Westinghouse Experience in Kozloduy NPP Units 5&6 I&C Modernization

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Abstract – The paper will describe the background, current implementation approach and experience on the largest ever modernization program on operating units VVER 1000 (PWR) at Kozloduy Nuclear Power Plant in Bulgaria. The Modernization Program itself includes more than 212 measures. Westinghouse is modernizing the major I&C Systems at VVER 1000.

I. INTRODUCTION

The largest ever modernization program on operating VVER-1000 units started back in 1995/1996, when major nuclear technology international suppliers, together with Bulgarian engineering companies, participated in a series of studies to evaluate the implementation of the modernization program on two operating VVER (PWR) 1000-MW units. Since VVER (PWR) 1000-MW Units have been designed and built at the end of 70s - beginning of 80s, the purpose of the Modernization Program is the Units to be brought up in accordance with the new international requirements and regulations (especially after Chernobyl accident in 1986 in Ukraine) and make them “acceptable for long-term operation” by the public.

The main goals of the ongoing modernization program are to improve plant safety, availability and control by introducing new design solutions and technologies. Improving reliability of the equipment by replacing it where the design life of the equipment has expired.

The modernization program is following the full scope of recommendations of the IAEA documents “Ranking of Safety Issues for VVER-1000, Model B-320 Units”. The implementation plan for the modernization of the units is based on analysis and expert assessment of each issue (modernization efforts). The goals of the modernization program determined the following main features of the actual implementation:

- Phase-by-phase approach for implementation;
- Replacement activities only during the planned outage windows without affecting electricity production and availability of the units;
- Strong project management organization;
- Concerned efforts to manage the interfaces and integrate the new systems into the existing plant.

The overall cost of the Modernization Program is 491 million Euros. There are two major contractors involved into the implementation of the program, selected as a result of open bid – European Consortium “Kozloduy”, which includes Framatome ANP and Russian organizations (about 280 Million Euros) as well as Westinghouse Electric Company (about 72.4 Million US Dollars). While the European Consortium is being involved in modernization of the mechanical equipment and replacement of electrical equipment, Westinghouse scope includes replacement and modernization of the major I&C systems including Computer Information Systems, Primary and Secondary Control Systems, Turbine Control (including Digital Electro-Hydraulic System) as well as some of the Radiation Monitoring Systems (Stack Releases Monitoring and Severe Accident Monitoring). Separately, Kozloduy NPP is investing 135 Million Euros. Representatives of more than 15 countries (USA, Germany, France, Russia, Ukraine, Czech Republic, Italy, Spain) are involved in the actual implementation of the Modernization Program. A significant portion (about 15%) of the works has been subcontracted to Bulgarian Engineering/Installation companies.

The major topics of the modernization program and specific approach are described below as follows:

- Design Approach and Feature;
- Installation Approach;
- Test Strategy;
- Licensing Strategy, applicable codes & standards;
- Conclusions.

II. DESIGN APPROACH AND FEATURES

Considering the complexity and the interconnections between different modernization efforts performed by different Contractors, one of the major requirements of the Modernization Program is to coordinate all the interfaces between the systems, long-term planning of all processes and relations in order to eliminate the risk. In general, the implementation of the Modernization Program is in different phases. Actually, the modernization program started with an Engineering Phase, followed by an
Implementation Phase. The Engineering Phase 1 (see Figure 1) included development of documents identifying the technical scope, feasibility, interfaces, system requirements, environmental requirements, requirements to the cabling and installation, licensing basis, and input data requirements.
PHASES OF CONTRACT IMPLEMENTATION

- **PHASE 1 - ENGINEERING**

- **Input Data**
- **Terms of Reference**
- **Technical Project**
- **Feasibility**
  - **Scope**
  - **Time**
  - **Cost**
- **Submission to NRA**
- **Measure Authorized**

Figure 1  Phase 1 Engineering
The Detailed Design Phase, as part of the Implementation Phase (Figure 2), was based on the documents and requirements developed and agreed to during Phase 1 Engineering. In order to achieve continuity and consistent design, at the beginning of the Detailed Design Phase, Westinghouse developed a set of documents, which outlined the main requirements to achieve the design goals, as follows:

- Overview of Functional Requirements;
- Overview of System Performance Requirements;
- Overview of Interfaces to External Systems;
- Preliminary System Architecture.

