Transmission Infrastructure for Renewable Generation

Scottish Power Transmission Limited Boundary B5

POST CONSTRUCTION TECHNICAL REPORT

- Final Report
- 30 November 2012

Boundary B5

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Contents

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1. Executive Summary

In 2007, Scottish Hydro Electric Transmission Limited (SHETL) was forecast to connect in excess of 1.5GW of renewable energy after system reinforcement. In addition Scottish Power Transmission Limited (SPTL) anticipated an additional 90MW by late 2008 with additional generation to follow in later years.

To support these increasing amounts of renewable generation the Beauly-Denny scheme was developed which would replace the existing 132kV line between Beauly and Bonnybridge with a 400kV line. This scheme included upgrade works known as Boundary B5.

The planned completion date of the Beauly-Denny project was originally 2008/09 but due to planning approval and consents issues the scheme was expected to be delayed until 2012/2013 or later. To release additional capacity prior to completion of Beauly-Denny and alleviate network constraints SPTL proposed to separate the Boundary B5 works from Beauly-Denny for completion in 2009/2010.

The aim of this document is to provide a post construction technical report setting out the extent to which the Boundary B5 scheme complies with the Transmission Investments for Renewable Generation (TIRG) output measures, as defined in SPTL's licence conditions, and to provide a post construction completion certificate. The report and certificate will enable SPTL to discharge its licence obligations under Special Licence Condition J3 –Restriction of Transmission Charges (Part B 10 (d) (ii)).

The output measures are specified in Schedule C of the SPTL TIRG licence for the Boundary B5 scheme both prior to and post construction. They are shown in table 1.1 below.

Table 1.1 – Boundary B5 Scheme Output Measures

Project scope	**Capability as at 31 March 2005**			**Forecast capability prior to construction start date**			**Forecast capability post construction**		
Line upgrade	Circuit voltage (kV)	Winter rating (MVA)	Summer rating (MVA)	Circuit voltage (kV)	Winter rating (MVA)	Summer rating (MVA)	Circuit voltage (kV)	Winter rating (MVA)	Summer rating (MVA)
Windyhill – Neilston	275	955	760	275	955	760	275	955	760
Longannet - Easterhouse	275	953	953	275	953	953	275	1500	1500

Project scope	Capability as at 31 March 2005			Forecast capability prior to construction start date			Forecast capability post construction		
Longannet – Clydes Mill	275	953	953	275	953	953	275	1500	1500
Easterhouse – Clydes Mill	275	953	953	275	953	953	275	1500	1500

The scheme design works are described in detail in section 4 of this report.

Site visits were undertaken to selected substations on 02 August 2012, whereby construction data and photographic evidence was collected to support verification of scheme completion. Power flows in the reconfigured networks were confirmed via recorded data taken from SCADA systems. Where site visits were not made supporting evidence was provided by SPTL.

Based on the evidence gathered it was verified that the works undertaken on the Boundary B5 scheme fully meets the requirements of the output measures. The works undertaken on the Windyhill – Neilston circuit do not impact the forecast capability as the limiting factor is the existing overhead line part of the circuit, upon which no works were undertaken.

A construction completion certificate is provided in Appendix A.

2. Introduction

SPTL appointed Sinclair Knight Merz (SKM) as Independent Technical Reviewers to carry out a post construction technical review to meet the TIRG licence conditions as set out by Ofgem. The Ofgem approved TIRG project under consideration is the Boundary B5 reinforcement scheme. The scheme incorporates replacement of 275kV switchgear at Clydes Mill and Easterhouse substations and the installation of a 1000MVA series reactor at Windyhill substation.

To discharge SPTL's licence obligations under Special Licence Condition J3 –Restriction of Transmission Charges (Part B 10 (d) (ii)), SKM were to provide:

- A post construction technical report setting out the extent to which the project complies with the TIRG output measures
- A construction completion certificate

This document fulfils the requirement for the post construction technical report. A construction completion certificate is provided in Appendix A.

To facilitate the review, site visits took place on 2nd August 2012 together with a visit to SPTL's offices in Bellshill on 3rd August 2012. SPTL personnel presented a description of the project and the status in terms of the construction. Documentation related to the scheme construction was presented to SKM for review. SPTL's staff was very cooperative and SKM had access to all information requested and required for the purposes of the review. SPTL also provided additional documentation and evidence via e-mail when requested where additional clarifications were required following the consideration of the information obtained during the visit.

SKM is satisfied that it had access to the relevant documentary evidence that allowed review of the technical construction details of the scheme and to assess compliance with the appropriate output measures.

2.1. Methodology

To facilitate the post construction technical review, documentary and photographic evidence was collated to aid verification that the scheme:

i) has been constructed in accordance with the scheme designs outlined in the TIRG licence submissions;

ii) that construction is complete;

iii) that the scheme is in operational service;

iv) that the scheme forecast output measures are fully met.

The technical review provides an overview of scheme configuration and construction. High level design documentation has been reviewed and in some cases site visits undertaken to verify that the scheme complies with the outline TIRG scheme design and is complete. The technical review does not include a detailed design review of documents such as primary plant layouts, calculations, plant rating and design, civil works, protection & control and LVAC / LVDC schemes; nor is any review of quality of installation undertaken.

Verification of completion of construction and scheme operation is facilitated by:

i) review of plant "completion certificates"

ii) site visits and / or review of photographic evidence

iii) SCADA data

Capability of circuits given in forecast output measures is verified by review of circuit rating schedules that provide information on the limiting plant ratings of the circuits.

