17th February, 2013

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

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

Please find enclosed my fifth quarterly E. S. Cornwall Scholarship report outlining my period of employment from the 24th of October 2012 to the 24th of January 2013.

During the past three months with Iberdrola Engineering and Construction (IEC), I have been working on the substation automation system (SAS) base design for Scottish Power's IEC 61850 pilot project; the Windyhill 132kV Switchgear Replacement project. In addition to this, I have been involved with scoping the protection and control requirements for Scottish Power's second IEC 61850 substation. I have also provided input into an additional services project that aimed to scope the high level requirements of implementing Iberdrola's IEC 61850 SAS standard (iSAS) in the Scottish Power network. This quarter, I have also had the opportunity to visit a number of Scottish Power's substations and also Scottish Power's Whitelee wind farm, which is one of the largest on-shore wind farms in Europe.

It should be noted that due to confidentiality, I am not able to include specific information relating to customer projects.

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 2

2 Work Experience 3

2.1 Windyhill 132kV Switchgear Replacement Project 3

2.2 Scottish Power's Second IEC 61850 Implementation Project 6

2.3 Scottish Power iSAS Additional Services Project 7

3 Site Visits 8

3.1 Bonnybridge 132kV GIS Substation Site Visit 8

3.2 Windyhill 132kV and 275kV Substation Site Visits 8

3.3 Wind Farm Visits 9

4 Planned Future Experience 10

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 focuses on gaining technical experience with the design, integration and testing of such systems whilst working for an international manufacturer and power engineering services company. The program will also provide exposure to the challenges and issues that face organisations when adopting a new technology.

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 was with ABB Switzerland in Baden, where I worked as part of the Substation Automation System (SAS) Engineering and Test Team. Last quarter, I commenced my second nine month placement in Scotland with Iberdrola Engineering and Construction (IEC), a subsidiary of the Iberdrola Group, where I am working as a protection and control engineer.

My work this quarter has focussed on developing and documenting the proposed substation automation design solution for Scottish Power's IEC 61850 pilot project – the Windyhill 132kV Switchgear Replacement project. In conjunction with this work, I have done a number of site visits to various Scottish Power substations including a new 132kV double busbar GIS substation at Bonnybridge. I have also been involved with scoping the protection and control requirements for Scottish Power's second IEC 61850 substation and have provided input into an additional services project that aimed to scope the high level requirements of implementing Iberdrola's IEC 61850 SAS standard (iSAS) in the Scottish Power network.

This report is the fifth of six reports and outlines the work that I have undertaken from the 24th of October 2012 to the 24th of January 2013.

2 Work Experience

My main task this quarter has been to undertake the substation automation system (SAS) base design for Scottish Power's IEC 61850 pilot project; the Windyhill 132kV Switchgear Replacement project. In addition to this, I have been involved with scoping the protection and control requirements for Scottish Power's second IEC 61850 substation. I have also provided input into an additional services project that aimed to scope the high level requirements of implementing Iberdrola's IEC 61850 SAS standard (iSAS) in the Scottish Power network. This project was initiated prior to approval of the pilot project and addresses iSAS installations for all typical substation configurations and voltage levels in the Scottish Power network. These projects will be discussed further in the following sections.

2.1 Windyhill 132kV Switchgear Replacement Project

Scottish Power's Windyhill substation is located in the north-west of Glasgow and consists of a 400/275kV yard and a 132kV yard. The 132kV substation consists of 15 bays of double busbar outdoor air insulated switchgear (AIS) that was installed in the 1960's. Due to the age of the switchgear, it has been identified for replacement.

Under the Windyhill 132kV replacement project, a new gas insulated (GIS) switchboard will be installed in a new purpose built building, adjacent to the existing AIS yard, to facilitate an offline build. The scope of works includes replacement of all protection, control and telecommunications systems. This project has been identified as the pilot project for the implementation of Iberdrola's IEC 61850 SAS standard (iSAS) in the Scottish Power network. An overview of the new 132kV GIS switchboard arrangement is shown in Figure 1.

During my first quarter with IEC, I undertook high level scoping of the protection and control requirements for Windyhill, in order to develop the System Construction Authorisation report and the Main Connections and Protection diagram. I was also involved in assessing the range of protection and control devices available on the market, to determine their current level of compliance with Iberdrola's iSAS specification, as well as their ability to meet the specific requirements at Windyhill. As a result of this work, the selection of the protection and control IEDs required for the Windyhill project is now nearing completion.

