I&C MODERNISATION OF DUKOVANY NPP

Petr Janda, Pavel Douda

Engineers
SKODA JS a.s, Pilsen, Czech Republic

INTRODUCTION

The purpose of Dukovany NPP I&C modernization is to replace the existing protection and control system by new one based on digital technology. At the start of I&C modernization in 2000, Dukovany NPP had been ca. 15 years in operation.

The goal is full replacement of existing systems so that to meet the level complying with current requirements for reactor unit control from the reliability, safety, availability and maintainability point of view, what can be expressed as a general term dependability. I&C modernization is a special task specific by its wide scope, which has to be realized during normal operation of the plant. This paper deals briefly with the process of I&C modernization and main features technical features of modernized I&C.

The general concept of Dukovany I&C modernization, based on field-proven and modern technologies, meets the following needs:

- Improvement of the man-machine interface for control, maintenance and diagnosis,
- Insurance of a high safety level as well as high availability,
- Insurance of ability for long-term operation,
- Improvement of electrical and physical separation between safety divisions and between safety equipment (BS), safety related equipment (SSB) and non-safety related equipment (SNB).

1 SCOPE OF MODERNIZATION

The I&C modernization of Dukovany NPP units has been prioritized into five basic modules, M1 to M5, which shall be carried out in successive steps based on their priority. From the possible I&C modernization variants that were considered, a limited number variant was selected for implementation that requires an exchange, reconstruction or addition of those systems only that have a high priority impact on nuclear safety, or which could be a significant limiting factor on the further NPP operation in the future. Such systems are included in modules M1 and M2.

The scope of I&C refurbishment is shown in the Table 1. Because of digital integrated protection system implementation, the functions of individual systems are distributed by the manner shown in that table.
Table 1  Scope of I&C Refurbishment

<table>
<thead>
<tr>
<th>New</th>
<th>Old</th>
<th>SJS</th>
<th>System Name</th>
<th>Classification</th>
<th>SUBJ Directive</th>
</tr>
</thead>
<tbody>
<tr>
<td>EX-CORE</td>
<td>AKNT</td>
<td>DIS</td>
<td>Ex-core Neutron Flux Measurement System</td>
<td>A</td>
<td>BT2</td>
</tr>
<tr>
<td>RTS</td>
<td>HO</td>
<td>DIS + DRPS</td>
<td>Reactor Trip System</td>
<td>A</td>
<td>BT2</td>
</tr>
<tr>
<td>ESFAS</td>
<td>SOB</td>
<td>DIS + DRPS</td>
<td>Engineered Safety Feature Actuation System</td>
<td>A</td>
<td>BT2</td>
</tr>
<tr>
<td>ELS</td>
<td>APS</td>
<td>ELS</td>
<td>Emergency Load Sequencer</td>
<td>A</td>
<td>BT2</td>
</tr>
<tr>
<td>SAS</td>
<td>TOPG</td>
<td>SAS</td>
<td>Support Actions System</td>
<td>B</td>
<td>BT2</td>
</tr>
<tr>
<td>RLS</td>
<td>ROM</td>
<td>DRLS</td>
<td>Reactor Limitation System</td>
<td>B</td>
<td>BT3</td>
</tr>
<tr>
<td>RCS</td>
<td>ARM</td>
<td>RCS</td>
<td>Reactor Control System</td>
<td>B</td>
<td>BT3</td>
</tr>
<tr>
<td>RRCS</td>
<td>SORR</td>
<td>RRCS</td>
<td>Reactor Rod Control System</td>
<td>B</td>
<td>BT3</td>
</tr>
<tr>
<td>SGPS</td>
<td>LOPG</td>
<td>SGPS</td>
<td>Steam Generator Protection System</td>
<td>C</td>
<td>BT3</td>
</tr>
<tr>
<td>PAMS</td>
<td>---</td>
<td>PAMS</td>
<td>Post Accident Monitoring System</td>
<td>A</td>
<td>BT2</td>
</tr>
<tr>
<td>PCS</td>
<td>IVS-URAN</td>
<td>PCS</td>
<td>Process Computer System</td>
<td>C</td>
<td>BT3</td>
</tr>
<tr>
<td>IN-CORE</td>
<td>KVRK</td>
<td>IN-CORE</td>
<td>In-Core Measurement System</td>
<td>C</td>
<td>BT3</td>
</tr>
</tbody>
</table>

2 INVOLVED COMPANIES

I&C Dukovany modernization is a complex project, demanding from the technical and organizational point of view. There are several companies involved in the refurbishment process. The supply and organization chart is depicted on Figure 1. The Prime Contractor of the whole Work is ŠKODA JS a. s. having more than forty years experience in nuclear engineering.

