageous compared to the systems life extension management.
2.2. Assystem’s involvement in the French nuclear power plant’s maintenance

Assystem Energy & Infrastructure (hereby referred to as “Assystem”) is Europe’s leading nuclear engineering consultancy, with 4000 employees, of which 2000 work in the nuclear sector. Assystem accompanies various French nuclear companies and institutions, including the 58 reactors of the French fleet, for which Assystem continues to be the favoured partner for maintenance, operation and development projects.

Assystem offers Long term maintenance and sustainability solutions to the nuclear industry, with a particular focus on security and monitoring systems’ LTO management for NPPs operated by EDF. These systems are easier to maintain because they’re not safety classified and therefore aren’t subject to heavy regulatory constraints. On the other hand, for the most part, these systems have not been originally designed by Assystem, so an appropriation phase has been necessary for Assystem to be able to be efficient.

Since technological obsolescence can become a very important risk factor for an optimal continuity of operation, Assystem studies and implements maintenance strategies for these complex systems (based on electronic, IT and network technologies). Our industrial maintenance approach has for objective to guarantee, on the long term, the systems performances regardless of the technological evolutions since the original design.

Assystem has 50 years of experience working in the nuclear sector. The maintenance & sustainability activity for control systems was originally created in 1991, its goal being to study and implement maintenance strategies for complex systems – with a commitment on the availability and the life cycle of the maintained systems. With our long term maintenance experience side by side with EDF, based on the lessons learned while maintaining various systems like for instance the Central data acquisition system for the French 900/1300MW NPPs, Assystem has developed and implemented its System Maintenance & Sustainability activity, with a particular focus on security and monitoring systems.

Assystem is one of the main contractors involved in EDF obsolescence management process for control systems, through several maintenance contracts. We provide the French operator with a complete obsolescence management service. In addition, we operate a strategic spare parts storage service and control system simulators in our back office near Paris.

For instance, one of the systems we manage is the “KIT N1”. It’s a data acquisition and monitoring system which manages approximately 5000 binary and nearly 2000 analog inputs for each site. This system is implemented across 54 reactors (the 900MWe and 1300MWe variants).

A part from these monitoring systems aging issues, Assystem is also responsible for maintaining and upgrading the security systems (video surveillance, anti-intrusion and access control) for all 19 nuclear power production sites of EDF. This topic will actually be the subject of a presentation in Vienna during the international conference on Physical protection of nuclear facilities organized by the IAEA in November (CN254).
3. ASSYSTEM’S LTO APPROACH FOR C&I SYSTEMS

3.1. Management of C&I obsolescence

Assystem has now more than 25 years of experience working to make sure that some equipment part of the control systems in operation in several French NPPs are still working optimally regardless of their age, their technology or their origin. In the course of this long commitment to helping EDF’s efficiency guarantying the French government the success of their mission to continuously deliver electricity to the nation, Assystem has being able to organise, to implement and to refine their LTO approach.

The first step of the process is to learn and absorb the characteristics of the system to be maintained (especially when you haven’t taken part in the original design and development), then to do support and sustainability engineering by continuously performing feedback analysis, obsolescence detection, evolution proposals, and technological surveys while making sure your team’s necessary skills and know how are always adequate. The design phase consists of mitigating component obsolescence, performing hardware and software development when necessary and integrating and testing the upgraded system. Then comes the support phase where you correct bugs, you repair or remanufacture existing faulty hardware and you create strategic storage. In addition, you implement on call and on site assistance with specific training sessions.

This process can be outlined by describing each step that contributes to successfully managing the availability and the sustainability of complex systems used in the French nuclear power production facilities.
3.2. Use cases of LTO maintenance

3.2.1. Sustainability of NPP data acquisition systems

The standardization of the Human Machine Interface (HMI) systems that monitor the most of the French nuclear power plants (900 MW and 1300 MW units) built in the 70s and 80s led to use the same data acquisition systems. At the beginning of the 90s, EDF decided to sustain these systems to insure the maintenance of its power plants on the long term (25 - 45 years). Assystem was awarded by EDF the mission to insure the sustainability of the acquisition systems deployed across the 54 nuclear reactor units of EDF’s current park of nuclear installations.