3. Background

3.1. Requirement for Reinforcement

In 2007 there were three critical transmission system boundaries that existed on the SPTL transmission system. The SPTL north – south boundary (Boundary B5) comprised the following circuits:

400kV

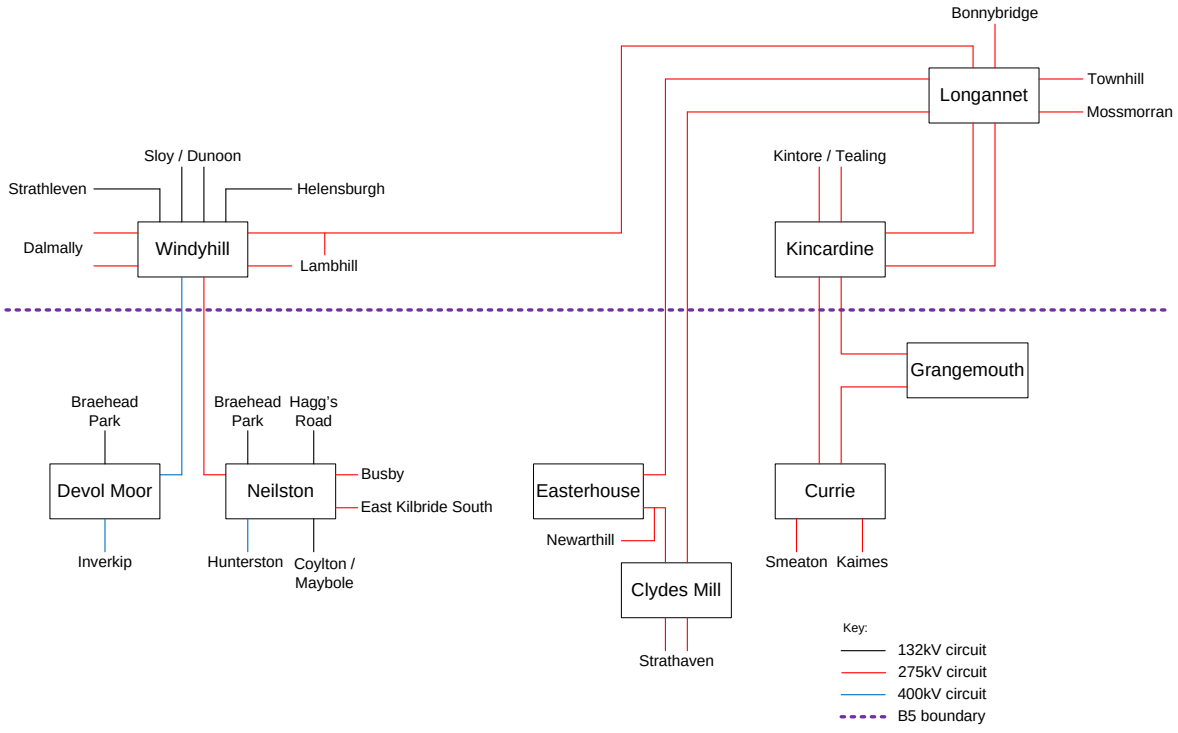
- Windyhill – Devol Moor

275kV

- Windyhill – Neilston
- Longannet – Easterhouse
- Longannet – Clydes Mill
- Kincardine – Grangemouth
- Kincardine – Currie

A simplified illustration is shown in figure 3.1 below.

Figure 3.1 – SPTL Boundary B5 Network



At this time the SHETL system was able to accommodate up to 1.5GW of renewable energy with additional generation forecast to connect beyond this figure after system reinforcement. In addition to this SPTL anticipated an additional 90MW of renewable energy would connect to their system by late 2008 with additional generation to follow in later years.

To accommodate increased north to south power flows through central Scotland to support the increasing amounts of renewable generation being connected, a scheme was developed which would replace the existing 132kV line between Beauly and Bonnybridge with a 400kV line known as Beauly-Denny. This scheme incorporated works within both SHETL and SPTL transmission boundaries and included the Boundary B5 reinforcement works described in this report, which were designed to release system capacity.

However, as a consequence of planning delays to the Beauly-Denny project the Boundary B5 works were also delayed, despite not being dependent on planning consents. This resulted in NG submitting a Planning Request asking SPTL to consider advancing the Boundary B5 works independently of Beauly-Denny.

3.2. Proposed Solution

SPTL conducted an economic analysis in accordance with the System Operator-Transmission Owner Code (STC) which resulted in Ofgem amending its electricity transmission licence to isolate the Boundary B5 works from the Beauly-Denny scheme.

The proposed Boundary B5 works were then progressed in 2007/08 in advance of the Beauly-Denny scheme and were scheduled to be completed following a 3-year construction programme. The works included the following:

- Replacement of two switchgear bays and associated connections at Clydes Mill 275kV substation to deliver a 1500MVA capacity on the Longannet – Clydes Mill and Easterhouse – Clydes Mill 275kV circuits.
- Replacement of switchgear and connections at Easterhouse 275kV substation to deliver a 1500MVA capacity on both the Longannet – Easterhouse and Clydes Mill – Easterhouse 275kV circuits.
- Relocation of a 275kV, 1000MVA series reactor from Smeaton 275kV substation to Windyhill 275kV substation on the Neilston circuit; including the replacement of the associated 275kV switchgear bay at Windyhill.

Capacity would be released by upgrade of 275kV switchgear and by the introduction of a series reactor on the Windyhill – Neilston circuit to improve post-fault load sharing on the Windyhill – Devol Moor 400kV and Windyhill – Neilston 275kV circuits.

Table 3.1 shows the boundary limit capacities for N-D secured events before and after the proposed Boundary B5 reinforcements for three different generation scenarios.

Table 3.1 – Boundary Limit Capacities Pre and Post Boundary B5

Generation Schedule	*System Pre Boundary B5 (MW)*	*System Post Boundary B5 (MW)*	*Capacity benefit across Boundary B5 (MW)*
1	2,936	3,471	535
2	2,860	3,487	627
3	2,849	3,401	552

The Boundary B5 scheme would provide an increase in transfer capacity across the boundary estimated at a minimum of 535MW under an N-D secured event as shown in Table 3.1.

Typical constrained generating capacity at the time was estimated at 380MW to the north of the B5 boundary. The increase in available capacity shown in Table 3.1 would therefore mitigate the generating constraints and accommodate further increases in connections of renewable generation prior to completion of Beauly-Denny.

