Royal Military College of Canada SLOWPOKE-2 Facility Integrated Regulating and Instrumentation System (SIRCIS) Upgrade Project

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ABSTRACT – The SLOWPOKE-2 Facility at the Royal Military College of Canada has operated the only digitally controlled SLOWPOKE reactor since 2001 (Version 1.0). The present work describes ongoing project development to provide a robust digital reactor control system that is consistent with Aging Management as summarized in the Facility's Life Cycle Management and Maintenance Plan. The project has transitioned from a post-graduate research activity to a comprehensively managed project supported by a team of RMCC professional and technical staff who have delivered an update of the V1.1 system software and hardware implementation that is consistent with best Canadian nuclear industry practice. The challenges associated with the implementation of Version 2.0 in February 2012, the lessons learned from this implementation, and the applications of these lessons to a redesign and rewrite of the RMCC SLOWPOKE-2 digital instrumentation and regulating system (Version 3) are discussed.

1. Background

A SLOWPOKE-2 reactor was installed at the Royal Military College of Canada (RMCC) in 1985, using an analogue Mk2 control system. In 2001 RMCC initiated the first, and to date only, transition from analogue to digital control. The 15-year-old analogue Mk2 control system was replaced with a computerized regulating system, SIRCIS Version 1.0, which was developed as a Master's project [1]. Minor modifications were made 2001 to afford SIRCIS Version 1.1 (Figure 1). The system, based on 1990's Apple computer technology and National Instrument's signal conditioning (SXCI) and LabVIEW object-oriented development workbench, operated satisfactorily thereafter with occasional maintenance to address minor issues.

Figure 1 SIRCIS V1.1

In 2009 RMCC initiated the development of a comprehensive Life Cycle Management and Maintenance Plan (LCMMP) to maintain and develop the SLOWPOKE-2 as a technical resource to the Department of National Defence through to 2020 and beyond. The LCMMP included the intention to develop academic and technical resources from across the RMCC Science and Engineering Faculties to provide a highly stable long-term support to the SLOWPOKE-2 Facility. Concurrent with LCMMP development, RMCC embarked on a project to update the computer, peripherals and operating system supporting SIRCIS to address the unsupported PC and operating system as well as aging components. Initial activity, designated SIRCIS 2010, represented a direct extension of the original Master's thesis. However, changes in technology in the intervening decade since Version 1.0 and the desire to integrate wider RMCC resources into SIRCIS development and maintenance were not consistent with the original 2001 approach. A project and technical review identified changes in project approach and organization that would result in a system that was more consistent with the overall goals and objectives of the LCMMP. The new project was tasked to deliver the requirements of an upgraded system in two phases; firstly, a system update followed by a system redesign and development (upgrade).

The updated system V2 (Figure 2) was implemented and commissioned in February 2012. The project is continuing into the upgrade phase where the system will be redesigned and redeveloped based on the discoveries made in the completed update phase of the project.

Figure 2 SIRCIS V2

Project activities and standards requirements were discussed with CNSC staff regularly. Specific implementation structures are not defined by the CNSC with regard to SLOWPOKE systems and software, although all plan changes received CNSC review prior to implementation. The principal of using qualified resources, for example, AECL for activity within the reactor container as well as the qualification of RMCC resources for the V2 implementation, was observed.

2. Project Scope and Objectives

The overall objective of the project is to upgrade the system used to monitor and regulate the reactor to ensure that it can be operated reliably for the next 10 years. This involves organizational and process improvements as well as technical enhancements with a view to reliable operation and ease of maintenance.

The technical aspects of the project are to:

- Investigate, document and rebuild the system,
- Update the computer technology,
- Replace the SCXI Chassis and SCXI modules with re-certified components,
- Implement and commission updated SIRCIS,
- Redesign and redevelop the software to use contemporary architecture and technologies, and
- Implement and commission the upgraded system.

The management aspects are to:

- Establish and maintain effective Project Management,
- Create a diverse project team involving as many indigenous RMCC staff as possible to establish an internal support team for the future,
- Reinforce Quality Assurance (QA) and maintain conformance with the required software engineering and development standards [2],[3],[4],
- Establish and maintain effective system configuration management (includes document management) and change control,
- Establish effective and re-useable project, product, development, test and commissioning procedures.

3. Observations and Lessons Learned

3.1 Project Initiation Review

An external review of the project management, system technical design and Quality Assurance (QA) was conducted. The Subject Matter Experts recognised that expectations with respect to all aspects of the review have increased over the past decade, and concluded that management, design and QA should be consistent with current best Canadian nuclear industry practice in all these areas. Consequently, update of the Facility QA procedures and adherence to the OASES system engineering standard [2] and the Category III software engineering standard [3] were undertaken. The strategy to update and then upgrade the system was confirmed.

3.2 V1.1 System Component Replacements

The replacement of the V1.1 system components was completed in April-May 2011. Difficulties were encountered, some of which were not related directly to SIRCIS. A failure of the primary self-powered Cadmium neutron flux detector and maintenance issues that were not addressed in the original reactor design; restricted access to the system cabinet, the wiring and component arrangements that were inconsistent with current practice and the system's apparent sensitivity to noise compounded the replacement work. Another self-powered Cadmium neutron flux detector was inserted into inner irradiation site (Site 3) and employed to provide a more reliable neutron flux current signal. As a result, design changes were recommended and approved for the update of SIRCIS. AECL was engaged to replace the original flux detector, which was accomplished when the original 1985 flux detector could not be removed from its design location. Thus, a newly calibrated flux detector was installed permanently in inner irradiation Site 3.