The Main Sub-suppliers are

- Consortium AREVA NP (formerly FRAMATOME ANP) and Data Systems & Solutions (DS&S). Both companies are considered to be the world leaders in the field of nuclear technology and I&C safety systems.

Figure 1 - Organization Chart
Technical section

- ZAT Control Systems is a supplier of RRCS and SGPS systems and Process Computer System including In-Core processing part.
- I&C Energo is in charge of the field instrumentation delivery and systems installation
- Of course, the cooperation on specific tasks with other companies is necessary in regard of the projects wide scope. Therefore this fact has been considered in the organization chart that is depicted below.

3 MAIN PROJECT ASPECTS

- Purpose I&C Refurbishment:
  Replacement of analog system (Russian origin) by advanced digital one
- Goal: Increase reliability and nuclear safety increasing, availability and maintainability to the level of current requirements and legislature
- Specific parts in the T544 Project:
  - Wide scope of individual I&C systems refurbishment
  - Systems delivery is divided into two main modules – M1 and M2
  - Wide scope of modernization during normal operation of the NPP
    - Full replacement of 10 Safety and Safety related Systems in the module M1
    - Full replacement of 2 Safety related System in the module M2
    - Provision of full compatibility with current technology and other support systems

4 MAIN CEZ REQUIREMENTS

- All systems based on digital technique
- High technical level and verified solutions, proven and already licensed technologies
- Each equipment is designed and located taking into account the existing cabling
- Limited modification of control rooms i.e. manual controls, alarm displays to be kept, implementation of new screens
- No fundamental functional modification
- Compliance with measures of national, IEC, EU, US Standards and IAEA recommendations
- High level of safety and availability and economically acceptable solution
- Qualification according to nuclear standards
• Requirements: Lifetime corresponding with the NPP lifetime
  State of the art technology and performances

The most important part of I&C system - especially safety and safety related systems - are based on the SPINLINE 3 technology (DS&S) delivered by consortium AREVA NP / Data Systems & Solutions. This is digital technology currently in use at French reactors with the background of many years of experience (over 20 years on these reactors). There are also another technologies used for some parts of I&C. The survey, see in the Table 2.

Table 2 Used Technologies

<table>
<thead>
<tr>
<th>System</th>
<th>Technology</th>
<th>Supplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTS, ESFAS, RLS, SAS, ELS, RCS</td>
<td>SPINLINE-3</td>
<td>DS&amp;S</td>
</tr>
<tr>
<td>RRCS</td>
<td>PRIMIS</td>
<td>ZAT</td>
</tr>
<tr>
<td>PAMS</td>
<td>VME</td>
<td>AREVA/SAGEM</td>
</tr>
<tr>
<td>SGPS</td>
<td>ZAT 2000 MP</td>
<td>ZAT</td>
</tr>
<tr>
<td>PCS</td>
<td>ZAT 2000 MP</td>
<td>ZAT</td>
</tr>
</tbody>
</table>

5 ARCHITECTURE OF MODERNIZED I&C SYSTEMS

The overall I&C architecture is shown on the following figure.
6  MODULE M1 SYSTEMS

The reactor protection system includes the following systems:

- Reactor Trip System (RTS) including Ex-core neutron flux measurement and reactor trip breakers,
- Engineered Safety Feature Actuation System (ESFAS)
- Support Actions System (SAS) - trained part of SAS
- Emergency Load Sequencer (ELS)

The Protection Functions are distributed, over the hardware architecture, into three main groups of cabinets DIS, DRPS + DRLS and ELS as described in the following table:

<table>
<thead>
<tr>
<th>Function</th>
<th>Cabinets</th>
<th>DIS</th>
<th>DRPS + DRLS</th>
<th>ELS</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTS</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>ESFAS</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAS</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ELS</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Ex-CORE</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

