NPP I&C SYSTEM MODERNIZATIONS IN THE CZECH REPUBLIC

The NPP Dukovany example

P. KRS
State Office for Nuclear Safety,
Prague, Czech Republic

Abstract

There are four units of WWER 440/213 type reactors under operation at Nuclear Power Plant Dukovany site in the Czech Republic. The ÈEZ utility has decided to include upgrade of existing Instrumentation & Control (I&C) systems as one of the most significant parts of a larger scale modernization project. The original I&C systems designed in the late 70's and early 80's with analogue equipment and relays will be subjected to an integrated modernization programme developed to replace obsolete equipment, to balance operational and maintenance costs, to improve performance and to enhance plant safety. To achieve this objective within next decade, the utility has already started preparatory phase of the overall modernization project, including analytical and planning activities related to the I&C part.

1. INTRODUCTION

There are four units of WWER 440/213 type reactors under operation at Nuclear Power Plant (NPP) Dukovany site and two units of WWER 1000/320 type reactors under construction at NPP Temelín site in the Czech Republic. Both of the nuclear power plants are operated by the largest Czech utility Èeské Energetické Závody (ÈEZ).

For the Dukovany units, the ÈEZ utility has decided to include upgrade of existing Instrumentation & Control (I&C) systems as one of the most significant parts of a larger scale modernization project. The original I&C systems designed in the late 70's and early 80's with analogue equipment and relays will be subjected to an integrated modernization programme developed to replace obsolete equipment, to balance operational and maintenance costs, to improve performance and to enhance plant safety. To achieve this objective within next decade, the utility has already started preparatory phase of the overall modernization project, including analytical and planning activities related to the I&C part.

To enhance the level of safety and availability of the future operation, the ÈEZ utility has decided to introduce significant improvements in original NPP Temelín design, including complete change of the I&C systems design and equipment/systems vendor. This I&C system design upgrade was, in contradiction to most of other cases, started during the construction of the plant and exposed the regulatory body, utility and all other parties involved to a specific set of problems.

With the aim to support these significant system and technological changes in existing regulatory framework, the authority reflected the specific aspects of different NPP Temelín and Dukovany cases in developing a detailed licensing procedure for large I&C upgrade and in introducing a specific licensing tools for this purpose. In addition, the new nuclear legislation adopted by the Czech Republic from the mid of 1997 incorporates all the licensing, technical and quality issues of such cases.

2. NPP DUKOVANY I&C MODERNIZATION PROJECT

2.1. Current state of I&C systems in the plant

The ÈEZ utility operates at Dukovany site situated in southern Moravia approximately 40 km from town Brno four units of WWER 440/213 type reactors. Basic design of NPP was developed as a

result of contract between Atomenergoexport and Škodaexport signed in 1973. The designer of the Nuclear Steam Supply System (NSSS) was LOTEP Leningrad, the designer of Balance Of Plant (BOP) was Energoprojekt Prague. General supplier of technology was Škoda Prague. First unit was connected to the grid in beginning of 1985, other three units vent into operation till the end of 1987.

The NSSS I&C architecture of the NPP Dukovany units is almost identical to that of other WWER 440/213 units of the same generation (NPP Paks in Hungary, NPP Bohunice V-2 units in Slovakia), including the original analogue equipment designed and developed by the former Soviet Union companies in late 70's. The original I&C design of the BOP system was tailored to domestic fluid and mechanical systems (such as ŠKODA turbine units), the major part of the BOP instrumentation was designed and produced by electromechanical industry of former Czechoslovakia in early '80.

The use of analogue equipment and relays of certain quality forced the original designer to incorporate a high level of redundancy in to the WWER 440 I&C design to ensure the necessary function. In addition, the I&C system of these units is rather robust and extensive also due to relatively complex design of the plant (6 loops of primary coolant, 2 turbine generators). This impose large requirements as to the number and qualification of operating and maintenance personnel. For example, the need for permanent I&C maintenance interventions requires approximately 10 specialists at each shift, planned inspections and repairs participates relatively big number of „non-shift" personnel (about 350 000 man-hours per year) [1].

More than twelve years from commissioning of the first unit, most of the equipment is approaching or exceeding its life expectancy, resulting in additional increase of already high maintenance efforts to sustain system performance.

