Modernization of NPP's Safety I&C - Challenges and Solutions

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Abstract: A substantial share of the world's fleet of nuclear power plants reached already a service life were modernization of the I&C systems needs to be considered. Such I&C modernization projects present various challenges for plant owners as well as for suppliers. In the past more than 10 years, multiple modernizations of safety I&C systems based on digital systems have been successfully implemented or are currently under execution, in addition to the current new builds that are equipped with digital I&C. Nevertheless, concerns regarding modernization based on digital I&C still exist or even seem to increase.

As a leading supplier of safety I&C modernization solutions AREVA NP has implemented a wide range of project types from small scale to comprehensive, and with highest qualification requirements, including its digital safety I&C platform TELEPERM® XS.

The presentation provides an overview of the challenges, approaches and solutions of I&C system modernizations based on selected examples.

Information will be shared related to modernization drivers, definition of modernization scope, project constraints, the selection of the I&C platform, the technical solution, the project implementation, the cooperation between the parties as well as the success factors

Main key success factors are, of course, a well-defined perimeter of the modernization project, proven engineering solutions, a suitable and modular I&C platform, suppliers' competence and strong teamwork between operator and supplier.

This said I&C modernization based on digital technology is a proven and sustainable investment in a nuclear power plant's safe and reliable operation.

Keyword: Digital I&C, Modernization, TELEPERM® XS

1 Introduction

Most of the operating nuclear power plants (NPPs) have been designed and built based on analog I&C and are already more than 20 years old. Since their design years there have been tremendous advances in electronics and computers. Many of these new achievements have been incorporated in digital I&C platform designs. Even though advanced digital I&C systems are used extensively in all industries, their application in the nuclear industry is still quite limited. This correlates with the fact that since the end of the 1980s only few new NPPs have been built, and modernization of older NPPs have not been performed widely as utilities have had concerns due to cost, complexity and licensing issues. Despite these issues numerous modernization projects have successfully demonstrated that the improvements based on digital I&C actually do provide benefits in safety, availability and operation & maintenance cost. In addition modernization and the switch to digital resolves the obsolescence threat as well as the fact that the current generation of engineers is more acquainted to digital than to discrete analog technologies, This paper is intended to outline the benefits, challenges and means to plan and implement modernizations, all gained from digital I&C projects already performed. This paper will focus on the safety I&C aspects as many of these can also be applied to non-safety systems.

2 Benefits of Digital Safety I&C

Proven by various industries, such as aviation, fossil power plants and also new build NPPs, digital I&C provides multiple advantages. Digital I&C can provide far more functionality allowing for more economic plant operation. Thus providing a more precise monitoring of plant performance, giving more accurate data to plant control systems and identifying opportunities to improving the performance of equipment and systems. Digital I&C allows the operations and maintenance staff to better anticipate, understand, and respond to potential plant situations.

The availability and reliability of digital systems is even higher than the analog counterpart, thus leading to a higher safety. The reliability of a proven digital technology reduces unplanned, forced operator interaction with the system and prevents challenging of the safety systems. The actually observed failure rates of digital modules are significantly below the calculated values, which have to assume some conservatism. At the same time the failure rates of digital equipment are found not higher than of conventional hard-wired modules. As an example Fig. 1 shows the comparison of a selection of TELEPERM® XS modules.

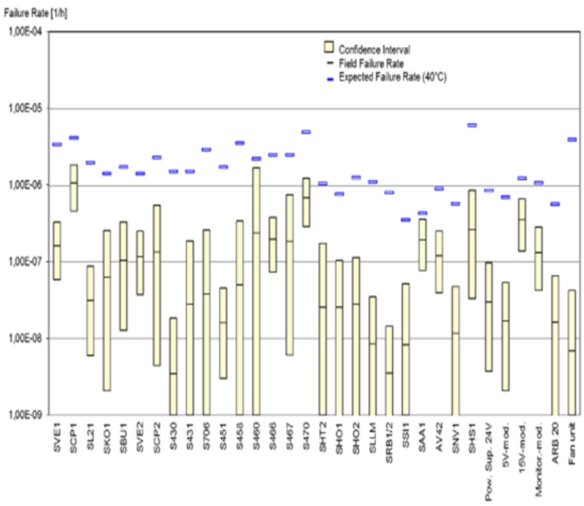

Fig. 1 TELEPERM® XS; typical failure rates demonstrated by a subset of modules

Customization of system functionality through application software offers sophisticated engineered alarms, self-checks, and automated surveillance checks. State of the art digital I&C platforms, such as TELEPERM® XS, provide a high level of self-test coverage in accordance with the requirements of IEEE 603, allowing a significant reduction of periodic surveillance test performed by maintenance staff during operation or in outages.

One of the greatest advantages of digital technology is the reduction of spare parts and modules in use, which will in future significantly reduce obsolescence issues. As existing old (mostly analog) systems age, operators are tasked to repair rather than replace broken equipment.

