31st January, 2012

Mr Simon Bartlett
Chairperson
E. S. Cornwall Scholarship Advisory Committee
PO Box 1193
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Dear Simon

First Quarterly Report - E. S. Cornwall Memorial Scholarship – Sarah Hiley

Please find enclosed my first quarterly E. S. Cornwall Scholarship report outlining my period of employment from the 10th of October 2011 to the 10th of January 2012.

During my first three months with ABB, I have been involved with the system level detailed design for two of Powerlink's iPASS IEC 61850 upgrade projects – Millmerran and Bulli Creek. To date, I have undertaken the IEC 61850 system level engineering and MicroSCADA application engineering for both of these substations. This experience has provided valuable insight into the tools, processes and philosophies that ABB employ in IEC 61850 system design.

It should be noted that due to the confidential nature of the work I have undertaken I am not able to include any technical information relating to ABB specific tools and processes.

I welcome the committee's feedback on this report and my goals for the next quarter.

Yours faithfully,

Sarah Hiley

Table of Contents

1   Introduction

My program of work under the E. S. Cornwall Memorial Scholarship is aimed at gaining international experience in substation automation systems using the IEC 61850 standard. More specifically, the program focusses on gaining technical experience with the design, integration and testing of such systems whilst working for an international manufacturer, utility and consultancy firm. The program will also provide exposure to the challenges and issues that face organisations when adopting a new technology.

IEC 61850 is an international standard for substation automation that marks a new era in substation design and development for power utilities. The standard defines communication in and between electrical substation automation systems using fibre optic serial communication, with the goal of facilitating interoperability of substation devices whilst simplifying engineering and maintenance. This technology eliminates thousands of copper wires within a substation resulting in significant cost savings for power utilities in terms of installation and maintenance, while at the same time increasing worker safety and power system reliability. It also allows for the complete substation configuration to be documented in a single file in a standardised way, which is an advantage for maintenance and future expansion. Although originally written for substation automation applications, the standard has now been extended to meet the requirements for almost the whole electrical energy supply chain including control and monitoring of wind power systems, hydro power systems and distributed energy resources.

My tenure of the E. S. Cornwall Memorial Scholarship is from the 10th of October, 2011 to the 10th of April, 2013. My first nine month placement is with ABB Switzerland in Baden, where I am working as part of the Substation Automation System (SAS) Engineering and Test Team. ABB is a world leader in the development and manufacture of IEC 61850 products. Experts from within the company have participated with the standardisation work from day one and ABB was one of the first manufacturers to adopt a 'native IEC 61850 implementation' philosophy. ABB also established the world's first UCA accredited System Verification and Validation Centre (SVC) here in Baden, to verify correct implementation. ABB was the manufacturer and system integrator for the first high voltage IEC 61850 station bus installation and since then has installed hundreds of systems all over the world, resulting in comprehensive experience.

During my time with ABB, I will be involved with the detailed design, system integration and testing of two of Powerlink's iPASS IEC 61850 secondary system upgrade projects – Millmerran and Bulli Creek. To date, I have undertaken the system level detailed design for both of these projects. This includes the IEC 61850 system level engineering and MicroSCADA application engineering.

This report is the first of six reports and outlines the work that I have undertaken from the 10th of October, 2011 to the 10th of January, 2012. As this is my first report, I will also provide some background on the SAS Engineering and Test Team.