Another serious problem, unavailability of spare parts, is caused mainly by accelerated deterioration of the infrastructure of the manufacturers that support original WWER I&C equipment, majority of the original equipment is not manufactured any more.

A number of small modifications of existing I&C systems was implemented during the years, which eliminated the major shortcomings and, consequently, the share of I&C on the plant unavailability is kept on an acceptable level. Nevertheless, surveys of safety related events from the NPP Dukovany units show, that a large number of them are related to I&C issues. This was confirmed within the framework of ASSET 1993 and 1996 missions to NPP Dukovany. Practically all the events were evaluated as the INES-0 level, but there is a relatively high number of them.

2.2. Integrated assessment of the plant and I&C systems

WWER 440/213 units, including the I&C systems, were in the past subject of several in-depth assessments, majority of which was concentrated on the safety related aspects. Some of these assessments were topical ones [2], other - were performed for particular power plants [3],[4],[5]. In specific NPP Dukovany case, the ÈEZ utility vent first for an integrated plant evaluation, so called „technical audit". This audit, carried out in two stages, was designed to provide basis for preliminary decisions in plant modernization strategy, including the I&C system.

The first stage, an internal audit, was entirely the plant's own effort. The I&C system, as well as other systems, was evaluated according to the following criteria :

- impact on nuclear safety,
- impact on availability,
- operation and maintenance costs,
- lifetime, maintainability,
- compliance with regulatory requirements.

The probabilistic approach applied in the internal audit study for evaluation of the individual systems impact on nuclear safety did not show, in compliance with PSA level 1 study results, significant shortcomings in I&C system. Significant problem, however, represents expiring lifetime and maintainability of existing equipment. Current stock of spare parts, especially for the NSSS instrumentation, is not sufficient for the remaining plant's design life, and new spare parts are practically unavailable. Evaluation according to the last criterion, i.e. compliance with regulatory requirements, identified areas where the existing I&C system do not comply with applicable nuclear safety standards. One of the basis for this evaluation were the results of the regulatory evaluation of the NPP Dukovany Safety Analysis Report (SAR), the Revision after ten years of operation.

The second stage, an external audit, performed by ENAC consortium in 1994 - 1996 was primarily focused on the safety aspects and used the deterministic approach to evaluation. Recommendations for the existing equipment modifications were divided into 5 categories, according to the urgency, and in the I&C part they comprised, especially:

- improvement of mutual separation of the main and emergency control rooms,
- complementing the information systems (first of all - for post accident conditions),
- improvement of the control room's man-machine interface,
- replacement of obsolete systems (starting with the „safety classified").

Following the „technical audit", the individual I&C system of Dukovany NPP were analysed and evaluated. One of the first assessments was performed within the framework of PHARE programme. The EdF and NNC companies provided independent deterministic evaluation of I&C design and proposed a set of technical recommendations how to eliminate the identified shortcomings [5]. In the second stage of this project the NNC developed a number of system specifications (SRS) for replacement and upgrading of the individual I&C subsystems [6].

Another assessment of the current I&C system status was conducted in course of the initial phase of the overall safety related equipment re-qualification programme which is under way at the NPP Dukovany. The subject of actual re-qualification testing and analysis will be only that I&C equipment, which is not a candidate of modernization (replacement, upgrade).

2.3. Planning for I&C upgrade

The results of individual analyses and assessments identified the need for I&C system modernization and recommend the general approach to that. The I&C upgrade has become an integral part of the plant modernization programme. The decision for modernization programme is based on the overall vision for the plant and supports the objective to ensure reliable and safe plant operation throughout the expected lifetime.

The corresponding feasibility study was prepared, based on the following principles:

- complex preparation, step-by-step implementation,
- conservative approach,
- implementation in the course of operation and standard refueling outages.

Existing I&C was divided into 5 relatively independent modules, which, if necessary could be upgraded individually. The following table describes these modules, and ranks their priority/ urgency of upgrading:

A detailed technical specification is being now prepared for the individual modules, as they are shown in the table 1. Within the following stage, a more detailed and accurate schedule of modules upgrading will be developed and the procurement strategy will be defined. Present feasibility assumes that first I&C system upgrading will start in the year 2000. Actual implementation will be carried out

both in the course of operation and during outages. The overall I&C upgrading programme shall be completed in 2007.