The architecture of module M1 systems is organized according to a three-fold redundant structure. Each division is located in rooms, specific to existing reactor protection systems (PPR rooms).
Block diagram of one division is presented on figure 3

**Figure 3** – Block diagram of M1 systems

Brief description of individual systems:

- DIS, dedicated to conditioning, acquisition and processing of the sensors (neutron flux sensors and technological parameters sensors).
- DRPS, dedicated to reactor protection systems, processes data from the DIS channels through the safety networks. It houses RTS, ESFAS and SAS functions and sends the orders to the trip breakers, arranged in two sets of reactor trip breakers, RRCS and actuation systems.
- ELS, dedicated to diesel generator start-up system and load sequencing, receives data from sensors
- PAMS-1, dedicated to the Post Accident Monitoring processes parameters of category 1 as specified in US NRC RG 1.97

The other systems (classification as category B and C, according CSN IEC 1226), are the following:

- DRLS, dedicated to reactor limitation, embedded in DRPS + DRLS set of cabinets
• RCS dedicated to reactor control and receives data from the three safety networks and sensors. It exchanges data with DRLS, RRCS and TVER.

• SAS-N, receives data from the three safety networks, manual controls and binary inputs for failure signaling of I&C feeding system. It performs the technological protection of the steam generators and the control of the non-trained actuators of SAS, ESFAS and RTS. It sends data to SGPS and sends orders to actuators to initiate isolation of the steam generators and other non-trained actuators.

• PAMS-2 processes parameters of category 2 as specified in US NRC RG 1,97

• IDMS, channel A/B, receives data from the three safety networks and the surveillance networks connected to SP3 equipment. It is dedicated to perform the common functions as surveillance, diagnosis for maintenance, reactivity calculation, and displays in MCR and ECR and data transfer to PCS. For data transfer between systems and divisions are used safety networks (NERVIA and MODBUS) and serial data links RS 485.

• PACQ, located in MCR room performs the following functions:
  ➢ Neutron detectors power calibration (maintenance),
  ➢ Neutron threshold acknowledgement (operation),
  ➢ Source range interlocking (operation),
  ➢ Sensor management (maintenance).

7 MODULE M2 SYSTEMS

Main features

Process computer information system (PCS) for Dukovany NPP is tailored specially for the needs of VVER nuclear plants. PCS system has to meet the high requirements on functionality, performance, reliability, security, and compatibility with connected systems.

PCS system provides full and entire information on NPP technology state and a state of reactor core for its monitoring, control and reporting. The system also includes functions for monitoring of safety parameters and other special functions for nuclear applications.

8 INSTALLATION STRATEGY

The phases of realization at NPP are split over four regular outages for each unit (see Table 4). The reason is to learn experience and minimize the of installation costs.

The implementation is being performed during normal operation of the plant. The older safety systems are fully functional until the fourth outages. In the fourth outage
(ca. 65 days) in the sequence, the modernized systems are connected with the current actuators, tested with NPP technology.

Between the last two outages the appropriate equipment installed in successive steps operates only off-line i.e. with real sensors but actuators are disconnected. Such progress is useful for the comprehensive testing of new systems behavior in real conditions of the plant. Such testing is applied to comparison their dynamic features with old equipment, which is operating parallel in on-line mode.

The feedback from new systems off-line operation brings important information and feedback to be used in Design.

During unit start-up, the special dynamic tests have to be performed to verify safety and control functions. At the end of all activities, the performance test of new modernized systems is carried out to prove that all guaranteed and performance requirements have been met and systems operate properly.

Such process of installation is very demanding on the coordination of all activities on-site.

**Table 4  Project Schedule**

<table>
<thead>
<tr>
<th>Year</th>
<th>Unit B3</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
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<tbody>
<tr>
<td>Unit B3</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>L</td>
<td>A+G</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Unit B1</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>L</td>
<td>A+G</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unit B2</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>L</td>
<td>A+G</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Unit B4</td>
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<td>S</td>
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<td>E</td>
<td>A+G</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend:  
S – Regular Short Outage (approx. 35 days)  
L – Regular Long Outage (approx. 65 days)  
E – Extended Short Outage (approx. up to 50 days)  
A+G – Additional + Guarantee Tests