In order to achieve EDF’s requirements, Assystem performed the following missions:

- **Long Term Maintenance and Sustainability of hardware and software** (20 000 electronic boards, 5 600 types of components, 23 versions of software, …). Implementation and management of a Hot line, Repairs with traceability at the component level to detect the recurring breakdowns and propose improvements, Correction and evolution of the software, On site expertise.

- **Anticipate the components obsolescence** and propose solutions guaranteeing the equipment’s maintainability: storage, equivalent components, cloning, …

- **Implement the approved solutions** to handle the obsolescence including the development of electronic boards and the associated software when "Cloning".

- Rebuild **inventory management** and Update of the documentation.

Besides the guaranteed functionalities and the operators’ full satisfaction, this contract was positively evaluated by EDF’s Quality System management and by the perfect follow-up of metrics in our annual activity reports. No glitches occurred thanks to our anticipation of obsolescence. Constant trust in Assystem is granted every 3 to 5 years by continuously renewing the maintenance contracts since 1991.

3.2.2. Maintenance & Control panels for CLX calculators

In order to sustain maintenance and control panels (CLX calculators) used in each of the French nuclear power plants (900 MW, 1300 MW and N4 units), it was decided to replace the existing devices using old push button technology (Octal numeral system based) by digital touch screens. The maintenance panel is used for the CLX maintenance and allows visualizing the anomalies. The control panel allows the manual implementation of the programs to monitor the system’s overall functioning.

![FIG 3: Upgrading maintenance & control panels for CLX calculators](image-url)
Both Maintenance Panels and Control Panels are replaced by a touchscreen PC in the same cabinet. This is intended to improve the HMI ergonomics of the CLX interface. Ultimately, it allows better diagnostics of the calculator through onboard autotests.

4. NEW TECHNOLOGIES INVOLVED IN LTO MAINTENANCE

Long term operational maintenance doesn’t necessarily mean dealing only with old technologies. Upgrades and improvements are also part of the PLM process by integrating new technologies (like for instance Internet of things, big data, high speed networks, Eco-design, digital and of course Cybersecurity…), wherever regulatory constraints allow us to introduce such advanced technologies.

It’s particularly true when it comes to integrating cybersecurity within the LTO evolutions. We then talk about Long term security maintenance, like incorporating a SIEM (Security Information & Event Management) within the safety and control systems for instance, to continually monitor cyber security efficiency throughout the plants life time. Especially nowadays with the increased threat level link to cyber criminality, that’s an integral part of the plant’s PLM.

In this paper, we will focus on three of the above new technologies (Eco-design, cybersecurity and digital) that Assystem takes into account in its LTO strategy.

4.1. Eco-Design

An Assystem study performed in 2015 to analyze the environmental impact of a data acquisition electronic module used on the French NPPs shows that a strong environmental gain is obtained by repairing and recycling the module, rather than throwing it away and replacing it by another one. We’ve also identified generic eco-design opportunities such as the module’s energy consumption optimization, the circuit board size reduction linked to new smaller components, and subsequently the reduction of polyurethane foam packaging.

In details, these opportunities are obtained:
- By first of all choosing the correct components. It helps reducing their amount, their size and increasing the power efficiency,
- By reducing the power consumption by adopting stand-by modes and by optimizing the software,
- By limiting dangerous substances (mercury and lead) by dismantling the sensitive components, at the end of the modules lifetime,
- By optimizing the quantity of material used for packaging, and by reducing the amount of transportation for delivery.

4.2. Cybersecurity

When it comes to cyber issues, industrial Control Systems have specificities and vulnerabilities that have to be addressed in order to secure vital operating installation like NPPs.

