SAP Nuclear – a new software for radiation protection in Slovenské Elektrárne / Enel company

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1. BACKGROUND

Slovenské Elektrárne (SE), a subsidiary of Enel, owns and operates four VVER 440/213 reactors at Bohunice (EBO) and Mochovce (EMO). These plants have historically used processes and IT solutions developed internally over many years. The IT solution for plant maintenance planning and implementation support previously in place was an in house custom developed software solution named ARSOZ. The ARSOZ product supported maintenance and other core nuclear processes within SE, including Radiation Protection and Access Management. The ARSOZ product was not currently in use outside the Slovak Republic. The organization had not selected or developed a standard tool for

the scheduling of plant activities and therefore there were gaps between EBO and EMO across many processes.

1.1 Gap Analysis

A Nuclear Business Improvement Group was established in 2006 to evaluate the performance of the SE nuclear facilities in relation to the industry top decile performers and benchmarking efforts in the fall of 2006 showed performance gaps in multiple measured processes between the Slovenské Elektrárne nuclear organization and the highest performing nuclear organizations in the world. While overall performance of the SE nuclear fleet was good and routinely in the second quartile, SE nuclear leadership set new goals to improve safety and operational performance to the first decile of the worldwide pressurized water reactor (PWR) Fleet. To meet these goals the SE nuclear leadership initiated a project to identify and implement the Best Practice nuclear processes in multiple areas. The result of those evaluations showed opportunities for improvement in multiple key process areas:

- Work Management
- Outage Management
- Equipment Reliability
- Corrective Action – Problem Identification and Resolution
- Self Assessment
- Benchmarking
- Industry Operating Experience
- Risk Management

Benchmarking also showed the need to provide a fully integrated IT platform to support the implementation of the improved process models.
Later on a decision was made to also integrate the multiple Radiation Protection, Chemistry, Environmental monitoring, and metrology programs and systems into the integrated software solution.

1.2 Best Practices Baseline

The design criteria used for the review and update of the current processes was based on the Institute of Nuclear Plant Operations (INPO) Standard Nuclear Process Model (SNPM). The standards for the Work Management processes are defined in INPO AP-928 and for Equipment Reliability they are defined in INPO AP-913.
A nuclear industry best practice Continuous Improvement program was identified through benchmarking to provide the basis for the SE Corrective Action Program (CAP), Operating Experience Program (OE), and the Benchmarking and Self Assessment (BM/SA) processes.
The current Slovenské Elektrárne processes were used as a baseline for the integration of all the Radiation Protection, Environmental monitoring and Metrology processes, with the aim of improving them where possible.

The declared objective of the Nuclear organization was *"To Achieve Top Decile Performance in Safety, Reliability, Production, and Efficiency and Become the World's Premier Operator Of VVER Technology"*

1.3 IT solution

The SAP Enterprise Asset Management (EAM) platform and its modules (Plant Maintenance - PM, Material management - MM, Work Clearance Management - WCM) were chosen as the core for work management support.
Primavera was chosen as the scheduling platform for all on line and outage scheduling activities.

Radiation Protection, Dosimetry, Environmental releases, Radioactive Waste management, Metrology, Chemicals Management, Radiation Controlled Area (RCA) access management were integrated using a combination of SAP PM module, SAP MM module, SAP Environmental Health and Safety (EH&S), SAP HR, Enel Learning System (ELS), MS Access and Electronic Personal Dosimetry System (SEOD), a dedicated dosimetry management software.

The fundamental principle that was followed is that SAP has to be considered the Master system for all the relevant plant and personnel information, including medical records, professional qualification training and legal dose records.

SEOD was chosen as the system where all the necessary Radiation Protection operational activities, reports and day-to-day dosimetry records and calculations have to be executed, while SAP remained the official doses repository.

All the applications were provided in Slovak as well as English, meaning that in many cases an extensive translation job had to be commissioned.

2. PROJECT ORGANIZATION AND CHALLENGES

Although the project required a substantial Information Technology (IT) investment, it was initiated at the request of the line organization and the final decision to implement the new process design and the supporting IT systems was made by the functional organization and not the IT department. The project was truly driven by the functional organizations.