Fig 2 shows the well-known “bathtub curve”, indicating that once the failure rate starts to increase again it may be highly recommended to consider an I&C system replacement rather than module exchange or repair. Feedback from some customers indicate that the increase of the failure rate starts after approximately 15 years.

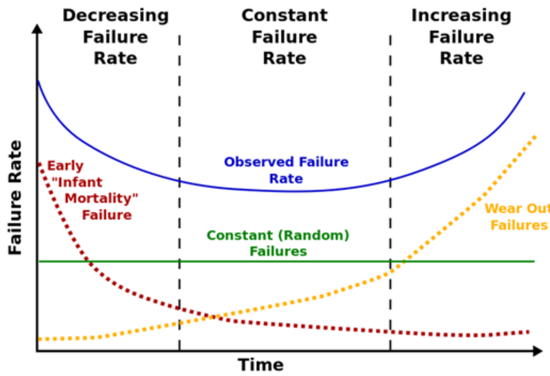

Fig. 2 “Bathtub curve”

As a consequence the use of, or the switch to advanced digital I&C systems directly improves and secures the performance of the entire plant, the economics and therefore most important the safety.

3 Challenges of Modernization Based on Digital Safety I&C

Modernization of analog systems in many cases requires more than just replacing existing systems one by one, as the digital counterparts typically are functionally not identical and provide in most cases more functionality. Hence, an analog system structure cannot and should not be replaced one-by-one by digital technology. Instead, the I&C requirements (safety and functional objectives) need to be defined, either based on already existing documentation, or by interpretation of the analog system. The complexity of I&C systems requires that the modernization follows a comprehensive and

structured implementation plan. This plan needs to define the targets and perimeter of the modernization, the related scope of functionality and signals, the applicable codes and standards, the verification and validation (V&V) requirements, the sequence of implementation, and the project time schedule.
Successful management of digital I&C modernization requires close cooperation of utility (operator), I&C vendor and regulator.

The operator is challenged by defining the modernization scope and requirements, by selecting a time window suitable for the modernization, by selecting the I&C system vendor and by coordinating with the regulator. It should be noted that “requirements” should not be a description of a solution, but the description of the functional needs, in order to enable real competition for the elaboration of a safe and reliable solution. Depending on in-house capabilities of an NPP operator or utility a solution to this challenge may be the involvement of an organization having proven expertise in the field of digital I&C or a feasibility study performed by vendors of digital I&C for NPPs. The vendor selection is more complex than only considering the best price and I&C platform. Even more, the vendor’s experience, competence and proven capabilities are key for a successful project. In addition also the vendor’s solutions and track record regarding long term evolution strategy of the I&C platform, its infrastructure for a long term operation support should be considered.

TELEPERM® XS is an example of a digital safety I&C system that has been installed in virtually all NPP types in more than 15 countries and accepted by related national regulators. Figure 3 shows the global distribution of more than 80 applications of TELEPERM® XS and demonstrates that digital safety I&C has been realized in the majority of countries with NPPs.

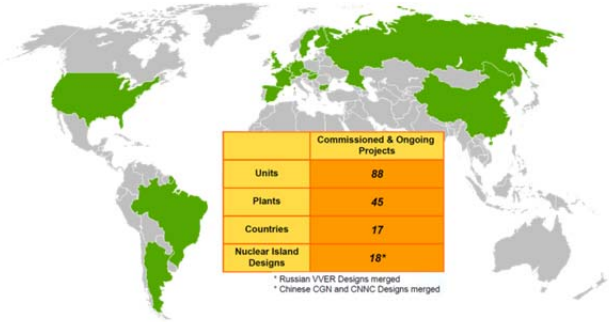

Fig. 3 Global references of TELEPERM® XS

4 Lessons Learned from Digital Safety I&C Modernizations

Based on the broad variety of executed safety I&C modernization projects, the following recommendations can be given:
Licensing of a new I&C for a NPP is not a separate task and needs to be considered in the implementation plan right from the beginning of modernization considerations. The utility or NPP operator is in charge of licensing and needs to coordinate with the regulator the applicable codes and standards and their interpretation, meaning how or in which way these have to be applied. As the I&C vendor is usually expected to support the licensing of the new digital I&C solution, the vendor’s expertise on this field should also be a bid evaluation criteria.
The planning of an I&C modernization project is one of the key activities for a successful project execution. It needs to reflect the project environment. In other words, various topics need to be addressed, such as, modernization targets, regulatory requirements and expectations, vendor and its solution, NPP environment, such as time schedule and site requirements. Sufficient time need to be reserved for the individual modernization project phases, such as project planning, tendering and bidder as well as solution selection and of course the project execution. A key success factor is availability of all I&C input data, which can also be derived from an analysis of the “as build status” of the I&C system currently being installed, prior real start of the project execution, which itself starts with the related engineering and design phases.
Regarding vendor and selected I&C platform, a supplier with comprehensive references in different reactor types and various licensing environments may be in a better position finding

an optimized solution to challenges emerging at a later project phase. An I&C platform, which has been developed based on a modular concept right from the beginning, allows applications in all project sizes ranging from small to very comprehensive ones as well as more easily for solution adaption and extension in a later state of a modernization project. The achieved higher degree of flexibility will allow to more efficiently coping with specific issues. The platform design should also comprise robust cyber security aspects as well as features to satisfy common cause failure concerns. Fig. 4 shows the modular concept of TELEPERM® XS as an example of a digital safety I&C system.