Aside from the relocation of the 275kV series reactor from Smeaton to Windyhill the Boundary B5 works do not change the configuration of the 275kV transmission circuits; hence figure 3.1 has not been updated to reflect post Boundary B5 works.

4. Review of Reinforcement Works

In 2007, SPTL commenced development work on the proposed Boundary B5 works.

These works have now been completed at each of the three substations with the upgraded circuits at Easterhouse commissioned in 2008 and the new series reactor circuit at Windyhill commissioned in 2010. The TIRG works at Clydes Mill substation were commissioned later than planned as a consequence of a Suspension of Operational Practice (SOP) which led to an SPTL decision to completely refurbish the substation. The TIRG works, in conjunction with completion of the works at Easterhouse and Windyhill, were commissioned and operational prior to the final commissioning of the refurbished substation in 2011.

Site visits have been made to selected substations where major works have been completed to gather evidence in support of verification of scheme completion and operation. Where site visits were not made supporting evidence has been provided by SPTL.

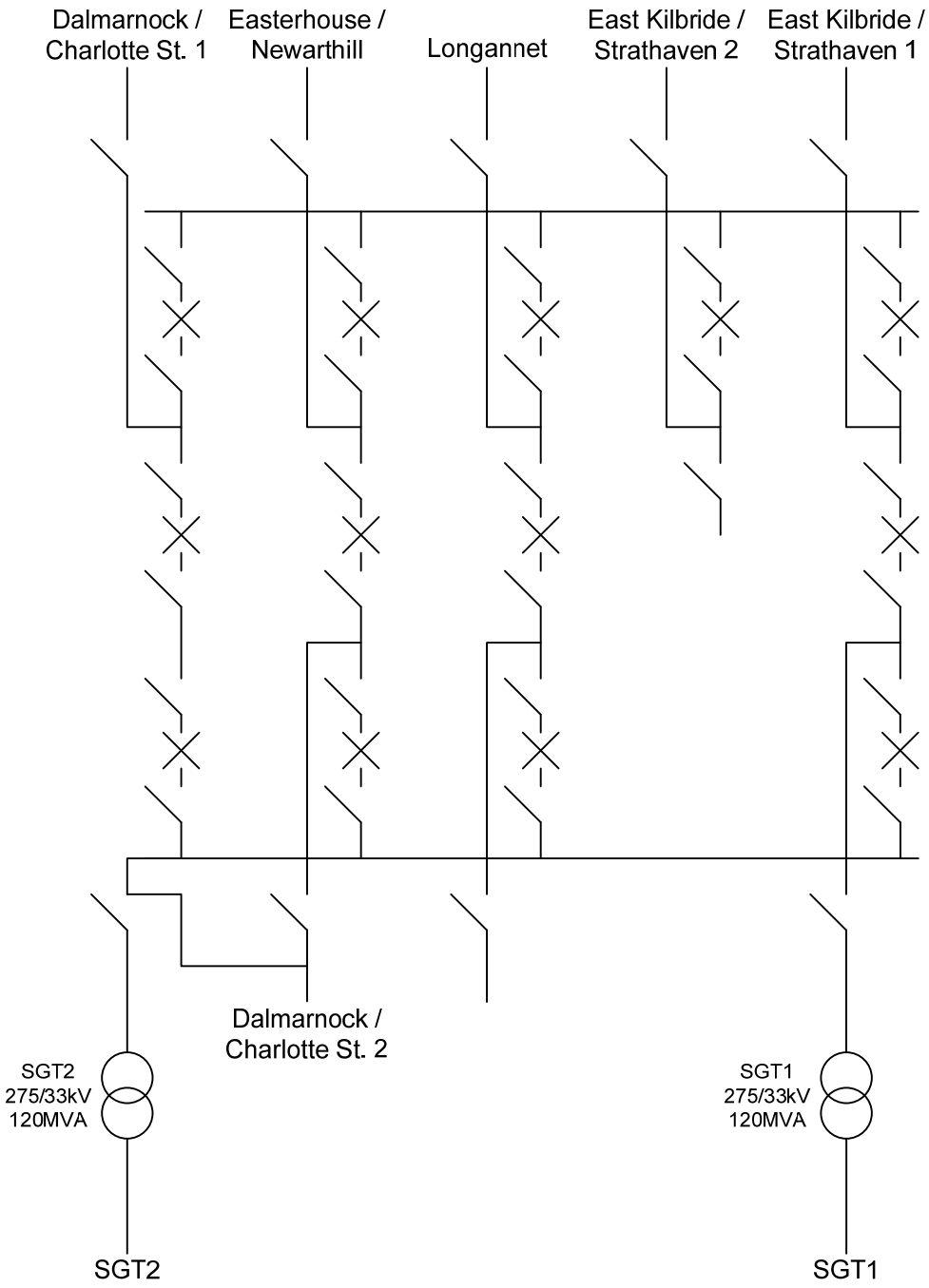
4.1. Upgrade of Clydes Mill 275/33kV Substation

Although the Clydes Mill substation was completely refurbished, the scope of works for the TIRG Boundary B5 scheme covered replacement of only two 275kV switchgear bays and associated connections for the Longannet and Easterhouse circuits. Switchgear replacement not covered by the TIRG scheme was funded separately under the SPTL transmission price control review.

4.1.1. Re-configuration of Substation

Clydes Mill was originally constructed circa 1960's and incorporated 275kV and 33kV switchyards. The configuration of the original 275kV switchyard was of the breaker-and-a-half type. A simplified single line diagram of this arrangement is shown in figure 4.1 below.