TABLE 1: I&C MODULES [1]

Module No.	Module components	C1	C2	C3	C4	C5	Priority
1	Reactor control, limitation and protection (Sugan, ARM, ROM, HO1-4) ESFAS (SOB/SAOZ)	2	2	3	1	1	1
2	Process computers (Uran, Hindukus) Post accident monitoring	2-3	3	3	1	1	2
3	NSSS Interlocks and Logic/Modulating control	2	3	3	1-2	1	3
4	Turbine and Generator Control and Protections	3	2	3	2	2	4
5	BOP Interlocks and Logic/Modulating control	3	3	3	2	2	5

Criteria:
C1 - safety impacts, C2 - availability impacts, C3 - maintenance costs
C4 - maintainability, spare parts availability, C5 - Regulatory requirements

Conservative approach to the I&C upgrading will be represented by maintaining most of the current concepts of controls as well as the majority of current algorithms. The reasons for such approach are as follows:

- insufficient data of the current system's design basis,
- relatively good operational experience on the current system functions,
- necessity to limit risks caused by the simultaneous replacement of equipment and functions
- expected simplification of the new system's licensing procedure .

Nevertheless, the solution proposed in the feasibility study comprises some principal changes, as for instance:

- computer based equipment will be used also in the safety systems,
- reactor trip function and ESFAS will be combined into one system of reactor protection and a common set of sensors will be used for both functions,
- reactor trip functions will be separated from limitation one,
- reactor trip redundancy will be increased from two to three better separated trains,
- some functions of safety systems will be changed or supplemented (e.g. detection of main steam header rupture, post accident monitoring),
- decreased load on operator during first phase of emergency situation („30 minutes rule"),

- computerized functions of the operator support will be significantly extended and the MMI will be improved,

- improved technical level and quality of core monitoring.

Optimal solution for some parts of the I&C upgrading will be chosen after the results of the appropriate practicability studies will become available. This especially concerns the control room upgrading procedure and acceptability/suitability of the CRT controls.

Requirement of minimal influence of the NPP operation during the upgrading of the I&C system is determining factor not only for the implementation schedule, but also for selection of the technical concept. For some of I&C parts this requirement practically predetermines application of distributed systems with minimum demand as to the new cabling volume. The current system of cabling excludes the selective/partial dismantling, and free volume in the cabling trays allows to accommodate only very few new cables. Issue of the service life and usability of the current cabling represents the highest risk for the whole of the I&C upgrading project.

2.4. Involvement of regulatory body

The concept of plant I&C systems upgrade utilizing a modern technology, especially digital technology, will bring a number of licensing issues specific to computer-based portions of safety systems. The licensibility of different upgrading concepts should be considered thoroughly during the preparatory phase of the project.

The new regulatory framework determined by the new legislation (in power from July 1997) will enable SONS to implement smoothly the detailed licensing procedure developed for licensing of the NPP Temelin I&C design replacement. Specific licensing tools, such as Safety Issues Licensing Database, will be implemented.

3. CONCLUSIONS

I&C upgrading is a dominant part of the Dukovany modernization programme which imposes mutual time, cost and technological limitations and link-ups between these two projects. Correct management of individual projects and effective QA system will be very important for successful implementation of the programme. Necessary know-how will result from the relevant PHARE projects, also experience of partner power plants which operate similar reactors as the NPP Dukovany, will be most helpful.

REFERENCES

[1] Rosol, B. Horak. Operation, Maintenance, and Refurbishment of the NPP Dukovany I&C System. International Topical Meeting on VVER I&C, Prague (1997).

[2] Safety Issues and Safety Improvement Measures Connected with I&C. IAEA - WWER - SC - 106.

[3] GRS Safety Assessment of Unit 5 of the Greifswald NPP. GRS mbH, GRS - 92.

[4] Safety Improvement Review Mission to Dukovany NPP. IAEA - WWER - SC - 160.

[5] Safety Reassessment of the Paks NPP. AGNES project.

[6] Basic Engineering for I&C Replacement for V213 Nuclear Reactors. PHARE/90/ENE/15 - first phase final reports. EDF 1993, NNC (1993).

[7] Basic Engineering for I&C Replacement for V213 Nuclear Reactors. PHARE/90/ENE/15 - second phase final report. NNC 1994.

[8] Karpeta. NPP I&C System Innovations in the Czech Republic, a Regulatory Perspective presented on IAEA Advisory Group Meeting on Modernization of I&C Systems in NPP's. Vienna, (1996).