The Project structure had functional teams reporting to the Project Management and dedicated supporting teams to cover integration with the existing systems and processes.

The functional teams were:

- Assets Configuration & Data Migration (ACDM)
- Work Management System (WMS)
- Outage Management (OM)
- Work Clearance Management WCM)
- Corrective Action Program (CAP)
- Environment, Health & Safety (EH&S)
- Supply Chain Management (SCM)
- Financial integration (FI)
- Key Performance Indicators (KPI)

The project leadership and SE line management recognized that the key to a successful implementation laid not only in the process and technical aspects of the project but also in the organizational acceptance of the need for change and the readiness of the organization to successfully use the new organizational alignment, processes, and tools to improve performance.

For this reason members of the line organization were used extensively as Team Leaders and Team members, and all the functional teams could count on full time support by a dedicated Change Management team consisting of in house line organization personnel as well as consultants. This team developed and managed implementation of detailed communications strategies, training strategy and implementation plans, readiness assessment processes, and Project Management Organization logistical support.

Internal resources were used for the final users' training, according to a train-the-trainer approach.

The main organizational changes at the NPPs were following:
- The redesign of the Continuous Improvement (CI) process as the top process of Corrective Action Program (CAP), Operating Experience (OE) and Self-Assessment & Benchmarking (SA&B) led to the creation of a new team inside the Nuclear Safety Dept;
- A Work Management (WM) department was established, responsible also for Outage Management.;
- The work planners were assigned to the WM Dept. and relevant positions were moved from the Maintenance Dept.;

- the process of Blocking & Tagging was fully under control of Operations Dept. and ten new positions were created inside the Operation Support Dept.

3. THE EH&S TEAM

The Radiation Protection Processes play an important part in operating the plants safely, reliably and in accordance with the Act 355/2007 on the Protection, Support and Development of Public Health. and on modification and amendment of certain acts.
Other processes, dealing with Radioactive Waste, Metrology, Chemical Management are also subject to regulations under Slovak Acts and EU requirements.
The EH&S Team was responsible for the process implementation and System customization within the following areas:

1. Access management to the Radiation Controlled Area (RCA)
2. Radiation Work Permits and ALARA management
3. Operational Dosimetry
4. Legal Dosimetry
5. Laboratory Measurements and Releases
6. Radioactive Waste
7. Management of Chemicals
8. Management of RA-sources and RA-materials transport
9. Metrology

Over twenty professionals from the line organization composed the team, with the Team Leader and Deputy TL acting as coordinators and interfacing with the Project Management.
As mentioned the existing practices were used as baseline, so the first task was to map the processes in detail analyzing all the possible interfaces and data sources. While doing so actions were taken to optimize and change the processes wherever there was room for improvement. One major goal during this phase was the unification of all the practices between the two NPP sites, since in many cases there were formal as well as substantial differences between the two. In those cases where the discrepancies were impossible to eliminate (i.e. different parameters due to varying equipment suppliers) the system was set up parametrically in order to allow both sites to operate the application as desired.
The process mapping phase was long and demanding, as the process description was influenced by the radicated presence of the old software, and it was hard at times to separate the pure activities from the existing tool. An additional barrier was posed by the language, as the project documentation had to be provided in English while not all of the team members were proficient English speakers or writers.
The process blueprints, the list of supporting procedures, the expected reports and printouts, the system interfaces, the data to be migrated, the description of the functional responsibilities were all collected in the Business Design Document (BDD). This paper represented the baseline for all the To-be processes, and was used as the model around which the IT system had to be built.

The Team started working on the Business design in the summer of 2008, and the final document was delivered in January 2009 although it was later modified to reflect the organizational adjustments that followed.
The approved project schedule anticipated a preliminary Go-Live for the SAP Production System in August 2009 and then a gradual development and roll-out of all the other systems and interfaces. The final Go-Live of the integrated solution was scheduled for January 2010.
The bulk of 2009 was spent on the software's design, development and testing, as the team was involved on several fronts crossing different organizational areas and technical solutions. The new procedures were also developed, approved and released according to plan.
SAP Nuclear went live on Jan 1, 2010 followed a few days later by ELS and SEOD. The latter was improved in the following months as technical bugs were found and emerging issues were solved.