2 Engineering and Testing Team

I have been assigned to the Substation Automation System (SAS) Engineering and Test Team 2, which is a subset within the Substation Automation Systems group – Engineering and Testing Team as highlighted in the diagram below.
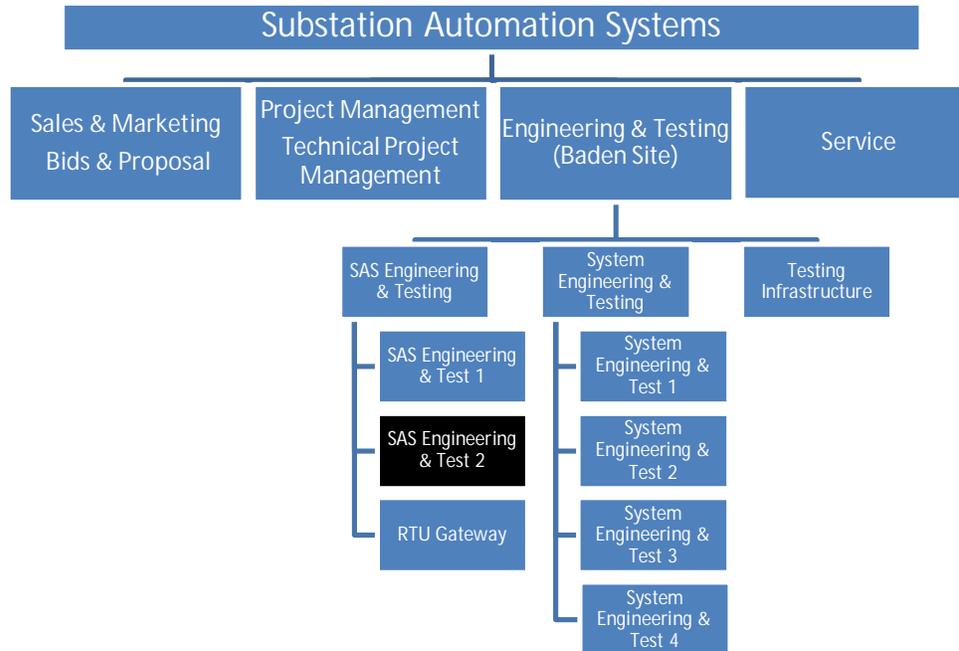

Figure 1 – Structure of the Substation Automation System Team

My group is responsible for the design, engineering, system integration and testing of the Substation Automation Control System (SAS) and its related interfaces. The main roles and responsibilities of a SAS engineer include:

- Base design for SAS station level including station overview diagram and functional description for SAS applications, signal lists and naming convention, HMI picture proposals and Network Control Centre (NCC) interface lists
- Detailed engineering of SAS station level including:
    - Final MicroSCADA Picture Engineering
    - System integration
    - Database engineering
    - Software application engineering
    - Gateway engineering (SYS600)
    - Operator Manuals
- Setup and testing of SAS including:
    - Configuration of station level equipment
    - Setup of communication between SAS and Bay level devices
    - Setup of communication between SAS and Network Control Centre (NCC) (simulation only)
    - System testing
- FAT of SAS station level equipment

The core substation automation system project team (for example the team executing the Powerlink iPASS upgrade projects) consists of a Project Manager (PM), Technical Project Manager (TPM), System Engineer (SE), Protection Engineer (PE) and SAS Engineer.

3   Work Experience

To date, I have been involved in the detailed design phase of the Millmerran and Bulli Creek 330kV iPASS substation secondary system refurbishment projects for Powerlink Queensland.

The work that I have done for both the Millmerran and Bulli Creek projects includes the IEC 61850 system level engineering and MicroSCADA application engineering. This involves:

- Undertaking the Communication Engineering on the IEC 61850 level using ABB's system configuration tool to create the overall "Station.SCD" file
- Generating signal lists and the MicroSCADA Process Database (PDB)
- MicroSCADA application engineering

This experience has provided valuable insight into the tools, processes and philosophies that ABB employ in IEC 61850 system design. Working as the SAS engineer on these projects has enabled me to gain a good understanding of the IEC 61850 systems being implemented for Powerlink, as well as an appreciation of the individual system components and how they interact with each other. I am also developing a good working knowledge of the IEC 61850 standard.

In the following sections, I will give an overview of the Millmerran and Bulli Creek projects and describe the SAS engineering processes that I have undertaken to date.

3.1   Overview of the Millmerran and Bulli Creek iPASS Upgrade Projects

Commencing in 1999 with the Queensland – New South Wales Interconnector project, Powerlink began the construction of a series of six ABB turnkey iPASS (Intelligent Plug and Switch System) substations. Powerlink is currently replacing all secondary systems in these substations with fully compliant IEC 61850 systems that utilise both Process and Station Bus technologies. ABB Switzerland has been contracted to design, fabricate and test these new IEC 61850 systems and I am currently involved in the detailed design phase for two of these substations: Millmerran and Bulli Creek.