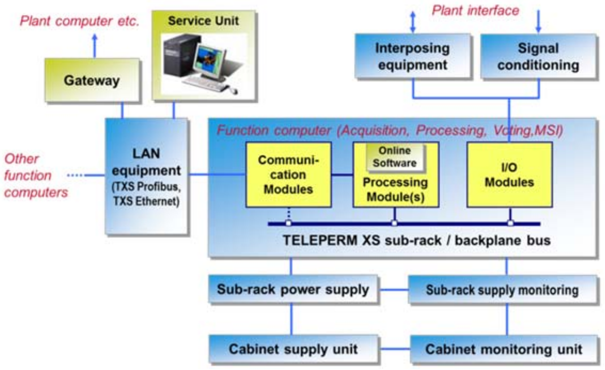

Fig. 4 Modular structure of TELEPERM® XS

5 Selected Digital Safety I&C Modernization Projects

Besides the variety of existing modernization references, special focus is put on projects listed in Table 1.

Table 1 Focus Projects

NPP	Country	Commissioning Year of I&C modernization	Scope
Beznau 1&2	Switzer-land	1999, 2001	RPS, ESFAS
Kola 3&4	Russia	2010, 2014	RPS, ESFAS, Limitation
Qinshan 1	China	2007	RPS, ESFAS, excore n-flux
Oconee 1,2,3	USA	2011,2013,2012	RPS, ESFAS

The rational for this selection are the following: (1) References from different countries with significantly different regulatory environment, (2) Different reactor types, (3) Different modernization scopes and (4) different modernization dates covering more than 15 years.

In the following Table 2 some key information related to the listed digital upgrade projects is compiled. In Table 2 "Project duration" covers the entire project: Engineering, Manufacturing, V&V, Installation, Commissioning

Table 2 Key Information of Focus Projects

NPP	NPP type	Commercial Operation Date
Beznau 1&2	2loop PWR 380 MW	1969, 1972
Modernization drivers	Spare parts procurement challenging Localization of failures required increasing efforts and time Time demanding testing	
Additional requirements	Realize installation & commissioning during a normal refueling outage	
Number of cabinets/unit	20 TELEPERM® XS cabinets	
Project duration	Appr. 2.5 years	
NPP	**NPP type**	**Commercial Operation Date**
Kola 3&4	VVER 230 440 MW/V231	1982, 1984
Modernization drivers	Safety improvements Intention to switch to digital I&C	
Additional requirements	Realize installation & commissioning during a normal refueling outage	
Number of cabinets/unit	24 TELEPERM® XS cabinets	
Project duration	Approx. 2 years	
NPP	**NPP type**	**Commercial Operation Date**
Qinshan 1	2loop PWR 380 MW	1981
Modernization drivers	Safety improvements intention to switch to digital I&C	
Additional requirements	Realize installation & commissioning during extended outage 2007	
Number of cabinets/unit	21 TELEPERM® XS cabinets	
Project duration	Approx. 2.5 years	

NPP	NPP type	Commercial Operation Date
Oconee 1,2,3	PWR 934 MW	1973, 1974
Modernization drivers	Safety improvements intention to switch to digital I&C	
Additional requirements	Realize installation & commissioning during outage	
Number of cabinets/unit	21 TELEPERM® XS cabinets	
Project duration	Approx. 2.5 years	

Our experience from safety I&C projects dealing with modernization of analog by digital I&C proves that there are quite a few projects being successful in quality, keeping schedule and budget. The presented references also demonstrate that safety I&C modernization projects can be executed in a reasonable time frame.

6 CONCLUSIONS

Digital safety I&C provides several valuable benefits to NPPs besides solving obsolescence issues. Field experience proved that digital upgrade can be executed successfully provided that some key factors have been considered.

Key factors for successfully executed safety I&C projects are:

- A comprehensive and realistic implementation planning
- An early and continuous involvement of the regulator
- A close cooperation between utility (Operator), I&C vendor and regulator
- Upfront detailed definition of requirements on the new I&C systems, rather than trying to copy exactly the design of the old analog systems to digital platforms
- Clarification and definition of the I&C input data prior start of the project execution
- A cooperative mindset of main stakeholders of the modernization project
- An experienced and capable I&C vendor
- A modular based safety I&C platform

In addition important factors of I&C vendor selection beside price should be:

- Vendor’s long term support concept
- Vendor’s product infrastructure
- Vendor’s track record in long term support

TELEPERM® XS can be considered for safety I&C modernization in basically any reactor type and any licensing environment and comes with a proven long term support concept, track record and related vendor commitment.

Acknowledgement

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