Figure 4.1 – Clydes Mill 275kV Single Line Diagram (pre-upgrade)



The 275kV switchyard has been replaced with a double busbar type configuration that comprises main (principal), main (secondary) and reserve busbars where the reserve busbar is located between the main (principal) and main (secondary) busbars in a "wrap around" arrangement. Each circuit is capable of being selected for connection via busbar disconnectors to either a main busbar (principal

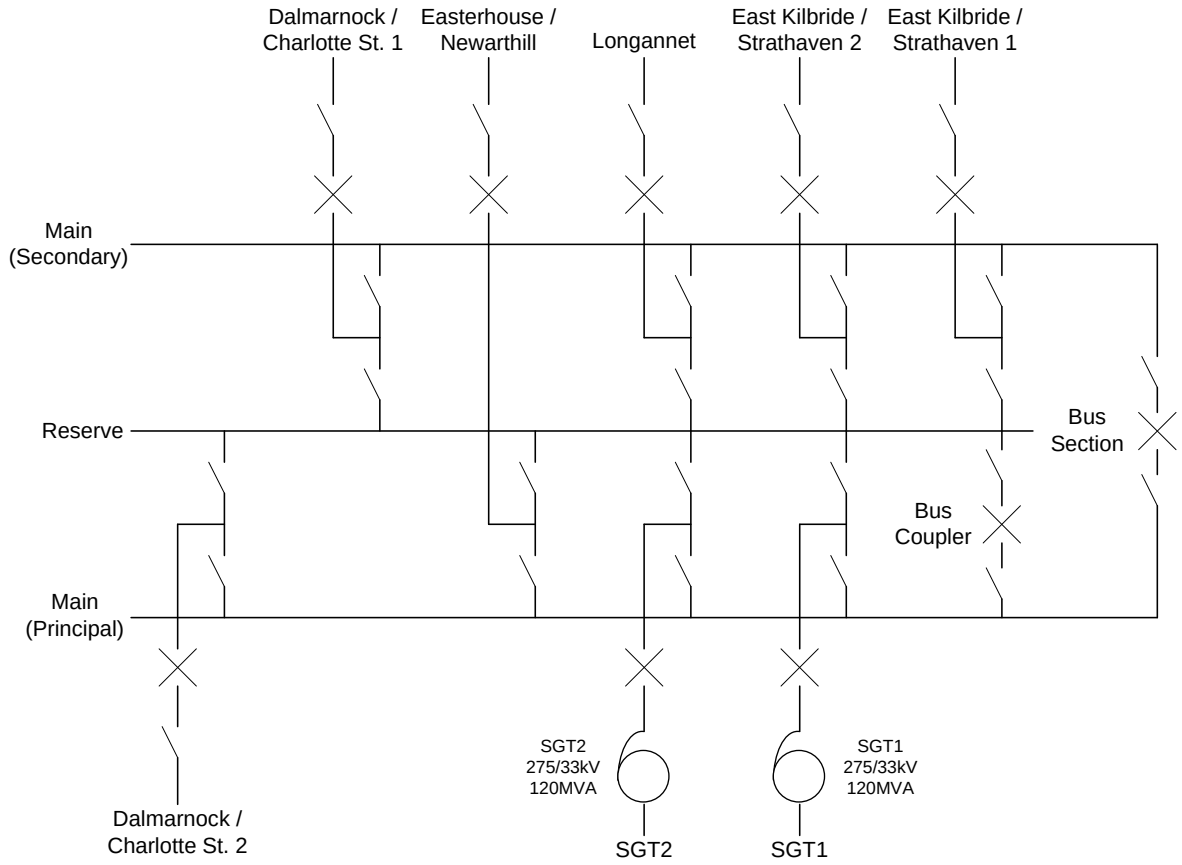
or secondary) or to the reserve busbar. In the event of a fault to a main or reserve busbar each circuit can be transferred to one of the un-faulted busbars with minimal disruption to supply.

The 275kV switchyard also includes a busbar section circuit breaker between the main busbars that allows each of the main busbars to be operated separately or as one single busbar. A busbar coupler circuit breaker is also provided between the main (principal) and reserve busbars to allow on-load transfer between the busbars; this prevents loss of supply when maintenance is required on a particular busbar.

The 275kV switchyard has two, 120MVA, 275/33kV SGT transformer circuits, namely SGT1 and SGT2, which facilitate connection to the 33kV switchgear. These transformers have not been replaced.

The simplified single line diagram of the new 275kV switchyard is shown in figure 4.2 below.

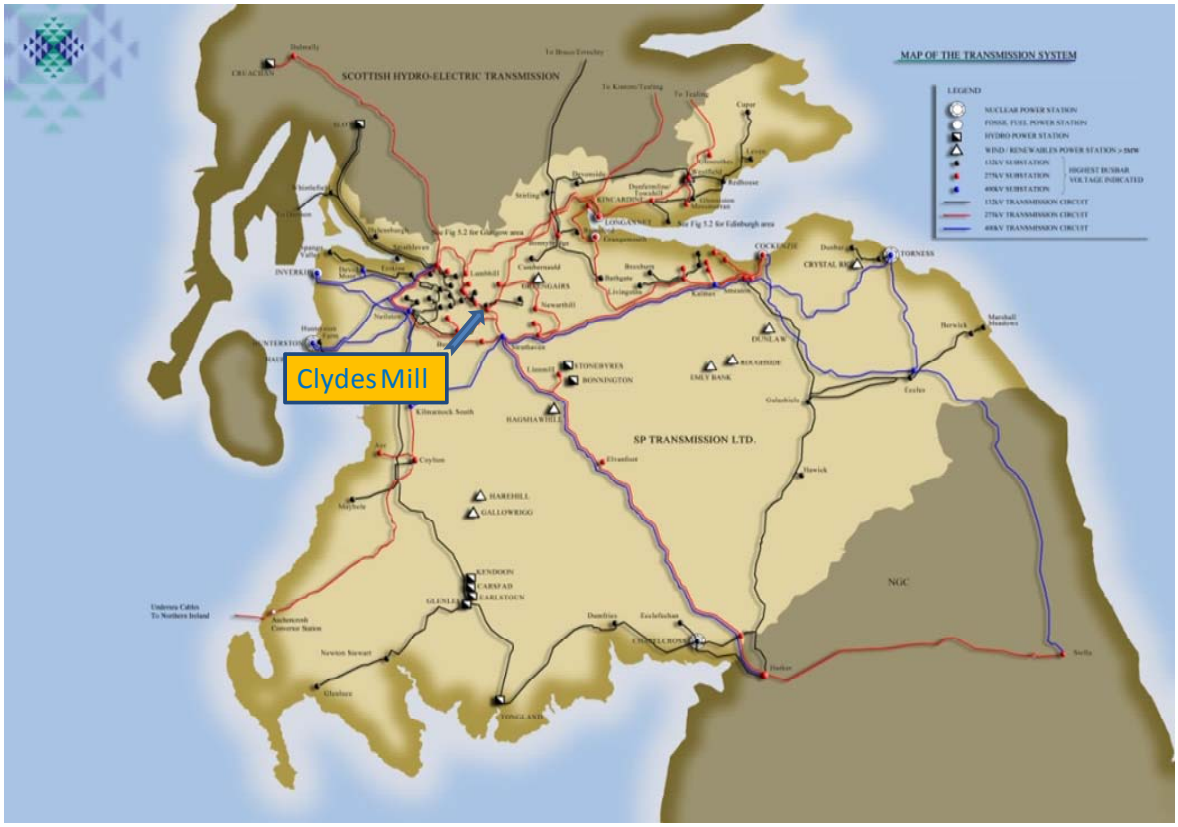
Figure 4.2 – Clydes Mill 275kV Single Line Diagram (post-upgrade)