This quarter, my main responsibility has been to continue with the design work for this project. This work has involved:

- Drafting a Design Intent Document detailing the proposed SAS design solution including process, bay and station levels. This document will be submitted to Scottish Power for approval prior to the commencement of the detailed design phase (wiring schematics, device configuration etc.).
- Developing a new format for Scottish Power's SAS design drawings that is more suited to integrated, IEC 61850 systems
- Reviewing the tender specification for the protection and control work that is to be done by an external design house
- Assisting in the development of new Current Transformer (CT) specifications for input into the GIS specification

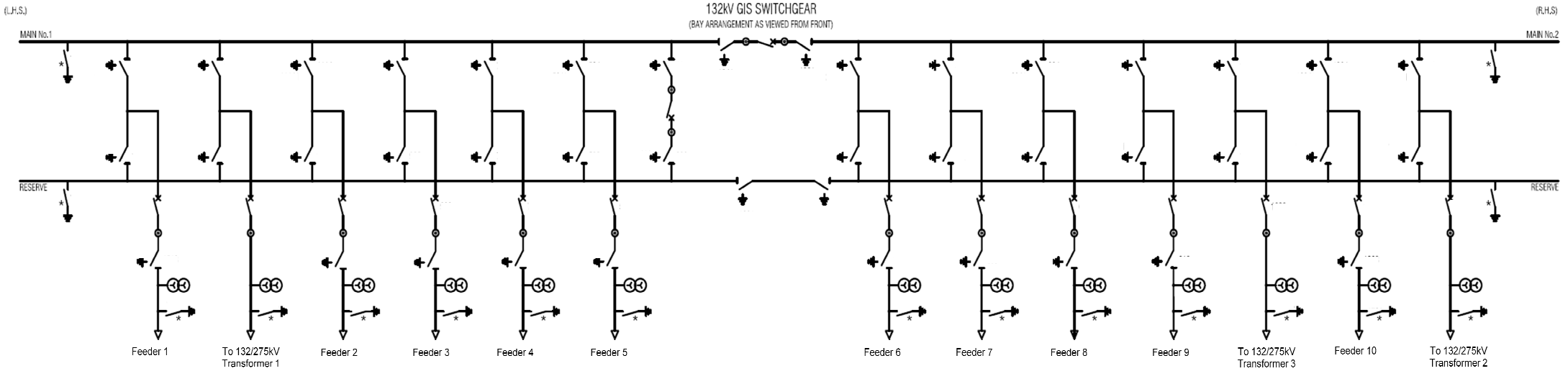

Figure 1: Windyhill 132kV GIS Substation – Proposed Single Line Diagram

- Writing a specification outlining the telecommunications services required for Windyhill
- Undertaking site visits to Windyhill and some remote end substations to determine the interface requirements with the existing system (discussed in Section 3)
- Undertaking a site visit to the new Bonnybridge 132kV GIS substation. The switchgear installed at this site is very similar to what will be installed at Windyhill and is discussed further in Section 3.

Over the past few months, my primary task has been working on the Windyhill Design Intent Document (DID). This document provides a detailed description of IEC's proposed iSAS solution, including the process level, bay level and station level design. It details all required functionality and specifies how it will be implemented. This includes:

- circuitry design at the process level
- bay level IED functionality
- IEC 61850 GOOSE and MMS communications
- IEC 61850 control and switching methods
- substation control unit functionality
- HMI configuration
- station bus architecture
- switch and time synchronisation requirements
- IP addressing
- remote access requirements
- security requirements
- testing requirements
- recommendations for future design evolution

iSAS poses a very significant technological shift for Scottish Power. As a result, existing SAS standards can no longer be applied, leaving many decisions to be made. An additional purpose of the DID is to provide a means of identifying, addressing and resolving these issues, as well as clearly documenting all outcomes. This documentation will not only aid the detailed design for Windyhill but also the design for all subsequent iSAS projects. Once the DID has been finalised, it will be sent to Scottish Power for review and approval. Once approved, works for the detailed design phase will commence. This work will include the detailed design drawings, device configuration and bench testing.