Generally, the scope of the modernization so far includes the following major I&C systems at Kozloduy NPP VVER-1000 reactors:

- Computer Information System (CIS);
- Turbine Control (including DEH) and Secondary Controls Systems;
- NSSS (Nuclear Steam Supply System) Control Systems Upgrade;
- BOP (Balance of Plant) Control Systems Upgrade.

While the Computer Information System and Turbine Control and Secondary Controls Systems, which used old digital technology, are being replaced using “fit, form and functional” replacement, i.e., replacement of the existing obsolete technology with new, “state-of-the-art” digital technology, the NSSS and BOP Control Systems upgrade is totally different. In this case, the existing analog technology is being replaced with state-of-the-art DCS (Distributed Control System).

“Fit, Form and Function” replacement in our case for the Computer Information System and Turbine/Secondary Control System means:

- Replacement of the old I/O cabinets with the identical number of new controller cabinets, located exactly in the same places in order to avoid the cabling;
- Replicating the same functions that have been performed by the old systems (with enhancement of functionality because of the level of technology).

In both cases, different design approaches were applied. In order to accommodate the existing location of the Input/Output cabinets of the Computer Information System, and to keep as much as possible the Man-Machine Interface, the architecture of the new Computer Information System, as well as the Turbine Control system, was developed in four different layers:

- Operator Monitoring and Interface Layer;
- Communication Layer;
- Processing and Computation Layer;
- I/O Data Acquisition and Processing Layer.

The architecture of the Computer Information System is shown on Figure 3.

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**Figure 3 Kozloduy Units 5&6 CIS Architecture**

While the replacement of the Computer Information System and the Turbine Control System was a “fit, form and functional” replacement, i.e., replacement of the existing I/O cabinets with new digital system controller cabinets and replication of the basic functions, the replacement of the Primary (NSSS) and Secondary Control Systems (BOP) adopted a different approach. The replacement of the Primary Control System is an “in-situ” replacement, i.e. partial replacement of the old analog control cabinets with new DCS controller cabinets, while keeping some of the marshaling cabinets of the old analog system that will bring the field signals to the digital controllers.

The installation of the Secondary Digital Control System, which will replace the old analog system, will be on the available free location, different from the original location of the old analog Secondary Control System. Such approach, also called “island approach”, will allow replacement of the system cabinets in advance, independently from the operation of the original Secondary Control System. Signals from their original destinations are to be brought to the new locations in the easiest and simplest possible way. This approach utilizes a new dedicated termination – marshaling cabinets located close to the new DCS replacement system cabinets.

The preliminary architecture of the Primary and Secondary Control System is shown in Figure 4.
During the project development, several main challenges were faced as follows:

- The large scale of replacement systems (there are about 16,000 I/O signals for the Computer Information System and about 40,000 – for the Primary and Secondary Controls Systems) required preliminary input data development and verification. Also, the number of documents, developed under the Detailed Design Documentation, is significant. This required coordination and close relationship with the Customer throughout the whole design process;

- Actual replacement work is spaced over 5-6 years and there are many interim stages of plant configuration that need to be considered during the implementation.

The time period for the project implementation imposed big challenges to the technology changes and keeping the hardware consistent with the changes and the new technologies. For instance, during the implementation of the Computer Information System design, Westinghouse had to adopt the new network technology and, instead of FDDI (Fiber Distributed Data Interface), to migrate to Fast Ethernet.