The following chapters describe each single area that was covered, briefly depicting the processes and the adopted technical solution.

3.1 Access management to the Radiation Controlled Area

A well designed Access management process is crucial in order to guarantee safety, regulatory compliance and work efficiency at the NPP. All the suppliers working at the NPP are managed the same way.

The personnel can access the RCA when in possession of a Permanent Entry Permit (PEP), or under a Single Entry Permit (SEP) under the supervision of an authorized person.

There are three main prerequisites to obtain a PEP :

- medical check
- training and exam in RP area (professional ability)
- personal dose history

The periodical (and extra-ordinary) medical records validity date are entered and stored in SAP HR; the validity of the professional capability is recorded in ELS for internal employees and then passed to SAP HR where similar records are stored for the contractors.

Both types of information are transferred to SEOD where they are combined with the IC record to provide a validity date for the PEP. This date is then sent back to SAP HR in order to make it available for work management purposes (see RWP and ALARA).

The SEP is managed entirely using the SEOD application. It covers the whole workflow from the premit creation to its approval, printing and archiving. It also offers reporting and exporting capabilities, including the personal dose reports to be provided to the supplementary workers' employers and txt files creation.

The application is also used to manage the physical entrance into the RCA and the change rooms. It assignes and tracks permanent and temporary lockers and shelves in the "hot" and "cold" change rooms to the possessors of PEP and registers the issuance of personal protective equipment.

A consistent hardware investment was made to guarantee the automation of the process, as the keys to the lockers on the "cold" side are distributed by dedicated dispensers that recognize employees through the badge and check their permit validity. New hardware and info panels were installed at the CA boundaries to support the new software and process.

The application is integrated with other parts of the system, like legal dosimetry and SEP, and is able to generate the following reports:

- Historical assignation of lockers/shelves.
- Comparison of the PEP and temporary lockers validity dates. This report helps identify persons that should return keys (have the key even though they can not enter the CA).

3.2 Radiation Work Permits (RWP) and ALARA management

Among other things a completely new Work Management process in compliance with INPO AP-928 was established at Slovenske Elektrarne NPPs, and the overall management of the RWPs was greatly improved as a result.

The Work Order (WO) was established as the main work control document, while the RWP is seen only as a supporting document. The existence of only one work control document is crucial to guarantee safety through appropriate risk management, and it is important that all the work is executed according to the official schedule, without the possibility to generate an RWP independently of an approved WO.

The RWP document structure and workflow was built within the SAP PM module, and it is also integrated with the HR module and with the SEOD application through a dedicated SAP interface.

A RWP is required for all the working activities to be executed in the RCA, and the system was set up in such a way that every time a WO is planned that requires a RWP, the RWP is generated and automatically linked to the parent WO.

It is possible to create a RWP for each single WO operation as well as group some operation into the same RWP. This was done to allow for a more specific approach to radiation safety when dealing with complex WOs containing great amounts of sub-activities.

The application allows the assignment of workers to the RWP in advance based on the validity date of their PEPs (stored in SAP HR) and then automatically stores the operational doses absorbed by each worker on a given RWP.

In order to do so a two-way interface with SEOD had to be built: SEOD manages the operational dosimetry in real time and also allows people to be assigned to the RWP directly on the field, with dedicated stations equipped with bar code readers and electronic dosimeters readers.

Operational reporting is also managed in SEOD, with SAP providing specific reports and graphical outputs on collective doses, manhours and their trends vs specific equipment and work types.

SAP also allows to store and archive data regarding the measured radiation situation prior, during and after the work completion and the assignation of special protective equipment.

The results of the new approach are:

- Enhanced safety and Radiation Protection effectiveness;
- Unification of the RWP management of EBO and EMO;
- Elimination of manual assignment of doses = minimization of human errors

The compliance with the ALARA principle is guaranteed for those activities exceeding the prescribed personal or collective dose equivalent (CDE) through a dedicated process.

ALARA instructions are prepared and reviewed in the stage of work preparation. Works can be executed after approval of the work procedure and measures by the ALARA Commission, and when the works have been executed, the ALARA instruction is evaluated.

The ALARA application was built in SAP PM and provides for documentation issuance, registration, approval, evaluation after execution of works and archiving. It is possible to connect a specific ALARA document to a series of RWPs which will cover a certain activity.