4.1.2. Location, Layout and Construction

The substation site is located approximately 8km south east of Glasgow. Figure 4.3 below shows a geographical representation of the location.

Figure 4.3 – Clydes Mill Substation Site



The 275kV switchyard required significant civil works for replacement of equipment foundations and structures for the new plant and modification to trenches/ducts where necessary to accommodate new control wiring. The existing substation control buildings were utilised to accommodate new protection and control for the 275kV switchyard in replacement of the existing 275kV protection and control equipment. Where necessary, refurbishment works were carried out on the buildings to extend their lifetime.

The substation comprises the following 275kV circuits:

275kV circuits

- Feeder circuit, East Kilbride – Strathaven No.1
- Feeder circuit, East Kilbride – Strathaven No.2

- Feeder circuit, Longannet
- Feeder circuit, Easterhouse – Newarthill
- Feeder circuit, Dalmarnock – Charlotte street No.1
- Feeder circuit, Dalmarnock – Charlotte street No.2
- Supergrid transformer circuit, SGT No.1
- Supergrid transformer circuit, SGT No.2
- Bus section
- Bus coupler

The design of the 275kV switchyard is based upon conventional air insulated switchgear construction. The layout comprises a two level construction with the main and reserve busbars at high level and the circuit connections at low level. The busbars run in parallel on a west-east plane and the circuit connections run in a north-south plane.

The 275kV circuits generally utilise switchgear equipment which includes:

- 275kV Open terminal circuit breakers
- 275kV Open terminal pantograph and rotating centre post disconnectors with integral earth switches
- 275kV Open terminal earth switches
- 275kV Capacitor voltage transformers
- 275kV Current transformers
- 275kV Surge arresters

The Longannet and Easterhouse circuits terminate onto a substation circuit entry directly via an overhead line connection. The double circuit terminal towers are located at the north side of the substation outside of the boundary fence.

The 275kV switchyard has been designed on the basis that maintenance, extension and repairs can be carried out with a maximum of only one circuit and one busbar section out of service simultaneously. Clearances for maintenance access have been designed to allow for mobile access platforms, scaffolding, cranes etc.

4.1.3. Construction Verification

SKM undertook a site visit to Clydes Mill substation on 02 August 2012 with a view to gathering evidence to confirm completion of construction and that the substation is fully operational.

Figure 4.4 shows photographic evidence of construction for the switchgear bays of the Longannet and Easterhouse circuits.

Figure 4.4 – View of 275kV Switchgear Bays (Longannet then Easterhouse from left)

Evidence of “Completion Certificates” was also presented by SPTL to confirm that construction and testing of each circuit was complete, fit for purpose and available for energisation.

Operational evidence was gathered in the form of recorded data taken from the SCADA system. Screenshots were taken of SCADA outputs which showed that the 275kV switchyard was configured with all feeder circuits, the bus section and the bus coupler circuits closed. Power flows were observed through all circuits and recorded at 110MW (Longannet) and 174MW (Easterhouse).

SKM were satisfied that the information presented was sufficient to confirm that the new 275kV Longannet and Easterhouse circuits are in full operation.

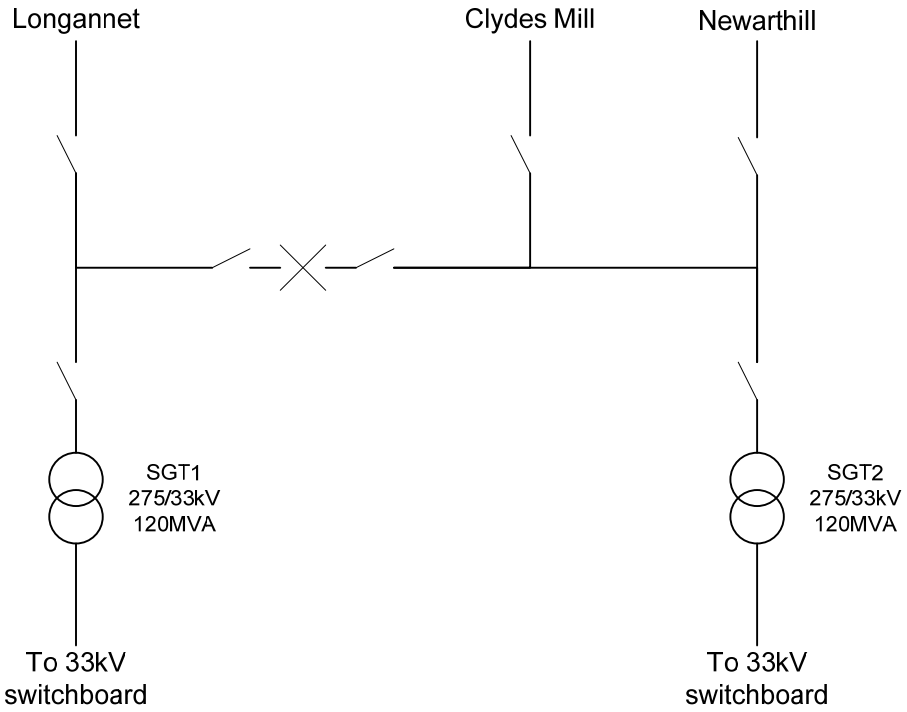
4.2. Upgrade of Easterhouse 275/33kV Substation

Easterhouse is a 275/33kV substation comprising of a single switch 275kV switchyard and a 33kV indoor switchboard fed by two 120MVA, 275/33kV transformers.