Millmerran 330kV substation is a breaker and a half arrangement, consisting of three diameters, each with two line bays and one spare bay. Only one of these diameters contains iPASS equipment and therefore the scope of work is to upgrade the secondary systems of this diameter only.

Bulli Creek 330kV substation is a breaker and a half arrangement, consisting of three diameters (each with two line bays), one transformer bay and four line reactor bays. All bays contain iPASS switchgear and are within the scope of work.

3.1.1   System Overview

The Substation Automation System (SAS) being implemented in these projects is based on ABB's SAS600 series, including MicroSCADA Pro Control System SYS 600. The SAS600 series is based on IEC 61850 and is fully compliant. The bay level comprises Relion 670 series protection and control IEDs as well as REB500 Busbar protection system, with IEC 61850 for station and process bus.

The system architecture facilitates three hierarchy levels:

1. Communication System to the Network Control Centre
2. Station Level
3. Bay Level

The Station Level comprises the Station Computer/HMI, X and Y Central Units for Bus Bar and Circuit Breaker Fail protection, Bay Control Units (BCU), two redundant dedicated GPS master clocks that provide the synchronisation of the entire system, alarm devices, OpsWAN connection and two RTU gateways that enable redundant communications to the Network Control Centre. The Bay Level comprises the protection and control Intelligent Electronic Devices (IEDs). The data exchange among the bay level IEDs, and between bay level and station level IEDs takes place via the fibre-optic station bus according to the IEC 61850-8-1 standard. The station bus has been implemented in a single ring topology using IEC 61850-3 compliant Ethernet switches. Dual connections between the station computer and gateways, to the station level Ethernet switches, have been implemented for increased availability.

The process bus facilitates communication between the process level devices (eg the iPASS units) and the bay level devices. Physically, an optical fibre links the CT/VT sensors installed on the primary Switchgear to the Merging Units (MUs) installed in each bay panel. The station and process level networks are two physically separate LANs. The process bus between the Secondary Converter (SC) and the MU is based on ABB's Multifunction Vehicle Bus (MVB). The process bus between the MU and protection/control IEDs is based on the IEC 61850-9-2 LE (Light Edition). In these projects, the process bus is being used for Sample Value (SV) data. Each bay has its own separate LAN.

To achieve full redundancy, two independent systems, X and Y, have been implemented, requiring duplication of secondary converters, merging units and protection units. The GPS clock and Time Synchronisation network are also duplicated as time synchronisation is critical to the protection system.

3.1.2   Project Timeline

The base design for the Millmerran and Bulli Creek projects was completed before I started work with ABB, therefore, I was not involved with this stage of the project. The base design defines the system architecture and functionality and forms the foundation for the detailed design. It includes the SAS system overview, signal lists, HMI pictures, control and protection function block diagrams, cubicle layouts, DC supply concept and functional descriptions.

In my first three months with ABB, I have been involved with the detailed design phase for both Millmerran and Bulli Creek. The detailed design for Millmerran is now being finalised and manufacturing is currently underway. System setup and testing for Millmerran is scheduled to commence in February with the ABB FAT scheduled for April. System setup and testing for Bulli Creek is scheduled to commence in April with the ABB FAT scheduled for June.

3.2 IEC 61850 Substation Automation System Engineering Process

This section provides an overview of ABB's IEC 61850 SAS engineering process. To date, I have undertaken this process for both the Millmerran and Bulli Creek projects.

In order to engineer an IEC 61850 system, there needs to be a facility for the interoperable exchange of configuration data between all system devices and application tools, including devices and tools from different manufacturers. This is achieved through the use of the Substation Configuration description Language (SCL) as defined in IEC 61850-6. SCL allows the description of each IED configuration to be passed to the system engineering tool and then for the overall system configuration to be passed back to each IED via the IED engineering tool in a compatible way. As a minimum, there are four different purposes for SCL data exchange and therefore, four types of SCL files with different file extensions have been defined in IEC 61850-6 as follows:

1. **IED Capability Description (.ICD) file** – allows for the data exchange from the IED configuration tool to the system configuration tool.
2. **System Specification Description (.SSD) file** – allows for the data exchange from a system specification tool to the system configuration tool. This file describes the single line diagram of the substation and the required logical nodes.
3. **Substation Configuration Description (.SCD) file** – allows for the data exchange from the system configuration tool to the IED configuration tools. This file contains all IEDs, a communication configuration section and a substation description section.
4. **Configured IED Description (.CID) file** – allows for the data exchange from the IED configuration tool to the IED. It describes a particular IED within a project.