3.3 Operational Dosimetry

The operational dosimetry application deals with the registration of employee entries into the CA, registration of obtained operational doses, calculation of their immediate dose reserve, and evaluation of the operative load. It cooperates with other dosimetry applications: RWPs, SEP and Legal Dosimetry. It is managed in SEOD and is interfaced on-line with SAP, where it sends data relative to the personal dose reserve.

The system works on-line through dedicated electronic dosimeters readers at the RCA boundaries and at other relevant spots, but data related to obtained doses can also be input manually if needed. Sets of specific EPDs warning and alarm levels can be managed through SEOD.

The operational doses are regulary replicated between the EBO and EMO sites since there are workers that can be working at both locations.

Among others, the following reports are managed in the Operational Dosimetry application:

- Comparison of doses from operational dosimetry with doses from legal dosimetry;
- Historical overview of entering RCA accesses per person;
- Overview of received doses (operational as well as from external dos.);
- Collective doses per different group of persons, per RCA, per different activities, equipments;
- Dose load;
- Comparison of operational load.

3.4 Legal Dosimetry

Legal dosimetry can be divided into External dosimetry and Internal Contamination (IC) and represent the official record of a person's dose history.

SEOD is in charge of Legal Dosimetry, while the official monthly records are replicated to SAP HR through interface and stored there.

The legally recognized dosimeter at Slovenske Elektrarne NPPs is the Film Dosimeter (FD), and the application provides personal FD assignment and management as well as dose evaluation from FDs evaluated according to specific algorithms and calibration curves. EBO and EMO receive films from different suppliers, thus the calculation procedure had to be separately established in the software.

New FDs are loaded every month into a dedicated set of dispensers, which recognizes and validates each worker's permit through optical readers and automatically distributes the same FD before each RCA entry. The system also checks that the FD has been returned to the appropriate slot after a person left the RCA, thus minimizing errors deriving from FD misplacement or loss.

At the end of the month the system generates a batch of FDs numbers coupled with the employees' ID. The system enables the comparison of registered doses with the limits, and can track the dose reserve over a certain period, various types of CAs and various types of doses.

It contains a system of monthly, yearly and long life registration of personal doses from various dosimeter types and for various RCAs. All the derived quantities and limit values can be parametrically set.

The application provides for various evaluations, print reports and exports, among which:

- Dose load over a period up to one year, in monthly steps;
- Updated dose load;
- Confirmation of received doses. This printout has to be provided on a monthly and yearly basis to the Companies employing the supplementary workers. It contains information about the effective dose E, the dose equivalent for skin, hands, legs, eyes and internal contamination (E_{50});
- Effective dose report to be used by personnel going to other NPPs;
- Dose reports (exports) to the State Dose Register of Slovak Republic.

As a part of legal dosimetry, IC management was developed in SEOD.

It contains the registration of various types of internal contamination measurements within various types of monitoring and a monthly and life registration of dose commitments IC.

It also manages the participation to regular Monitoring of Personnel Internal Contamination (MPIC) and the related invitations.

The application provides for various evaluations, print reports and exports required for monitoring, documenting and evaluation of internal contaminations of employees, including statistical evaluation on the occurrence of radionuclides. The reports can be filtered according to:

- Type of measurement
- Time interval
- Employer
- Measured values (above Minimum Detectable Activity (MDA) and/or above Derived Record Level (DRL) or other selected intervals);
- Radionuclide and/or intake;
- Others.

3.5 Laboratory Measurements and Releases

The basic requirement was to make the Laboratory measurements and releases of radioactive substances application in SAP Nuclear provide all the possibilities and activities which were already implemented in ARSOZ.

The software development was long and complex, as the SAP EH&S module had to be in many ways customized to satisfy the line organization requirements.

The final product is used to administer the processes at the On-site as well as Off-site laboratories (Environmental labs).

The on site laboratories deal with sample measurements and radioactive releases to the environment, both liquid and gaseous.
The Environmental labs (one per site) are responsible of the radiation monitoring of the environment surrounding the NPPs.