4.2.3. Industrial Control Systems Specificities

- More and more connected instrumentation and increased permeability between the plant’s management networks and the industrial networks.
- Increasing exposure of production data through Big Data concentration and interoperability between the field and the factory’s IT systems (MES, ERP, Supply Chain).
- Convergence of functional safety standards and information security standards.
- Criticality of the processes managed by the industrial control systems.
- Operation Technology (OT) is a new and easy target for hackers around the world.
Huge Cyber-attacks to international companies and industries have recently been brought to our attention in the press. With new connectivity technology available, industrial control systems like SCADA or DCS systems that control NPP operations are at risk. It’s also important to consider to cyber protect the systems that directly manage the security of the NPP (Video surveillance, access control, anti-intrusion…). And not to forget to monitor and control cyber access to system that aren’t directly controlling the power production aspect of the nuclear facility but the utilities linked to its operation (HVAC, service water, lighting…). Disrupting these systems could have a significant impact on the plant’s operation.

4.2.4. Industrial Control Systems Vulnerabilities

- Structural vulnerabilities of the systems architectures: no data encryption, absence of subdivisions and filtering, OS and Firmware weaknesses.
- Absence of security integrity monitoring and surveillance system: SIEM / IDS / IPS (Intrusion Detection / Protection Systems).
- Risks arising from the O&M activities: continuous connections, remote handling, access to critical elements, …
- Little or no plans of maintaining security level over time: no evolution watch on threats and vulnerabilities, no periodic revaluation of risk analyses, no business recovery and continuity plans in case of attack.

Therefore, integrating cybersecurity within the LTO evolutions leads to Long term security maintenance, by incorporating:
- New technology (like firewall, industrial data diode, …).
- New process (like a Security Information & Event Management - SIEM - within the safety and control systems for instance, to continually monitor cyber security efficiency throughout the plants life time).
- New skills and new knowledge (like cybersecurity training of staff in charge of development, system integration, or on site interventions).

At Assystem’s premises in Saint Quentin en Yvelines, both the cybersecurity R&D and the sustainability teams are working together to integrate new requirements from customers and from the national regulatory authority in charge of cyber security issues.

4.3. Digital

The two technologies described above, Eco-Design and Cybersecurity, have given birth to a new one, the Digital technology that has also appeared in our NPP maintenance procedures.

Assystem has integrated digital technologies, such as dematerialization, which provide a paperless eco-friendly environment for procedures and services via industrial tablets that run specifically developed applications used for instance for co-activity management, progress follow-up, conformity follow-up, and onsite maintenance interventions. Paperless procedures have also an impact on information confidentiality and on environment.

The SECTO application developed by Assystem is an example of this digital improvement. This tablet application, currently used by EDF, allows fire protection data centralization and maintenance of fire sectors of a NPP. Using this software mobile application improves:
- Reliability of the installations by centralizing data & by using a single and common channel of information,
- Reactivity (data is concentrated and available for all authorized users), with identification of construction sites and localization of perimeters identified by QR Codes,
- Safety, security and the quality of the interventions,
- Productivity (time saving, Capitalizing on feedback from the field, automatic and paperless procedures, avoiding errors like duplicate inputs).

5. CONCLUSION

The French nuclear fleet was mainly commissioned in the 80’s with an initial design lifetime of 40 years, even if, according to the French regulatory framework, there is theoretically no time limit for NPP operation. Recently lifetime expectancy has been increased by 10 years. Experts are even considering having the plants running up to 60 years and maybe beyond.

So when it comes to maintaining these plant’s and specially the systems that control the plant’s safety, one shouldn't be afraid of technologies getting old and obsolete. As long as the regulatory standards (seismic, CEM, security, …) don’t require evolution, applying a long term operation maintenance strategy like Assystem is applying on the French NPP for EDF, should guarantee, on the long term, the systems performances regardless of the technological evolutions since the original design and that longer lifetime expectancy can be reached at a reasonable cost.

But, Long term operational maintenance isn’t all about expanding life time expectancy of old technologies. Upgrades and evolutions are also part of Assystem’s LTO approach by integrating wherever it’s possible new technologies like digital mobile applications and cybersecurity to improve and secure the approach of long term operation maintenance for Nuclear Power Plants.