Figure 2 illustrates the engineering workflow used by ABB in the implementation of IEC 61850 systems and shows how the above SCL files are used for data exchange. The yellow shading indicates my project responsibilities as the SAS engineer.

Firstly, the initial IED configuration is carried out by the bay level engineer using the IED configurator tool and an ICD file is exported for each IED. The SAS engineer can then import these files into the system configuration tool and undertake the system level engineering to produce the overall SCD file. This includes defining the meaning of IED functions in the context of the switchyard by allocating Logical Nodes (LNs) to elements of the substation single line diagram, configuring the communication networks, defining the dataflow between all IEDs and configuring all IED names and communication related addresses and parameters. The resulting SCD file is a comprehensive description of the entire system in the context of IEC 61850. The bay level engineer then imports the SCD file into the IED configurator tool and the system related IED configuration is carried out. The SAS engineer also undertakes the HMI / Gateway Signal Engineering using the system configuration tool.

The next step for the SAS engineer is to carry out MicroSCADA application engineering. This involves building an application consisting of pictures, dialogues, SCIL programs and database objects. Firstly, base system configuration is carried out to define the project specific, base system parameters. Once this is complete, the Process Database (PDB) can be created. The process objects can then be mapped to picture elements in the process displays.

To facilitate the communication between the MicroSCADA application and the IEC 61850-8-1 Station Bus devices, the IEC 61850 OPC server and Data Access (DA) client need to be configured. This requires the SCD file as well as files that contain the mapping for the process objects in the process database. Similarly, the SNMP OPC server and DA client also have to be configured.

The final part of this process is the configuration of the Network Control Centre gateways. This configuration varies depending on the gateway device. If a SYS600 device is used, the configuration is carried out using the system configuration tool by the SAS team. If an RTU device is used, the configuration is done by the RTU gateway team.
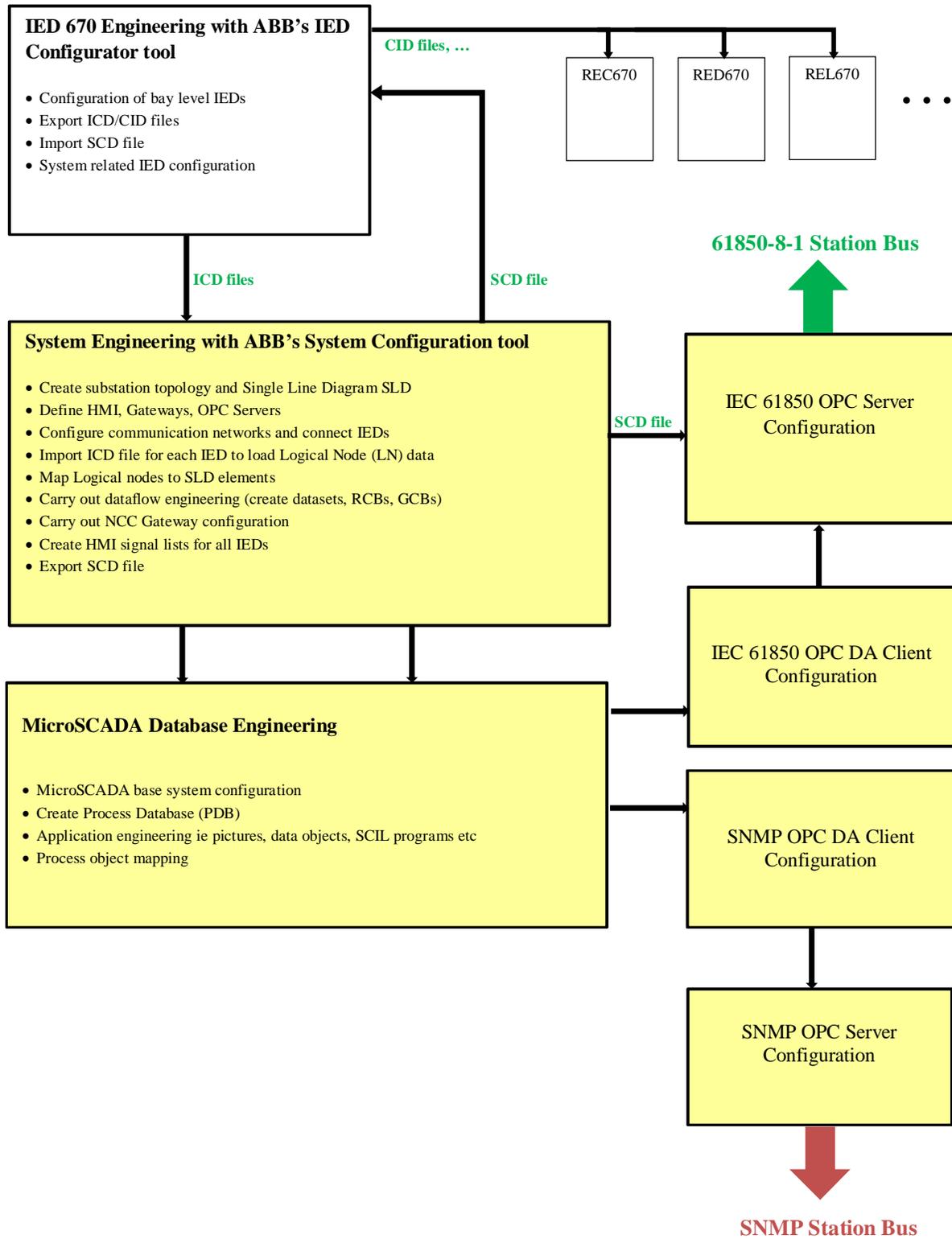
IED 670 Engineering with ABB's IED Configurator tool