In conjunction with drafting the DID, I have also been developing a number of design drawings for Windyhill. Due to the significant differences between Scottish Power's conventional SAS and an IEC 61850 SAS, this has required the development of new types of drawings and the reformatting of existing drawings. The new suite of drawings includes:

- Windyhill SAS network overview drawing
- General wiring schematics for each IED model
- IED block logic drawings detailing the functionality of each IED at Windyhill in terms of logical nodes, including GOOSE signalling, MMS commands and the allocation of conventional inputs and outputs.
- GOOSE signal matrices for each bay at Windyhill
- MMS Signal Lists for each IED model detailing all required alarms, controls and indications and how they will be displayed on the HMI.

As Windyhill is a pilot project, the majority of the SAS design will be done internally within IEC, however, external design houses will be used to produce the circuitry drawings, panel general arrangements, cable schedules, design of the battery system and auxiliary supply works etc. This quarter, I have also been involved in the review of the tender specification for the protection and control design including the production of circuitry drawings, cable schedules and panel general arrangements.

Due to the significant change in protection technology being implemented at Windyhill with the introduction of iSAS, Scottish Power's existing CT specifications were no longer applicable. I was required to assist in the development of new CT specifications for input into the GIS specification. This work involved analysing the protection algorithms of each IED to determine the required CT performance and then calculating the required knee point voltage based on these performance requirements and system fault levels. New CT burden requirements were also defined.

Finally, I was also required to write a telecommunications specification for issue to Scottish Power's external provider detailing the new protection and control services required for Windyhill.

2.2 Scottish Power's Second IEC 61850 Implementation Project

In addition to the Windyhill project, I have also been involved in scoping the protection and control requirements for Scottish Power's second iSAS implementation project. Like Windyhill, the switchgear at this site has reached the end of its life and it is proposed to replace it with a new, GIS switchboard, installed in a new building, adjacent to the existing 132kV switchyard. The substation consists of 14 AIS bays in a double busbar configuration.

I was required to scope the protection and control requirements for this project and document these requirements as part of the System Construction Authorisation (SCA) report. This involved determining:

- the most suitable protection schemes for each item of plant
- the control functionality required for each item of plant e.g. auto reclose, synchronising, tap changer control etc.
- feeder remote end works
- the communications requirements for each feeder
- temporary protection scheme requirements in order to facilitate staged commissioning
- AC and DC supply requirements

As part of the SCA, I was also required to develop the Main Connections and Protection Diagram. This drawing shows a single line representation of the substation, detailing the current and voltage transformer specifications and connections to the various protection and control functions.

The draft SCA has now been finalised and has been submitted to Scottish Power for review.

2.3 Scottish Power iSAS Additional Services Project

In order to facilitate the development of Iberdrola's global iSAS specification, a project was raised by Scottish Power, prior to the approval of the iSAS pilot project, to scope how an iSAS solution could be applied across all of the different substation configurations and voltage levels in the Scottish Power network.

More specifically, the iSAS additional services project aimed to:

- Describe and document the engineering process for iSAS systems
- Define the functions presently implemented in hardwiring to be implemented using IEC61850 services
- Describe and document the functionality required in IEDs with reference to existing Scottish Power protection policies.
- Define the areas of development required by IED manufacturers
- Describe and document the functionality required in the Substation Control Units
- Define the areas of development required by SCU manufacturers
- Engage with IED and SCU manufacturers to describe requirements
- Produce a scope of work and programme for the development of the specification and identify existing policies and specifications to be modified

The majority of this work was undertaken prior to my start with IEC. However, during my first quarter with IEC, I was fortunate to be involved in liaisons with IED and SCU manufacturers to address the areas requiring further development. This quarter, I have been involved in collating and updating the work previously undertaken by my colleagues and finalising documents detailing Scottish Power's hardwiring migration to IEC 61850, iSAS IED functionality requirements and iSAS engineering process. These documents have now been approved and issued to Scottish Power.

3 Site Visits

This quarter I have visited three Scottish Power substations as part of my work for the Windyhill IEC 61850 pilot project. This section will briefly describe the purpose and outcomes of these visits. In addition to this, I have also visited Scottish Power's Whitelee Wind Farm and also, a community owned wind farm on the Isle of Gigha.