4.2.1. Configuration

Prior to the proposed Boundary B5 upgrade works, the 275kV switchyard comprised three 275kV incoming circuits from Longannet, Clydes Mill and Newarthill which were connected in a single switch mesh arrangement. A simplified single line diagram of this arrangement is shown in figure 4.5 below.

Figure 4.5 – Single Line Diagram of Easterhouse 275kV Switchyard (pre-upgrade)



To accommodate the requirements of the Boundary B5 upgrade the switchgear on the Longannet and Clydes Mill circuits required replacement. The scope of modifications included:

i) Replacement of all 275kV switchgear and connections between SGT1 disconnector and mesh corner 1.

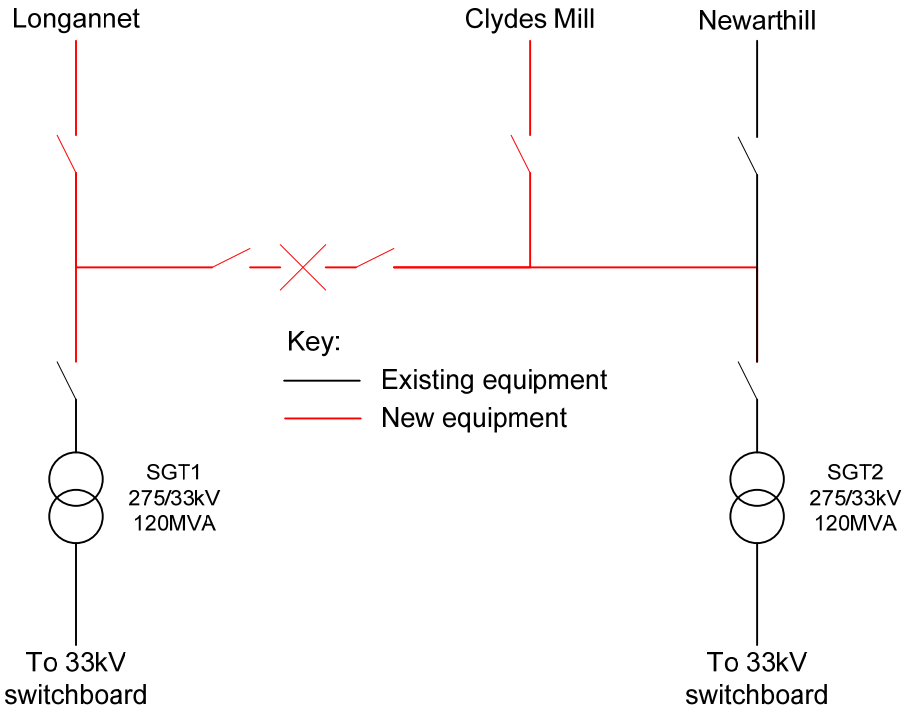
ii) Replacement of all 275kV switchgear and connections between mesh corner 1 and the terminal tower of the Longannet circuit.

iii) Replacement of all 275kV switchgear and connections between mesh corner 2 and the terminal tower of the Clydes Mill circuit.

iv) Replacement of all 275kV switchgear and connections between mesh corner 1 and mesh corner 2.

A simplified single line diagram of the upgraded arrangement is shown in figure 4.6 below.

Figure 4.6 – Single Line Diagram of Easterhouse 275kV Switchyard (post-upgrade)



4.2.2. Circuit Construction

The 275kV switchyard required significant civil works for replacement of equipment foundations and structures for the new plant and modification to trenches/ducts where necessary to accommodate new control wiring. The original structures that supported the overhead stranded connections between SGT1 and mesh corner 1 were retained but refurbished to mitigate any deterioration. The existing substation control buildings were utilised to accommodate changes to protection and control for the 275kV switchyard.

The design of the new 275kV switchgear and connections is based upon conventional air insulated switchgear construction. The circuits generally utilise switchgear equipment which includes:

- 275kV Open terminal circuit breaker

- 275kV Open terminal rotating centre post disconnectors with integral earth switches
- 275kV Open terminal earth switches
- 275kV Current transformers
- 275kV Capacitor voltage transformers
- 275kV Surge arresters

The new 275kV switchgear terminates directly onto the existing overhead line connections on both refurbished circuits, with the terminal towers being located on the eastern side of the substation outside of the boundary fence. A new line gantry was constructed to facilitate connection of the Longannet circuit whereas the existing concrete line gantry was retained and refurbished to facilitate connection of the Clydes Mill circuit.

4.2.3. Construction Verification

SKM undertook a site visit to Easterhouse substation on 02 August 2012 with a view to gathering evidence to confirm completion of construction and that the substation is fully operational.

Figure 4.7 shows photographic evidence of construction for the upgraded switchgear and connections.

Figure 4.7 – Mesh Corner 1 and Single Switch Circuit Breaker

Figure 4.8 – Longannet Circuit Line Gantry

Evidence of “Completion Certificates” was also presented by SPTL to confirm that construction and testing of the circuits was complete, fit for purpose and available for energisation.

Operational evidence was gathered in the form of recorded data taken from the SCADA system. Screenshots taken of SCADA outputs from Easterhouse substation showed that all 275kV circuits were in service. Power flows were observed through all circuits and recorded at 55MVA (Longannet) and 179MVA (Clydes Mill).

SKM were satisfied that the information presented was sufficient to confirm that the upgraded Easterhouse 275kV substation is in full operation.