The application enables the recording of samples in the database, the measurements of samples, the process of approval and document workflow together with information concerning the changes of the document. The records can be viewed, edited, printed and exported to TXT and PDF files according to predefined access rights.
It was necessary to keep the existing export format into the application ESTE-AI (Emergency Source Term Evaluation Code-Annual Impact).
One critical point is the execution of balances of liquid and gaseous releases of radioactive substances based on the samples recorded for a selected time period. It is possible to set up and control a predefined sampling schedule for a selected amount of measurement types.
New printed form templates were created, including:

- Sample accompanying letter it is a protocol accompanying the sample at the sampling location and in the laboratory during measurement. It serves as a task list for the sampler and the required information is filled in manually during sampling and measurement.
- Protocol of Sample Measurement – this form is used for the following types of measurements: Airborne Releases, Liquid Discharges, Non-Periodical Laboratory Measurements, Periodical Laboratory Measurements.

The Protocol of Measurement is an overview of analyses executed on a sample and it is used used by on site and off site Laboratories.The protocol contains header data, measured parameters and the list of persons responsible for the single steps during measurement.
The protocol can be printed either in Slovak or English depending on the user login language.

3.6 Radioactive Waste

Radioactive waste (RAW) management is of fundamental importance for the NPPs, and in order to achieve the minimization goals that have been set a sophisticated and reliable tool is paramount.
The complexity of the customization effort that would have been necessary to allow SAP as a process supporting tool led to the decision to use MS Access as the platform for the new system.
RAW is produced in the controlled area of nuclear power plant and is basically classified in two categories: solid waste and liquid waste.
Solid RAW is produced during maintenance interventions, repairs, general outages, control and inspection of equipment. RAW produced as a result of these activities is collected in collection points that can be permanent or temporary ones. The RAW producer is obliged to sort waste in the place of production (in-situ) preliminarily labeling it as "radioactive waste" (if it was produced in a contaminated environment) or "conditionally non radioactive (clean) waste".
The waste is classified further as "combustible" (i.e. protective personal equipment, rags, paper, wood, etc.) and "non combustible" or "compactable" (i.e. insulation, PE foil, metal, sheet, etc.). Sorting according to waste types is performed in accordance with the valid waste catalogue.
Sorted waste is collected in PE bags and the first radioactivity measurement is performed in-situ by a Radiation Protection technician. After this measurement bags are labelled as "Radioactive waste" or "Conditionally clean waste" and the bags are handed over to RAW storage where each bag is weighed and recorded in the RAW Logbook.
Waste labelled as radioactive is collected in 200 l drums. It is recorded and transferred to an outside organization for final treatment in concrete containers.
Waste that was labeled as conditionally clean is measured again and it is released into the environment if it is confirmed as non radioactive, otherwise it goes through additional measurements before being released or classified as radioactive.
The system allows tracking from the moment the waste is put in the PE bags, until it is moved to the metallic drums and finally to the concrete containers. It records waste's activity, type and origin. A

dedicated table was introduced in SAP to plan the amount and type of produced RAW at the Work Order level, as well as for other operational activities. The objective is to allow RAW personnel to compare the planned quantities with the real ones facilitating the RAW minimization initiatives.

3.7 Management of Chemicals

Management of Chemicals are activities related to treatment of CHS/CHP (CHemical Substances/ CHemical Preparations = mixture or solution of two or more chemical substances) in plants and facilities of Slovenske Elektrarne from their procurement, purchase, delivery, takeover, storage, use until their disposal, including empty CHS/CHP packages.
CHS and CHP are treated in SAP as MM module materials and their management and tracking was set up using the SAP EH&S module.
The chemicals are purchased and used according to the hazardous characteristics of individual materials and valid legislation.
The Slovak and EU legislation classifies CHS and CHP according to their hazardous characteristics, possible adverse environmental impacts, limitations due to major industrial accidents and special attributes (precursors etc.). All the given criteria, the so-called chemical bill of material, must be a part of the basic material data in the SAP Material Code List.
Each new CHS/CHP must be approved and submitted for authorization by administration, chemical control, environment and industrial safety and health protection departments with accompanying documentation (MSDS=Material Safety Data Sheet, etc.) and the result of the authorization process is recorded in form of authorization protocol.
Procurement of CHS/CHP is limited to authorized materials only. Purchase and takeover is controlled by delivery of relevant documentation (MSDS, etc.) and by check of fulfillment of delivery requirements (expiration time, purity etc.), or by evaluation of analysis if samples are taken from CHS/CHP. Accompanying documentation can be uploaded in SAP and linked to the CHS/CHP.
Output forms regarding the accepted, consumed and disposed amount of CHS/CHP, are created in form of tables/protocols. In case of regulated CHS/CHP, the volumes stored in at the NPPs must be controlled from the perspective of defined limits (concentration, amount) and a notification of exceeded limits is automatically generated in form of protocol.