3.1 Bonnybridge 132kV GIS Substation Site Visit

Bonnybridge substation is a Scottish Power site, located ten miles south of Stirling. The existing 132kV AIS switchgear at Bonnybridge has recently been replaced with a new GIS switchboard, consisting of 16 bays in a double busbar configuration. This new switchgear is very similar to what will be installed at Windyhill.

The primary purpose of this site visit was to inspect the primary plant interfaces and to identify possible improvements that could be made with respect to these interfaces including the secondary cabling arrangements and Local Control Cubicle (LCC) design.

The site visit resulted in a better understanding of the primary equipment and interfaces, which has aided the SAS design for Windyhill. In addition to this, a number of issues have been identified to be raised with the GIS manufacturer for Windyhill, in order to incorporate possible design improvements.

3.2 Windyhill 132kV and 275kV Substation Site Visits

In addition to Bonnybridge, I have also undertaken site visits to the existing Windyhill 132kV and 275kV substations and to one of Windyhill's remote end sites, to determine the interface requirements with the existing system. More specifically, the site visits aimed to:

- Identify the existing telecommunications equipment in order to assess the scope of works for the Windyhill 132kV rebuild and draft the telecommunications specification
- Check specifications of the existing 275kV CTs in order to specify the new CTs that will need to be interfaced with the existing 275kV transformer protection
- Check the specifications of the existing 132kV CTs that will be interfaced temporarily with the new protection system at Windyhill
- Confirm panel accommodation in the existing Windyhill 275kV building
- Assess how the existing transformer protection/control will be interfaced to the new 132kV system
- Confirm the telecommunications equipment at the remote end site and check that the existing panel can accommodate the new equipment being installed to interface with Windyhill

As a result of these site visits, the above issues have been resolved and the Windyhill design work has progressed accordingly.

3.3 Wind Farm Visits

I have recently had the opportunity to visit Whitelee Wind Farm, located 15km south of Glasgow. Whitelee is owned by Scottish Power Renewables, which is a part of the Iberdrola Group. Iberdrola is one of the world's leading developers of wind power, with more than 13 600 MW of installed capacity worldwide. At completion in 2009, Whitelee was the largest onshore wind farm in Europe, with 140 turbines, generating a total capacity of 322MW. In addition to this, a 75 turbine extension is currently under construction (due for completion in early 2013) which will add an additional 217 MW of capacity.

Wind power is Scotland's fastest growing renewable energy technology and is now a significant part of Scotland's energy mix. Approximately 35 per cent of Scotland's electricity needs are currently being met by renewables, with onshore wind making up the majority of this generation. Scottish Government policy is to generate the equivalent of 100% of Scotland's gross annual electricity consumption from renewable sources by 2020.

Figure 2: Whitelee Wind Farm, Scotland

Another target set by the Scottish Government is to develop 500 MW of community and locally-owned renewable energy by 2020. I have recently visited the UK's first community owned, grid connected wind farm, commissioned in 2005 on the Isle of Gigha. This small wind farm consists of three, pre-commissioned wind turbines that are capable of generating up to 675kW of power, which equates to approximately two thirds of the island's electricity requirements. The project was underpinned by a robust and adaptable financial model and as a result, the Gigha wind farm has led the way for many more community owned wind farms across the UK.

Figure 3: Community owned wind farm on the Isle of Gigha, Scotland

4 Planned Future Experience

During the past quarter, I have been primarily working on the substation automation system (SAS) base design for the Windyhill IEC 61850 pilot project. More specifically, this has involved drafting a Design Intent Document detailing the proposed SAS design solution including process, bay and station levels. In the coming weeks, this document will be finalised and submitted to Scottish Power for review.

Once the Design Intent Document has been approved by Scottish Power, my next task will be to produce the full set of Windyhill SAS design drawings that are required to be submitted to the external design house in order for them to produce the circuitry drawings and panel general arrangements. These drawings will be based on the templates that I have developed this quarter and will include general wiring schematics for each IED model, block logic drawings detailing the functionality of each IED and an SAS network overview diagram.

In addition to the drawings for the external design house, I will also develop the MMS signal lists for each IED and the GOOSE matrices for each bay at Windyhill. These drawings summarise the IEC 61850 communications requirements and will be used to aid device configuration and testing. In conjunction with this, I will be working with Iberdrola's IEC 61850 IED configuration tool, as well as the required proprietary configuration tools, in order to work toward developing configuration files for each IED to facilitate testing.