III. INSTALLATION APPROACH

In order to fit into the required outage window, Westinghouse had to prepare an installation technology considering the system design, available work forces, and detailed installation design. The installation design efforts were split into two tasks:

- Network Infrastructure Installation Activities;
- Replacement Outage Installation Activities.

Two different design packages were developed accordingly. The network installation activities are being implemented prior to the actual replacement outage, which significantly facilitates the installation efforts.

IV. LICENSING STRATEGY, APPLICABLE CODES AND STANDARDS

For each separate I&C system in Westinghouse scope of replacement, correspondent modifications of the Safety Analysis Report (as a referenced standard is being used the Russian PNAEG 01-036-95 “Requirements to the Safety
Analysis Report of NPP with VVER Reactors) has been provided. The content of the modification was described in general in the preliminary engineering documents, which were developed during Phase 1 Engineering (see Figure 1). In general it contains:

- Description of the Configuration;
- QA during Design, Manufacture, Installation, Start up and Operation
  - Performance during the Normal Operation;
  - Performance during Malfunction;
  - Reliability Analysis;
- Assessment of the system design adequacy to the requirements established during Phase 1 Engineering.

When the Modernization Program commenced, because of the fact that different suppliers were involved, the Bulgarian Nuclear Safety Authorities recommended each Contractor (supplier) to use during the design and manufacturing the equipment the applicable codes and standards of its own country. For Westinghouse this meant to apply during the design process the applicable US codes and standards. In order to evaluate the applicability of the US codes and standards during Phase 1 Engineering, Westinghouse have developed specific analyses for each system, which compared the requirements of the Bulgarian laws and regulations with the ones in the United States (and Europe). These analyses were used as a contractual basis. In general, the analyses cover the following areas:

- Quality requirements (applicability of 10CFR50, ASME NQA-1, ISO);
- Environmental Qualification (applicability of IEEE, IEC 61000, Reg. Guide 1,89; 1,92 and 1,100);
- System Classification – the systems are being classified using IEC 61226 -1993 (a separate study has been performed and each function was categorized following IEC 61226 requirements);
- General Design Criteria (applicability of 10CFR50);
- Periodic Testing Requirements (applicability of IEEE);
- Single Failure Requirements (applicability of IEEE);
- Independence Requirements (applicability of IEEE);
- Fire Protection requirements.

V. TEST STRATEGY

Considering the complexity of the project and the limited time for installation, an extensive test strategy was developed and applied, including:

1. Development of Equipment Qualification Requirements and Specifications:
   - Seismic Qualification;
   - Environmental Qualification;
   - Electromagnetic Compatibility.

2. Different levels of testing, as follows:
   - Level 1 Hardware Testing;
   - Level 2 Software Testing on Cabinet Bases;
   - Level 3 Integrated System Validation Testing;
   - Level 4 – Factory Acceptance Testing;

   Operation Acceptance Testing on operating equipment implemented together with the customer.

   Significant efforts were made to test the controls systems (ASYT, Primary and Secondary Controls) in close loop with plant model developed and verified specifically for Kozloduy Units 5&6. This approach assured optimal tuning of the systems and stable operation.

VI. CONCLUSIONS

- The project itself represents the largest ever and the most complex multinational modernization efforts on an operating plant. For the time being, Westinghouse completed installation of the Radiation Monitoring Systems and Computer Information Systems. The next step is installation of the primary and secondary control systems;
- Specific design solutions were required and developed in order to address the specific plant features. At each stage, representatives of the Client are being involved in the process of designing and testing of the equipment and systems;
- Phase-by-phase installation efforts were developed and extensive installation design documentation was prepared to fit in the limited outage window and to successfully complete the installation activities;
- Well-prepared, multi-phase testing strategy was developed and is being implemented to assure the proper and adequate operation of the equipment at the factory and at the real plant;
- Although the Modernization Program is being implemented as a “turn –key” project an important role is playing the close cooperation with the Client. This way guarantee detailed knowledge of the original design and full understanding of the Client requirements;
- Timely consideration and planning of all interfaces is essential for such large project.