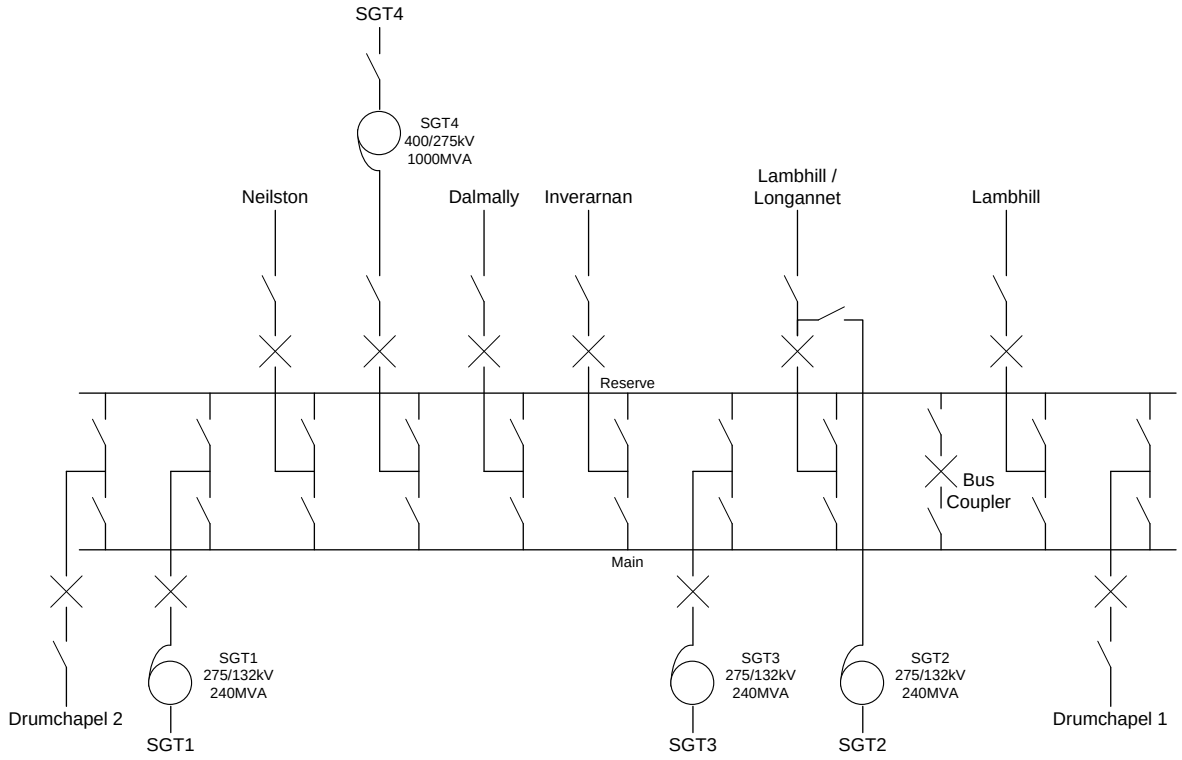
4.3. Reactive Compensation at Windyhill 275kV Substation

4.3.1. Configuration

Windyhill is a 400/275/132kV substation comprising double busbar 400/275kV and 132kV switchyards. The scope of works for the Boundary B5 scheme included the installation of a 275kV, 1000MVA series reactor on the Neilston circuit which was relocated from Smeaton 275kV substation.

Prior to the proposed Boundary B5 upgrade works, the 275kV switchyard comprised a double busbar arrangement with a 400kV circuit connection from Devol Moor substation and seven 275kV circuit connections, which included that from Neilston substation. A simplified single line diagram of this arrangement is shown in figure 4.9 below.

Figure 4.9 – Single Line Diagram of Windyhill 400/275kV Switchyard (pre-upgrade)



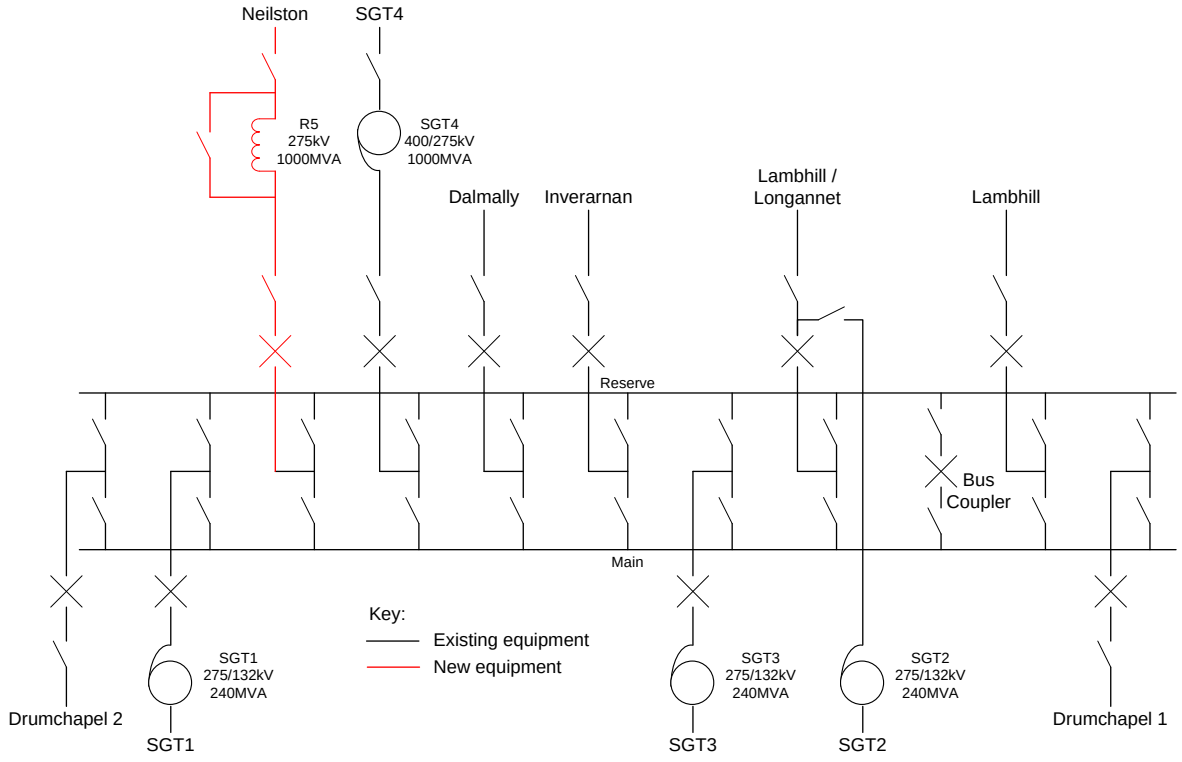
To accommodate the requirements of the Boundary B5 upgrade modifications were required to the Neilston circuit. The scope of modifications included:

v) Installation of relocated 275kV, 1000MVA series reactor.

vi) Replacement of all 275kV switchgear and connections between the busbar disconnectors and the outgoing overhead line circuit terminations.

A simplified single line diagram of the new arrangement is shown in figure 4.10 below.

Figure 4.10 – Single Line Diagram of Windyhill 400/275kV Switchyard (post-upgrade)



4.3.2. Circuit Construction

The installation of the relocated series reactor required significant civil works to modify the existing foundations and bund walls at the site and also the installation of a fire wall between the reactor and the adjacent SGT4.

The replacement of the 275kV switchgear on the Neilston circuit required replacement of equipment foundations and structures for the new plant and modification to trenches/ducts where necessary to accommodate new control wiring. New foundations and structures were installed for the reactor bypass disconnector. The existing substation control buildings were utilised to accommodate changes to protection and control for the 275kV switchyard.

The design of the new 275kV switchgear and connections is based upon conventional air insulated switchgear construction. The circuit generally utilises switchgear equipment which includes:

- 275kV Open terminal circuit breaker
- 275kV Open terminal rotating centre post disconnectors with integral earth switches
- 275kV Open terminal earth switches

- 275kV Current transformers
- 275kV Capacitor voltage transformers
- 275kV Surge arresters

The existing incoming overhead line connections were modified to terminate onto the circuit side terminals of the series reactor.

4.3.3. Construction Verification

A site visit has not been undertaken by SKM. In lieu of a site visit photographic evidence was presented by SPTL to illustrate construction of the new 275kV series reactor circuit. Figure 4.11 shows the 275kV series reactor installation on the Neilston circuit under construction.

Figure 4.11 – 275kV Series Reactor on Neilston Circuit (Under Construction)

Evidence of "Completion Certificates" was also presented by SPTL to confirm that construction and testing of the circuit was complete, fit for purpose and available for energisation.

Operational evidence was gathered in the form of recorded data taken from the SCADA system. Screenshots taken of SCADA outputs from Windyhill substation showed that the 275kV series reactor on the Neilston circuit was operational with a power flow recorded of 219MW.

SKM were satisfied that the information presented was sufficient to confirm that the new 275kV series reactor Neilston circuit is in full operation.

5. Output Measures

The output measures specified in Schedule C of the TIRG licence for the Boundary B5 scheme both prior to and post construction are given in table 5.1 below.

Table 5.1 – Boundary B5 Scheme Output Measures

Project scope	**Capability as at 31 March 2005**			**Forecast capability prior to construction start date**			**Forecast capability post construction**		
Line upgrade	Circuit voltage (kV)	Winter rating (MVA)	Summer rating (MVA)	Circuit voltage (kV)	Winter rating (MVA)	Summer rating (MVA)	Circuit voltage (kV)	Winter rating (MVA)	Summer rating (MVA)
Windyhill – Neilston	275	955	760	275	955	760	275	955	760
Longannet - Easterhouse	275	953	953	275	953	953	275	1500	1500
Longannet – Clydes Mill	275	953	953	275	953	953	275	1500	1500
Easterhouse – Clydes Mill	275	953	953	275	953	953	275	1500	1500

The scheme has been constructed in accordance with the design established in 2007. The 275kV switchgear at Clydes Mill and Easterhouse substations has been upgraded and the 275kV series reactor has been relocated from Smeaton to Windyhill substation on the Neilston circuit.

Prior to the proposed works the limiting factor in achieving the maximum capacity on the 275kV Longannet – Easterhouse, Longannet – Clydes Mill and Easterhouse – Clydes Mill circuits was the rating of the existing 275kV switchgear at Clydes Mill and Easterhouse substations. This switchgear has now been replaced to provide the post construction forecast capabilities given in table 5.1 above. The circuit capabilities have been verified via review of equipment rating schedules supplied by STPL to the system operator, NG and confirmed to be 1500MVA (winter and summer) based on disconnector ratings.

The post construction forecast capability of the 275kV Windyhill – Neilston circuit listed in table 5.1 has not changed from those forecast prior to construction as the limiting factor is the existing twin Zebra (2 x 400mm^2 ACSR) overhead line part of the circuit. The works undertaken on this circuit therefore do not impact the circuit capability.

The implementation and operation of the Boundary B5 works has been verified via the photographic and operational data gathered as described in section 4.

Based on the data gathered and technical review outlined in section 4, SKM concludes that the forecast output measures are confirmed to have been fully delivered by the Boundary B5 scheme.

A construction completion certificate for the Boundary B5 scheme is provided in Appendix A.

Appendix A Construction Completion Certificate

TRANSMISSION INVESTMENTS FOR RENEWABLE GENERATION

CONSTRUCTION COMPLETION CERTIFICATE

Licensee: Scottish Power Transmission Limited (SPTL)……

Scheme: Boundary B5……

It is hereby certified that the Licensee named above is considered to have completed all construction activities necessary to fulfil its obligations in terms of the output measures specified in Schedule C of the TIRG licence for the above named scheme. The construction activities were completed during the Licensee's 2011/2012 financial year.

Signature:  .....

Name: N Keeler .....

Date: 30/11/2012 .....

Designation: Senior Electrical Engineer .....