3.8 Management of RA-sources and RA-materials transport

The developed application covers the registration of Radioactive Sources (RaS) and the transportation protocols needed whenever moving a RaS or other Radioactive or contaminated materials outside of a CA. It was implemented using the SAP EH&S module.
The implemented document workflow crosses different departments: the source owner or the user of the contaminated material applies for the transport. The RP Dept. is responsible from the radiation safety standpoint and manages the sources database, the transport protocols, fulfills the notification duties to the Public Health Authority as well generates the reports for the State Radioactive Source Register of Slovak Republic. The Transportation Dept. evaluates and approves each movement from the logistic and transportation safety standpoint.
Different types of protocols are generated by the system to track the RaS and materials movements and transports:

- Transport within the CA;
- Transport to another CA;
- Disposal as RAW;
- Release to the Environment.

3.9 Metrology

The purpose of this application is to keep a record of measuring instruments not only within the NPPs but also within SE a.s. The extent of recording fulfills the requirements of Act No. 142/2000 on

metrology, requirements of standard STN EN ISO 10012, Measurement management systems and quality systems standards (STN EN ISO 9001, 14001, OHSAS 18001).

Recording regards designated measuring instruments (UM), working measuring instruments (portable, laboratory, controlling) and so called non classified measuring instruments (measuring instruments without Functional Location data, "informative" measuring instruments). Exceptions are represented by those measuring instruments possessing a F.Loc. and ionising radiation measurement equipment.

The system was configured to allow the following inputs: submission for calibration, verification or validation of both categories, report of changes; new measuring instruments (purchased, accepted, after an initial control, before transfer to the storage, and then to requestor/administrator).

Measuring instruments are recorded after the first calibration or verification, or after validation of existing protocols from the manufacturer, supplier, etc.

The measuring instruments that need to be periodically calibrated are verified or re-calibrated after the expiration of specified period of control type, and data from issued certificates are updated.

The system outputs are:
- Yearly and monthly calibration plans according to criteria defined in advance;
- Reports of Legally Controlled Measuring Instruments (LCMI): list of used LCMI and history of LCMI verifications;
- Database connection to evidence of measurement chains of ionising radiation;
- Database connection to evidence of Work Orders;
- Reports for metrology inspection bodies (Slovak metrology inspectorate – SMI), quality audit, environmental audit, safety audit (OHSAS), etc.

4. OPERATIONAL EXPERIENCE AND CONCLUSIONS

After the first few months of operation using the new softwares a first analysis can be made. From a processes standpoint a stabilization period was expected, and the organization is now starting to reap the benefits of an increased familiarity with the process and the new tools.

Further software improvements are being made, and the modification process has been regulated through an organizationally driven Peer Groups approach. The Change Requests are analyzed by a dedicated commission before being approved and eventually implemented.

From the project standpoint, a few of the learned lessons include:

- A language barrier can profoundly affect the project timing and its eventual success. It is very important to have a technical implementation team that is able to communicate in the native language of the organization.
- Direct participation of the line organization has been a key element of the project success. Selected people from the plants were used as Team Members, Trainers and change advocates. An extensive communication campaign has also helped to create awareness and acceptance toward such an extensive project.
- Two critical points are represented by system interfaces and data quality. When integrating several different platforms the stability and reliability of the whole system is only as high as the interfaces' one. In some cases, very minor interfaces problems have caused a communication break between key systems. As it can be expected, the quality of the initial data plays a crucial role in the system operability. A huge amount of historical and operational data was migrated to SAP and SEOD from the previous system, and despite the immense time and work effort some inaccuracy were present and are still being encountered and operationally solved.