3.3 System Update to V2

The updated system, verified and validated as required for standards [2], [3], [4] compliance, was ready for installation in January 2012. The intact removal of V1.1 and the cleanup of legacy wiring and conduit proved time consuming. AECL was engaged to replace the control rod (motor and optical encoder) assembly and inspect the control rod cable. The updated system, new racking and cable termination boxes were installed by RMCC resources, an activity consistent with the aims of the LCMMP. Commissioning of the system proceeded as planned and revealed two latent defects that were addressed satisfactorily before the system was declared in-service on 09 February 2012. Since February, three updates have been made to the system to improved performance and functionality.

3.4 Project Team Development

RMCC is fortunate in the talent available in its technical and academic staff. The project was able to garner the support of, and assistance from, several departments in providing design oversight, technical component design and fabrication, and LabVIEW programming. The Departments of Chemistry and Chemical Engineering, Mechanical Engineering, Civil Engineering, and Electrical and Computer Engineering have all contributed staff time and expertise. Further, the sponsor (RMCC Commandant) and key stakeholders (Principal and Vice Principal Research) were engaged and interested in ensuring the success of the project.

The team members worked together to understand and overcome problems and obstacles. Technical discussions and reviews resulted not only in the confirmation of requirements, specifications, etc., but also in viable alternatives and insights that resulted from timely and open communications. Creativity and resourcefulness were particularly evident during replacements and implementations when plans were victims of unforeseen challenges. The development of such team resources, built by the requirements of Version 2 are seen as key to the long-term implementation of the SLOWPOKE-2 Facility LCMMP.

3.5 Standards Compliance

SIRCIS is expected to comply with CE-0100-STD, Ontario Power Generation/AECL, CANDU® Computer Systems Engineering Centre of Excellence, Standard for Computer System Engineering [2], CE-1003-STD, Ontario Power Generation/AECL, CANDU® Computer Systems Engineering Centre of Excellence, Standard for Software Engineering of Category III Software [3], and CSA Standard N290.14-07, Qualification of Pre-developed Software for Use in Safety-Related Instrumentation and Control Applications in Nuclear Power Plants [4]. These standards, while rigorous and somewhat daunting, require that the work performed and its outcome are verified independently and validated fit for use. The project was able to demonstrate that it met the intent of the standards. This was a challenge with a small team with limited availability, but once again represented the intention to provide a rigorous, robust and fully documented outcome, which could be supported from within RMCC and that was consistent with the LCMMP.

3.6 Documentation

Aside from the system itself, the documentation provides the evidence of quality work. A documentation hierarchy (Figure 3), which encompasses the requirements of the standards, was defined to ensure that a complete set of documentation was generated from the work.

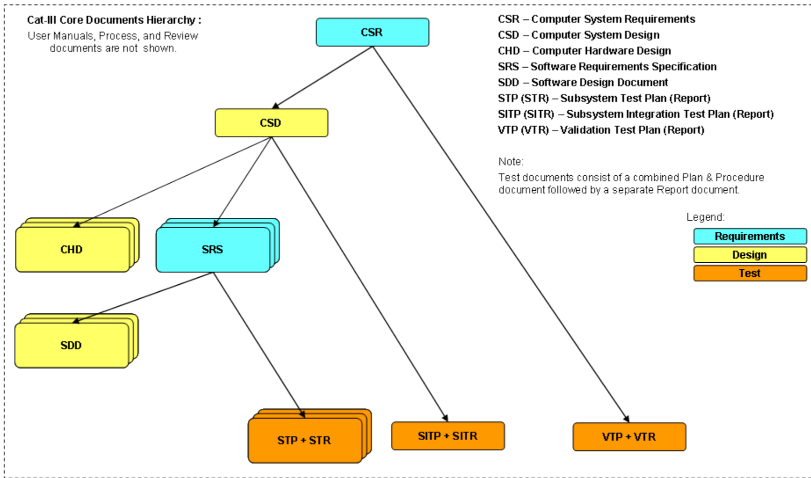

Figure 3 SIRCIS Cat III Document Hierarchy

These documents demonstrate compliance with the required standards as well as providing a solid foundation upon which the upgrade (V3) now can proceed.

3.5 Configuration Management and Change Control

With V2, a Configuration Item List (CIL) was created and will be maintained. Configuration management and change control processes were initiated with the V2 update and henceforth will be maintained. A dedicated Microsoft SharePoint site has been established on the RMCC Intranet to house the configuration list as well as project and system documentation. The SharePoint site provides secure access to authorized personnel associated with the Facility and the Project.

4. Conclusions

The ongoing upgrade project for the SLOWPOKE-2 Facility digital regulating system at RMCC has overcome a number of challenges and the V2 update has been successfully implemented for a number of reasons:

- Engaged and understanding sponsor and stakeholders,
- Cooperative, innovated team,
- Effective, open communications,
- Industry and ingenuity,
- Timely expert guidance and support.
- Plan flexibility
- Proven, achievable standards
- Completed documentation and effective Configuration Management and Change Control.

The experience gained during the V2 work effort will assist the design and development of the upgrade, V3.

5. References

[1] L.R. Cosby, SLOWPOKE Integrated Reactor Control and Instrumentation System (SIRCIS), Royal Military College of Canada, April 2001

[2] CE-0100-STD, Ontario Power Generation/AECL, CANDU® Computer Systems Engineering Centre of Excellence, Standard for Computer System Engineering.

[3] CE-1003-STD, Ontario Power Generation/AECL, CANDU® Computer Systems Engineering Centre of Excellence, Standard for Software Engineering of Category III Software

[4] CSA Standard N290.14-07, Qualification of Pre-developed Software for Use in Safety-Related Instrumentation and Control Applications in Nuclear Power Plants