- Configuration of bay level IEDs
- Export ICD/CID files
- Import SCD file
- System related IED configuration

CID files, …

REC670   RED670   REL670   • • •

ICD files

SCD file

61850-8-1 Station Bus

System Engineering with ABB's System Configuration tool

- Create substation topology and Single Line Diagram SLD
- Define HMI, Gateways, OPC Servers
- Configure communication networks and connect IEDs
- Import ICD file for each IED to load Logical Node (LN) data
- Map Logical nodes to SLD elements
- Carry out dataflow engineering (create datasets, RCBs, GCBs)
- Carry out NCC Gateway configuration
- Create HMI signal lists for all IEDs
- Export SCD file

SCD file

IEC 61850 OPC Server Configuration

MicroSCADA Database Engineering

- MicroSCADA base system configuration
- Create Process Database (PDB)
- Application engineering ie pictures, data objects, SCIL programs etc
- Process object mapping

IEC 61850 OPC DA Client Configuration

SNMP OPC DA Client Configuration

SNMP OPC Server Configuration

SNMP Station Bus

Figure 2 - Overview of ABB's IEC 61850 Engineering Process

4   Planned Future Experience

During my first quarter on the E. S. Cornwall Memorial Scholarship I have undertaken the IEC 61850 system level engineering and MicroSCADA application engineering for two of Powerlink Queensland's iPASS IEC 61850 secondary system upgrade projects. This work has enabled me to gain an understanding of IEC 61850 systems as well as a good working knowledge of the system level tools and processes required to engineer such systems.

Throughout the next few months, whilst manufacturing is underway for the Powerlink projects, I hope to have the opportunity to gain exposure to the IEC 61850 systems being implemented for various international utilities. In particular, I will be involved with an IEC 61850 retrofit project for a European utility and I will also be involved in the system setup and integration for the IEC 61850 SAS systems being installed at three new substations in the Middle East. I am also hoping to be able to witness the on-site commissioning testing for an IEC 61850 system being installed at a substation in Switzerland.

Towards the end of the next quarter and throughout my last quarter with ABB, I will be involved with the system integration, system testing and ABB FAT for the Millmerran and Bulli Creek projects. This will provide valuable insight into the setup of IEC 61850 systems and the different testing methodologies. I am also hoping to have the opportunity to be involved with bay level testing, in addition to doing the system level testing, which should afford a better insight into the protection and control devices and the communications across the station and process buses.